Monterey Bay Aquarium
Seafood Watch®

Rainbow trout

Oncorhynchus mykiss

Chile

Marine net pens

October 2, 2017
Seafood Watch Consulting Researchers

Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	6.36	YELLOW	
C2 Effluent	4.00	YELLOW	NO
C3 Habitat	5.87	YELLOW	NO
C4 Chemicals	2.00	RED	NO
C5 Feed	4.54	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Secondary species escape	-0.10	GREEN	
Total	**26.67**		
Final score (0-10)	**3.81**		

OVERALL RANKING

Final Score	3.81
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

The final numerical score for farmed rainbow trout from Chile is 3.81 out of 10 and a single red score in Criterion 4 – Chemicals leads to a final recommendation of Yellow "Good Alternative."

Executive Summary

Chile currently produces roughly 71,000 metric tons (MT) of rainbow trout per year (71,381 MT in 2016), exporting roughly two-thirds of rainbow trout, worth over 350 million USD. Production is centered in the Los Lagos and Aysén regions (Regions X and XI) with smaller quantities in Magallanes (Region XII). Although this production is small in comparison to Atlantic salmon (rainbow trout constitute 10.6% of total Chilean salmonid production), it remains an important industry for the country. The principal production systems are marine net pens and this report focuses on several key aspects of this production, including effluents, habitats, chemical use, feed, escapes, diseases and parasites, source of stocks, wildlife and predator effects, escape of unintentionally introduced species and the overall quality and availability of data.

Across the categories assessed, data availability ranged from moderate to high; for example, production statistics are easily accessible in the public domain, but detailed data on effluent and habitat impacts are somewhat limited. A large body of scientific literature on salmonid farming is available, but only a limited number of studies are specific to Chilean rainbow trout production. Data availability has improved considerably in the last decade, but there are still many unknowns regarding the environmental impact of Chilean rainbow trout farming. The final score for Criterion 1 – Data is 6.36 out of 10.

Because of the open nature of net pen production systems, virtually all waste discharged from an operation, including dissolved and particulate wastes, discharge directly to the surrounding environment with little or no intervention; however, there is contradictory or inconclusive evidence of direct impacts beyond the immediate vicinity. Monitoring day-to-day effluent discharges is not required in Chile; therefore, the availability of reliable data is limited. In this assessment, the calculations according to the Seafood Watch Standard produced a value of 77.02 kg N t^{-1}.

High stocking and farm densities and limited studies conducted on Chilean rainbow trout farming, in addition to concerns over the effectiveness of the regulatory systems in place, mean that the industry cannot be considered the same as similar activities in other places around the world. Chile does not require soluble nutrient monitoring in the water column surrounding rainbow trout farms, though benthic monitoring is required at both peak biomass and prior to restocking pens (addressed in Criterion 3 – Habitat). Literature suggests impacts beyond the immediate vicinity of farms are unlikely, but there is growing concern over the potential cumulative impacts in relation to the carrying capacity of the surrounding environment. There are ongoing questions about the effectiveness of the current regulatory system in regard to controlling possible expansion into southern pristine areas. It has been noted that the expansion until now has not been accompanied by a relative improvement in monitoring and regulation, and certain regulatory issues are yet to be fully addressed, including mechanisms to avoid over centration of operations, defining boundaries of production zones, and defining carrying capacities of production zones. The final score for Criterion 2: Effluents is 4 out of 10.

The habitat criterion assesses the direct impacts on the farm area, which in the case of marine net pen rainbow trout 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 unique benthic fauna of high ecological value, including sites important for cold water corals. The floating net pens used in salmonid farming have relatively little direct impacts with respect to conversion of habitat, but the seabed impacts under them can be severe. There is a high degree of overlap between sites highlighted as being ecologically important and the sites of farm operations. Yet, there is no consensus on the actual effects of such operations on the benthos, with some authors suggesting there are several effects with a wide area of impact, and others suggesting the effects are minimal and restricted to a minimal area around the net pens.

Benthic monitoring data show that the majority of Chile's salmonid sites are rated as being in good condition (aerobic), meaning that a significant proportion do not meet the requirements of "aerobic" (i.e., good) conditions. The total impacts of all salmonid 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 shown to be rapidly reversible, but the industry's southward expansion, albeit slow, has been, and continues to be, a cause for concern. Also, there is still uncertainty in the capability of the regulatory system, which has developed since the infectious salmon anaemia (ISA) outbreak in the salmon industry, to effectively monitor and control the impacts of the industry. The final score for Criterion 3 – Habitat is 5.87 out of 10.

Chilean rainbow trout production used 17.59 t of antibiotics in 2016, or 240 grams per MT trout (compared to 690 grams per MT for salmon) and ranks as one of the highest users in aquaculture in the world. Current data on the frequency of antibiotic use are not available, though it is estimated to be more than once per production cycle. There are no regulatory limits on the frequency or total quantity used should a disease outbreak occur, but various initiatives are underway to attempt to address the problem (e.g., the Pincoy project and the promising testing of new vaccines for *P. salmonis*). Nevertheless, there is evidence of developed resistance to florfenicol, the most commonly used antibiotic in Chile, and a treatment considered "highly important" for human medicine by the WHO.

Current data on the volume and frequency of antiparasite chemical use in rainbow trout production in Chile are not available. The most recent data (from 2013) show high volumes of use and, coupled with evidence of developed resistance for some treatments, are cause for significant concern. Studies examining the impact on benthic invertebrate communities are lacking, but given the open nature of net pen production systems, the potential risk of impact is high.

The high volume and frequent use of antibiotics, the confirmed cases of resistance to both antibiotic and pesticide treatments, and potential wider scale impacts to environmental microbial communities is balanced with the understanding that rainbow trout culture represents a small portion of total antibiotics used in Chilean salmonid culture (4.6% of the total is dominated by Atlantic salmon) and substantially lower relative usage of antibiotics (64.5% lower) than Atlantic salmon. As such, this results in a “moderate” to “high” concern in this Seafood Watch assessment and the final score for Criterion 4 – Chemical Use is 2 out of 10.

The drive to reduce the reliance on wild marine ingredients in salmonid feeds has led to a general decrease in fishmeal and oil inclusion by increasing levels of alternative proteins and oils; however, a paucity of trout-specific data provided by feed companies leaves gaps in the understanding of the exact situation regarding fish meal and oil inclusions, and the use of trimmings or byproducts in feeds.

According to the available data, current fishmeal and fish oil inclusion levels in Chilean trout feeds are estimated to be 12% and 5.7%, respectively, while it was assumed that 0% of fish meal and fish oil are derived from byproducts and trimmings. Using these figures, a FI:FO value of 1.73 was calculated meaning that for every ton of fish produced, the oil from 1.73 t of wild fish will be used. In addition to this, a penalty was applied due to the level of sustainability of fish stocks used in the production of fishmeal, which resulted in a final score for wild fish use of 3.59 out of 10.

In terms of protein loss or gain, there was a high net protein loss of –54.21% corresponding to a score of 4 out of 10 for this factor. Also, a feed footprint consisting of both total land and ocean area of 7.56 ha was calculated to be required to produce the feed ingredients necessary for 1 t of farmed fish, leading to a factor score of 7 out of 10.

The final score for Criterion 5: Feed is 4.54 out of 10.

Rainbow trout are farmed in open systems (net pens), and the available data (though incomplete over the time frame) indicate large numbers of fish (>500,000) have escaped each year since the early 1990s, and there is potential for this number to be higher due to undetected or unreported events. The impact on the environment from escaped rainbow trout has been tempered, historically, by intentional stocking of the species prior to aquaculture (resulting in established, self-sustaining populations); however, it is known that escaped rainbow trout have aided in the establishment of feral populations, and that they impact native fish by predation, competing for food, and acting as vectors for disease and parasites. When combining the score for Factor 6.1 (2 out of 10) with the score for Factor 6.2 (7 out of 10), the final score for Criterion 6 – Escapes is 4 out of 10.

The main disease of rainbow trout in Chile is salmonid rickettsial septicaemia (SRS or piscirickettsiosis), which causes nearly 20% of all rainbow trout losses (nearly 83% of all losses related to disease) and affects 12 to 23% of farms. Other minor diseases include those caused by *Flavobacterium* and infectious pancreatic necrosis (IPN) virus, as well as other diseases such as vibriosis, furunculosis, and mycosis. Although no major concerns were found regarding the effect of rainbow trout diseases on wild rainbow trout populations, some concern has been raised about the potential spread of disease to other native wild fish.

The main parasite is a sea louse called *Caligus rogercresseyi* and is of primary concern when considering amplification of disease or parasites to native populations. Incidence of salmonid sites on high alert (>3 gravid lice per female) in 2015 peaked at just under 10%. Sea lice are a natural parasite of many native species which inhabit areas around net pens, and as such the high infection pressure coming from net pens is a cause for concern, with infestation being linked to secondary impacts such as a greater risk of predation.

Despite a lack of direct evidence of impact on wild fish, evidence of on-farm disease mortality, parasite infections, and the risk of disease transfer posed by the open nature of net pen rainbow trout farming represents a moderate concern; therefore, the final score for Criterion 7 – Disease is 4 out of 10.

The rainbow trout industry globally has an established record of selective breeding and domestication; in Chile, the majority of eggs are sourced domestically, and all are derived from hatcheries and established captive populations (as opposed to the wild capture of juveniles). Thus, there is no reliance on wild fish populations for juveniles or broodstock, and the final score for Criterion 8X – Source of Stock – Independence from wild fisheries is 0 out of –10.

Aquaculture activities in net pens inevitably interact with wildlife and predators; entanglement, deliberate killing, habitat and space competition, acoustic harassment, environmental contamination, ingestion of debris associated with aquaculture activities, and changes in prey species assemblages are known to occur, but their exact impact on wildlife is largely unknown. This is mainly due to poor reporting and data capture, as well as a general lack of information regarding the scale of impacts and population status of several affected species. For example, the movement and behaviors of the Chilean dolphin, a rare dolphin species whose habitat overlaps with salmonid farm locations, may be affected by the general existence of salmonid farms, despite the lack of evidence of direct mortality. Overall, there is significant uncertainty surrounding the impacts to predators and wildlife, though the population statuses of most affected species are known and considered "least concern" and stable. Partnerships between environmental organizations and the salmonid farming industry have been established to monitor and reduce any interactions with key species, further mitigating concern. Thus, though wildlife mortalities may occur beyond exceptional cases, they are not considered to significantly impact the affected species' population size; therefore, the final score for Criterion 9X – Wildlife and predator mortalities is –4 out of –10.

The ISA crisis in the salmon industry led to significant tightening of regulations concerning the movement of fish and fish products into Chile. As a result, a very small portion of eggs are now imported into Chile, considerably reducing the risk of importing unwanted or dangerous organisms. The biosecurity of animal movements within Chile is understood to be high, with strict controls in place to prevent spread of non-target organisms, including pathogens. In terms of broodstock and fingerling biosecurity, broodstock are generally housed in tank-based recirculation systems with high biosecurity, while fingerlings are grown in lakes, introducing some possibility, albeit remote, of biosecurity breaches. Nonetheless, the utilization of health management zones, and the fact that trans-waterbody movements are between fresh and saltwater, dramatically reduce this risk.

The final penalty for exceptional Criterion 10x – Escape of unintentionally introduced species is –0.10 out of –10.

Much of the literature describes broader environmental concerns and impacts as they relate to the overall salmonid farming industry in Chile (inclusive of Atlantic and coho salmon), though this assessment has sought to distinguish the relative contribution of rainbow trout production (~10% of the total) to those impacts. Overall, though the Chilean rainbow trout farming industry is rapidly declining in scale from a peak in 2012, the industry is still quite sizeable and its operations represent several environmental risks. Most notably, the large volume of antibiotics and antiparasitic treatments used are some of the highest in the world, and there are still concerns relating to the high density of production and carrying capacity of the receiving environment. Also, feral rainbow trout are now found in waterbodies throughout southern Chile and, although the majority were intentionally stocked and established prior to aquaculture, escaped rainbow trout make up a substantial portion of the feral population (16%) and escape events are likely to have aided in establishment across a larger geographic range. The final numerical score for farmed rainbow trout from Chile is 3.81 out of 10 and a single red criteria in Criterion 4 – Chemicals leads to a final recommendation of Yellow “Good alternative.”

Table of Contents

Introduction

Scope of the analysis and ensuing recommendation

Species

Rainbow trout: *Oncorhynchus mykiss* (Walbaum, 1792) also previously known as *Salmo gairdneri* (Richardson, 1836) as reported in Billard (1989).

Geographic Coverage

Chile

Production Method

Marine net pens

Species Overview

Rainbow trout are native to the western seaboard of North America from Alaska to Baja California, Mexico, as well as the upper Mackenzie River drainage (Arctic basin), Alberta, and British Columbia in Canada. They have been intentionally introduced as a sport fish worldwide and are now naturalized on all continents except Antarctica. They are highly adaptable, and capable of inhabiting many different habitats ranging from an anadromous lifestyle in coastal waterways to permanent residence in freshwater lakes. From an aquaculture perspective, they are easy to spawn, fast growing, and tolerant of a wide range of environments and handling; the fry are also easily weaned onto artificial diets. Although they are non-native to Chile, they are now widely distributed and have established viable populations in the wild (FAO 2005, Luna and Torres 2011, Monzón-Argüello, Consuegra et al. 2014).

Production statistics

Chile is the world's foremost producer of rainbow trout, harvesting 71,381 metric tons (henceforth, "tons" or MT) in 2016, making it the third most produced salmonid in Chile (after Atlantic salmon and coho salmon), and comprising 10.6% of the country's salmonid production (DAS/SPA 2017). Los Lagos (Region X) and Aysén (XI) are the main regions producing rainbow trout (Figure 1), with 29,000 MT and 25,900 MT originating from Region X and XI, respectively in 2016 (DAS/SPA 2017). This figure is the lowest since 2005, and shows a reduction of 191,293 MT (73%) from a peak production of 262,674 MT of trout in 2012. The most recent global statistics indicate that Chile represented 63.3% of total marine rainbow trout production (net pens) in 2014, with 131,315 tons of production; this total is nearly double the second-largest producer, Norway (68,910 tons) (FAO 2016).

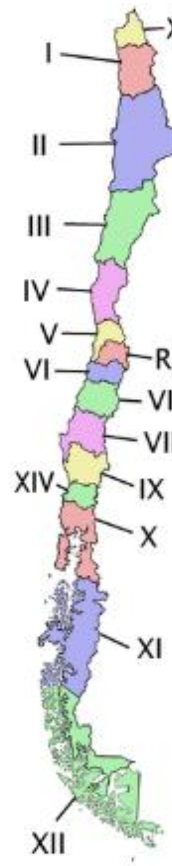

Figure 1: Chile regional map, copied from Wikipedia. Most rainbow trout production in net pens occurs in regions X (Los Lagos) and XI (Aysén).

The sharp drop in Chilean rainbow trout production is reported to have been due to two main factors: the first was infection, increasing the mortality to 21.81% in 2013 (Tallaksen 2013), while the second factor was production adjustments due to low prices during 2012 and 2013, which led to a strong price recovery at the start of 2014 (Villegas 2014). It is also thought that the Infectious Salmon Anaemia (ISA) outbreak, which began in 2007 through 2008 and caused the salmon industry to collapse between 2009 and 2011, led to a switch to rainbow trout to maintain production. Since the end of the crisis, producers have switched back to salmon production, in the process dropping trout production, and contributing to the return of trout production to pre-crisis levels.

Import and export sources and statistics

Chile exported 44,924 MT of rainbow trout in 2016 (through November), a value of $354 million, down 28.3% by volume and 13.3% by value since 2015 (DAS/SPA 2017). Chilean exports of rainbow trout peaked in both volume and value in 2012, with 141,092 tons worth $892.9

million being exported. Rainbow trout currently represent the second most valuable Chilean aquaculture export after Atlantic salmon (Figure 2).

Exports of salmonid products through November 2016 are dominated by sales to Japan, Russia, and the USA, accounting for 26.3%, 15.9%, and 12.2% of exported frozen aquaculture products (which is almost exclusively salmonids) respectively (Table 1, DAS/SPA 2017). The major recipients of fresh aquaculture products are the USA and Brazil, representing 53.3% and 33.6% of exported product, respectively (Table 2, DAS/SPA 2017). Although these statistics do not differentiate by aquaculture species, commentary by Subpesca indicates that rainbow trout exports to the United States accounted for roughly 95% of total rainbow trout exports in 2016; however, this value fell 47.1% since 2015, while rainbow trout prices increased 25.9% over the same period (DAS/SPA 2017).

Table 1: Export value “Valor FOB” ($1000USD) and quantity “cantidad” (tons) for frozen Chilean aquaculture products through November 2015 and 2016. Data from Subpesca (2017).

País / Ítem	Valor FOB (miles US$)		Cantidad (toneladas)	
	2015	2016	2015	2016
Japón	667.226	563.719	121.575	87.778
Estados Unidos	326.839	337.055	40.530	40.733
Rusia	297.549	307.180	62.916	53.320
Francia	65.915	73.775	16.371	16.470
Brasil	66.634	68.961	13.050	12.634
México	67.234	68.042	9.125	8.136
Alemania	56.238	68.010	9.300	10.727
China	53.983	67.834	11.994	12.661
Tailandia	58.996	64.301	14.114	13.697
Otros	407.975	374.860	93.906	77.338
Total	2.068.589	1.993.736	392.881	333.493

Table 2: Export value ($1000 USD) and quantity (tons) for fresh Chilean aquaculture products through November 2015 and 2016. Data from Subpesca (2017).

País / Ítem	Valor FOB (miles US$)		Cantidad (toneladas)	
	2015	2016	2015	2016
Estados Unidos	756.193	884.147	98.624	93.025
Brasil	377.880	397.802	74.089	61.042
China	31.872	87.429	6.152	12.308
Argentina	39.479	44.011	7.218	6.662
México	10.248	11.505	1.287	1.223
Colombia	10.120	10.975	1.391	1.241
Uruguay	3.426	3.919	404	421
Perú	2.108	2.861	342	362
España	1.850	2.533	230	285
Otros	5.484	7.023	762	859
Total	1.238.660	1.452.206	190.499	177.427

Figure 2 shows the division of export value by species, showing that rainbow trout export values were approximately US$335 million through November 2016, compared to approximately US$2,652 million for Atlantic salmon. Rainbow trout is the second most significant salmonid export, by value, from Chile.

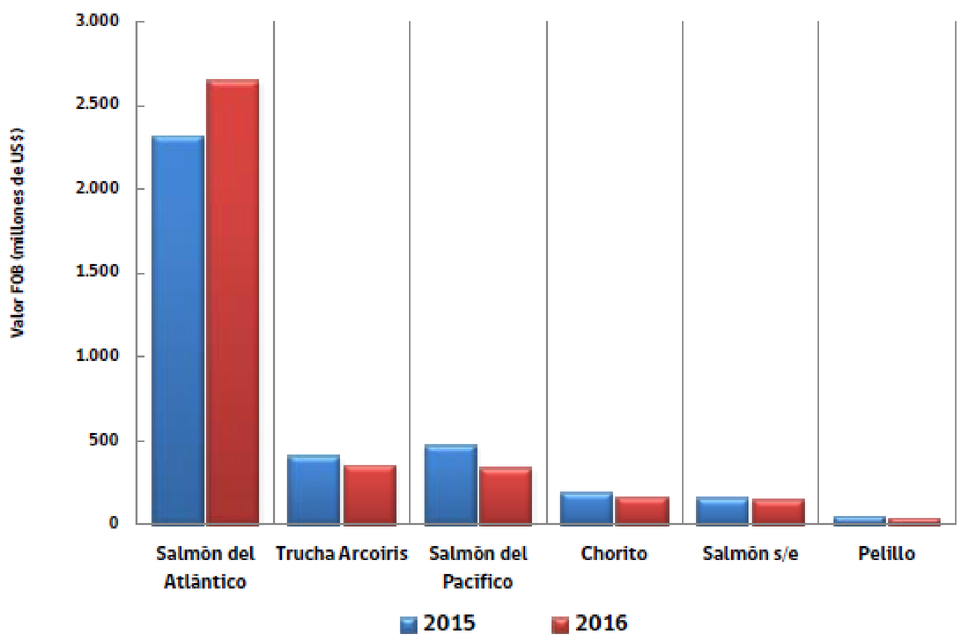

Figure 2: Value of exports of salmonids from Chile in 2015 and 2016, subdivided into species (DAS/SPA 2014). Relevant translations: Salmon del Atlántico (Atlantic salmon); Trucha arcoiris (rainbow trout); salmon del Pacifico (Pacific salmon).

Common and market names

Scientific Name	*Oncorhynchus mykiss*
Common Name	Rainbow trout, steelhead

Spanish	Trucha arcoiris
French	Truite arcenciel
Japanese	虹鱒 (Torauto)

Product forms

As shown in Table 3, rainbow trout take the following product forms:

- Frozen (87.8% of exports in 2013)
- Fresh (6.9% of exports in 2013)
- Salted (1.9% of exports in 2013)
- Smoked (3.3% of exports in 2013)

Table 3: Export quantity for the different product forms of combined salmon and rainbow trout in Chile between 2008 and 2013 (FAO 2014).

Exports (quantity)
Salmon and Trout: Chile

	2008	2009	2010	2011	2012	2013
	(1 000 tonnes)					
Salmon	**320.8**	**270.2**	**170.9**	**259.2**	**347.3**	**417.6**
Frozen	212.4	195.7	115.8	169.1	208.8	260.2
Fresh	100.8	65.3	49.1	81.0	132.2	151.7
Canned	3.4	2.7	1.1	0.5	0.8	1.1
Salted	0.9	3.7	2.4	5.3	2.4	1.7
Smoked	3.3	2.7	2.5	3.3	3.1	2.9
Trout	**124.8**	**99.1**	**126.2**	**130.0**	**141.0**	**110.5**
Frozen	115.8	88.3	107.4	113.0	126.3	97.0
Fresh	5.5	5.9	12.7	9.6	8.1	7.6
Canned	0.2	0.1	0.1	0.0	0.0	0.0
Salted	0.1	1.5	3.0	3.6	2.7	2.1
Smoked	3.3	3.3	3.0	3.7	3.9	3.7
Total	**445.6**	**369.2**	**297.2**	**389.3**	**488.3**	**528.1**

Source: Boletín de Exportaciones del IFOP

Analysis

Scoring guide

- With the exception of the exceptional factors (9X and 10X), all scores result in a 0 to 10 final score for the criterion and the overall final rank. A 0 score indicates poor performance, while a score of 10 indicates high performance. In contrast, the two exceptional factors result in negative scores from 0 to -10, and in these cases 0 indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in Appendix 1.

Production system

The production system focused on in this report is the marine net pen. Fish are hatched and weaned in freshwater (not covered in the scope of this study) and are transferred to seawater net pens when they achieve weights of around 100 to 200 g. They are grown to between 2.3 and 3 kg (5 to 6.6 lb), at which point they are harvested and processed for sale. Pens routinely used are floating steel (Figure 3) or circular plastic structures, both of which are considered "open" in that they allow full water exchange with the surrounding environment (M. Vera, PHARMAQ AS Chile, pers. comm. 04 June 2017).

Figure 3: An example of salmonid net pens as used in Chile.

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.*

Criterion 1 Summary

Data Category	Data Quality	Score (0-10)
Industry or production statistics	7.5	7.5
Management	7.5	7.5
Effluent	5	5
Habitat	5	5
Chemical use	5	5
Feed	5	5
Escapes	7.5	7.5
Disease	5	5
Source of stock	10	10
Predators and wildlife	5	5
Introduced species	7.5	7.5
Other – (e.g., GHG emissions)	Not Applicable	n/a
Total		**70**

C1 Data Final Score (0-10)	**6.36**	**YELLOW**

Brief Summary

Across the categories assessed, data availability ranged from moderate to high; for example, production statistics are easily accessible in the public domain, but detailed data on effluent and habitat impacts are somewhat limited. A large body of scientific literature on salmonid farming is available, but only a limited number of studies are specific to Chilean rainbow trout production. Data availability has improved considerably in the last decade, but there are still many unknowns regarding the environmental impact of Chilean rainbow trout farming. The final score for Criterion 1 – Data is 6.36 out of 10.

Justification of Ranking

The culture of Atlantic and coho salmon and rainbow trout is often carried out at the same site, and even when this is not the case, many of the same diseases, feeds, culture methods, effluent characteristics, regulations, and other factors are common between the three species.

Therefore, it stands to reason that much of the information available for evaluation in this assessment relates to salmonid farming activities in general; in many areas it does not differentiate between salmon and rainbow trout farming. As such, significant sections of this report are reproduced from the Seafood Watch report on Atlantic and coho salmon aquaculture in Chile (Bridson 2014) and are referenced as such, where appropriate.

Industry and Production Statistics

Industry data have been collected from government agencies and industry bodies, such as Sernapesca[1] (*Servicio Nacional de Pesca* – National Fisheries Service), Subpesca[2] (*Subsecretaria de Pesca* – Undersecretary of Fisheries), and SalmonChile (the industry association), though not all data are publicly available. Production figures and export information were obtained through Sernapesca and the Department of Sectorial Analysis (*Departamento de Análisis Sectorial*), as well as the Food and Agriculture Organization of the United Nations (FAO). Some of the data used in this report have been collected from papers or reports referencing these governing bodies. There is some variation among the figures across the various sources, though overall a good representation of the industry was obtained. The data score for Industry and Production Statistics is 7.5 out of 10.

Management and Regulations

Information regarding Chilean aquaculture regulations and national management are available in full through Sernapesca (in Spanish). A comprehensive understanding of the regulatory landscape in Chile was obtained, especially with input from the literature. On the other hand, company-level management regimes and information indicating compliance with existing management and regulations – such as reporting wildlife interactions – are not always available. As such, the data score for Management and Regulations is 7.5 out of 10.

Effluent and Habitat

Overall, there is a lack of data specifically related to rainbow trout among a general limited dataset for all salmonid culture, especially information regarding soluble effluent which is not required to be monitored in Chile. Data on nutrient discharges were taken from the primary literature, such as Bureau and Hua (2010) and Bouwman, Beusen et al. (2013) (studies of salmon culture); effects of effluent release on the environment were obtained from a number of sources, e.g., (Mayr, Rebolledo et al. (2014) (Iriarte et al. (2005, 2010, 2013, 2014) (Buschmann et al. (2006, 2007) (Navarro, Leakey et al. (2008) (Niklitschek, Soto et al. (2013) (Husa, Kutti et al. (2014). These studies deal mainly with salmonid or salmon cage culture; some may be considered potentially out of date, and some relate to countries other than Chile, so the contribution of rainbow trout to potential effluent impacts in Chile remains largely unknown. Regulatory information was taken again from the Sernapesca website and bolstered through the primary literature including studies by Alvial, Kibenge et al. (2012) and Quiroga, Ortiz et al. (2013), as well as some of those highlighted above. The Sernapesca website provides an abundance of information regarding site locations and groupings of concessions. Benthic

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[1] http://www.sernapesca.cl

[2] http://www.subpesca.cl/institucional/602/w3-channel.html

monitoring results were obtained from INFA reports (*Informes Sanitarios y Ambientales Acuicultura*) published by Sernapesca, but are not differentiated by species within the "Salmonidos" (salmonid) group. Considering all available information, both Chilean management and the literature have thus far not succeeded in providing a robust understanding of the potential cumulative effluent and habitat impacts of rainbow trout culture. Thus, the data scores for both Effluent and Habitat are 5 out of 10.

Chemical Use

Information regarding the use of antibiotics (total use by type, species, region, farming area, and diagnosed disease) was available through Sernapesca (*Informe Sobre Uso de Antimicrobianos en la Salmonicultura;* Sernapesca 2017; *Manual de Buenas Prácticas en el Uso de Antimicrobianos y Antiparasitarios en Salmonicultura Chilena*[3]). SalmonChile provides company-level antibiotic and pesticide use data, though these are not species-specific. The Global Salmon Initiative (GSI) also provides company-level antibiotic and pesticide use data for eight member companies in Chile, though not all is species-specific and appears to be incomplete at times for rainbow trout. These data were supplemented with information from the primary literature (Burridge et al. 2010, Wegener 2012) and personal communications (F. Cabello, pers. comm. 11 June 2014). No information about sea lice treatment frequency specific to rainbow trout could be obtained; Sernapesca has records of antiparasite treatments, though these are not publicly available, and at the date of writing, requests for information have not been completed.

In terms of resistance (to antibiotics and antiparasite chemicals), information was taken from a large body of recent literature (Lynch and Perez 2011, Buschmann et al. 2012, Miranda 2012, Laxminarayan, Duse et al. 2013, Shah et al. 2014, F. Cabello, pers. comm. 16 September 2014)). Yet, a lack of monitoring data from the government in terms of resistance, as well as some uncertain and limited information in the primary literature on the environmental effects of chemicals, resulted in an overall data score of 5 out of 10 for Chemicals.

Feed

Public information from the Chilean feed industry is limited, such as (Skretting, (2012, 2011a, 2011b). A request for data was completed by one company by the time of writing, and was largely in agreement with information from the primary literature such as Hernandez et al. (2016) and Tacon et al. (2011). Seafood Watch (2017) obtained ingredient composition data from two Chilean feed manufacturers for Atlantic and coho salmon, and some of this information was used as proxies in this rainbow trout assessment. As a result, a data score of 5 out of 10 is given for Feed.

Escapes

Data on escaped fish, not differentiated by species, were published by Sernapesca (2014d); they were combined with similar non-differentiated company-level data from SalmonChile (up to 2015) and estimates in the primary literature, such as those provided by Arismendi et al.

[3] http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=fileinfo&id=4097

(2014). These data are a few years out of date and information about recent escapes, though reported to Sernapesca, have not been updated in the public domain. Information relating to recapture after escapes was lacking, and several authors highlighted inadequate reporting procedures. A large body of recent literature details the impact of escaped and intentionally introduced rainbow trout in Chilean ecosystems (Arismendi et al. 2014) (Monzón-Argüello et al. 2014a/b) (Di Prinzio et al. 2013) (Garcia de Leaniz et al. 2013) (Marr et al. 2013) (Monzón-Argüello et al. 2013) (Sepulveda et al. 2013) (Arismendi et al. 2012) (Schroeder and Garcia de Leaniz 2011) (Garcia de Leaniz et al. 2010). Although an accurate number of escapes is not well known, the body of literature exploring their impact has become more robust recently; the final data score for Escapes is 7.5 out of 10.

Disease

A good amount of data on disease at the farm level was available from Sernapesca through annual fish health reports (*Informe Sanitario de Salmonicultura en Centros Marinos*), which detail disease and mortality by species and region. Several member companies of the GSI have provided mortality data and sea lice counts specific for rainbow trout production as well. Disease management data were obtained through Chilean disease management and surveillance programs, covering both infectious diseases and sea lice infections (*Programas de Prevención, Vigilancia y Control de la Enfermedades de Alto Riesgo*; *Programa Caligus*). Additional information was pulled from the primary literature, such as (Rees, Ibarra et al. (2014) (Zagmutt-Vergara, Carpenter et al. (2005) (Hamilton-West, Arriagada et al. (2012) and (Bravo, Nunez et al. (2013), among others. Although the literature is helpful in clarifying the on-farm impact and dynamics of disease, information regarding the impacts on wild fish populations (which are the focus of Disease Criterion) are limited. Therefore, the data score for Disease is 5 out of 10.

Source of Stock

There is a large body of literature and public information regarding domesticated broodstocks and selective breeding programs globally, inclusive of Chile (Janssen et al. 2015) (Cárcamo et al. 2015). Government data indicating the sourcing of imported rainbow trout eggs were well detailed (which applies to Criterion 10X as well). Therefore, the data score for Source of Stock is 10 out of 10.

Wildlife and Predator Mortalities

While some data could be found on predator and wildlife interactions and mortality through the literature and GSI, there is a lack of official data on mortalities. The aquaculture literature details interactions and direct impacts to major species such as sea lions, and the risk of population-level impacts to other affected populations (such as a variety of cetaceans and birds) was estimated using IUCN data. Yet, there is a lack of understanding of the impact that rainbow trout farms specifically may have on these populations, regardless of their status; therefore, the data score for Wildlife and Predator Mortalities is 5 out of 10.

Secondary Species Introduction

Detailed data regarding the number of egg imports for the last six years were obtained through Sernapesca (*Estadística de Importación de Ovas por origen*[4] and Sernapesca 2014b). No information was available regarding the movement of trout between freshwater smolt sites and marine growout sites. Regulations governing the import of eggs and other live fish movements are available through Sernapesca's website, and summarized by Alvial (2012). The data score for Secondary Species Introduction is 7.5 out of 10.

Conclusions and Final Score

In terms of the data availability, Chile has previously been considered as having relatively poor levels of publicly available data. Despite having significant levels of aquaculture production, in 2007 only 2% of the world's aquaculture environment studies focused on Chilean production (Buschmann, Costa-Pierce et al. 2007). Data collection, analysis, and dissemination have improved since that time, but significant gaps in the knowledge are still present. Government publications and the primary literature provide a good amount of information regarding many criteria, though limitations exist throughout; for example, although disease and mortality statistics are well recorded, the impact of aquaculture diseases on wild fish populations is not well understood. Overall, the final score for Criterion 1 – Data is 6.36 out of 10.

[4] http://www.sernapesca.cl/index.php?option=com_content&task=view&id=73&Itemid=185

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.*

Criterion 2 Summary

Effluent Risk-Based Assessment

Effluent parameters	Value	Score
F2.1a Waste (nitrogen) production per of fish (kg N ton^{-1})	77.02	
F2.1b Waste discharged from farm (%)	80	
F2.1 Waste discharge score (0-10)		3
F2.2a Content of regulations (0-5)	3	
F2.2b Enforcement of regulations (0-5)	3	
F2.2 Regulatory or management effectiveness score (0-10)		3.6
C2 Effluent Final Score (0-10)		4.00
Critical?	NO	**YELLOW**

Brief Summary

Due to the open nature of net pen production systems, virtually all waste produced from an operation, including dissolved and particulate effluents, discharge directly to the surrounding environment with little or no intervention; however, there is contradictory or inconclusive evidence of direct impacts beyond the immediate vicinity. Data on day to day effluent discharges are inherently difficult to gather, especially in the case of soluble nutrients; thus, the availability of reliable data is limited. In this assessment, the calculations according to the Seafood Watch criteria produced a waste discharge value of 61.6 kg N t^{-1}.

High stocking and farm densities and limited studies conducted on Chilean rainbow trout farming, in addition to concerns over the effectiveness of the regulatory systems in place, mean that the industry cannot be considered the same as similar activities in other places around the world. Chile does not require soluble nutrient monitoring in the water column surrounding rainbow trout farms, though benthic monitoring is required at both peak biomass and prior to restocking pens (addressed in Criterion 3 – Habitat). Although the literature suggests impacts beyond the immediate vicinity of farms are unlikely, there is growing concern over the potential cumulative impacts related to the carrying capacity of the surrounding environment. The expansion of salmonid production in Chile thus far has not been accompanied by a relative improvement in monitoring and regulation; certain regulatory issues are yet to be fully addressed, including mechanisms to avoid over centration of operations, defining boundaries of productions zones, and defining carrying capacities of production zones. Overall, substantial waste discharge combined with moderate regulatory effectiveness give a final score for Criterion 2 – Effluents of 4 out of 10.

Justification of Ranking

The Effluent Criterion considers the impacts of farm waste that is discharged beyond the immediate farm area as effluent (waste remaining within the immediate footprint of the farm is considered in Criterion 3 – Habitat).

It should be noted that there is a certain amount of overlap with Criterion 3 – Habitat. To clarify exactly what falls into each of the two related criteria, the Seafood Watch Standard assesses the environmental impacts of these wastes as follows:

- Criterion 2 – Effluent assesses impacts of both particulate and soluble wastes beyond the immediate farm area or a regulatory Allowable Zone of Effect (AZE).
- Criterion 3 – Habitat assesses the impacts of primarily particulate wastes directly under the farm and within a regulatory AZE.

The scientific community has extensively studied the direct environmental effects of marine cage culture at the farm site level, focusing on the fate and impacts of soluble and particulate wastes. Price et al. (2015) conducted a recent review of this literature, and conclude "modern operating conditions have minimized impacts of individual fish farms on marine water quality," while specifically noting that better management has effectively eliminated negative effects on dissolved oxygen and turbidity. The authors found that near-field water column nutrient enrichment is not detectable beyond 100 m under best management practices (use of formulated feeds at appropriate rates, properly sited in well-flushed deepwater sites), while also highlighting risk of impacts when these management measures—proper farm siting, feeding protocols—are not in place, especially when farms are sited nearshore. The authors also conclude that questions remain regarding the cumulative impacts of discharge from multiple farms in close proximity.

Included in Price's review was a study of the main environmental challenges posed by the southward expansion of the Chilean salmon industry in Patagonia (Niklitschek et al. 2013), which showed that, despite being naturally relatively poor in nutrients, there was no evidence of measurable nutrient enrichment or changes to fjordic pelagic ecosystems around salmonid farms in Region XI in Chile, where large amounts of nitrogen and phosphorus (12,300 MT and 1,600 MT, respectively) are discharged. Similar conclusions have been drawn from salmon operations in British Columbia (Brooks and Mahnken 2003) and Norway, which show that even in the most densely farmed region all nutrient and chlorophyll-a values were within the thresholds for high water quality set by the national authorities (Husa, Kutti et al. 2014). In contrast, a recent study on the changes in depositional rates of nitrogen and carbon in the Comau Fjord in Chile over the last 100 years found a doubling of mass accumulation within the last two decades (Mayr, Rebolledo et al. (2014). After considering various factors, the authors conclude that anthropogenic eutrophication by rapidly expanding aquaculture is the most likely explanation for increased accumulation rates in this area.

Iriarte et al. (2005, 2010, 2013) also postulate that aquaculture activities may modulate the seasonal phytoplankton blooms and stimulate growth of harmful algal blooms (HABs) in southern Chile. They state that increasing aquaculture activities may change water chemistry in the near future, by introducing additional nitrogen as ammonia as well as dissolved organic matter (DOM) (Iriarte, Van Ardelan et al. 2014), in turn affecting iron (Fe) bioavailability and potentially affecting phytoplankton-bacterial structure and function. Indeed Iriarte, Pantoja et al. (2013) highlight the complexity of the region's nutrient dynamics and the challenge of attributing causes and effects due to salmon aquaculture; they conclude: "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."

Both Mayr et al. (2014) and Niklitschek et al. (2013) reinforce the urgent and evident need to estimate actual carrying capacities of these water bodies, before allowing for a significant increase in the current aquaculture production levels. These authors conclude that the risk of exceeding the ecosystem capability to incorporate nutrients into the food-web (carrying capacity) is a matter of immediate concern. They note that no carrying capacity studies are available for the Aysén area (Region XI), and the limited scientific research conducted there appears to be a major obstacle to reducing the environmental risks of the imminent industry expansion. Iriarte, Gonzalez et al. (2010) state that the precise estimation of the carrying capacity of the fjord systems for aquaculture activities and the possible impacts of changes in the carrying capacity on ecosystem services is a major scientific challenge. As of 2015, Chilean aquaculture industry stakeholders, including aquaculturists, academics, fishers, government, and NGOs, generally agreed that in most cases, "carrying capacity of the [salmonid aquaculture] area is unknown and spatial effects are completely ignored." (Salgado et al. 2015).

The Seafood Watch Aquaculture Standard has two options for assessing the Effluent criterion: Evidence-Based and Risk-Based. Although there is a considerable amount of information regarding benthic impacts from salmonid net pen culture in Chile, there is a distinct lack of information regarding impacts beyond the immediate site area as well as cumulative effluent impacts, which this criterion aims to assess. This is primarily due to a lack of regulatory requirement to monitor soluble effluent in the water column, as well as cumulative spatial impacts, resulting in the accompanying lack of collected data regarding these. As the Risk-Based assessment includes an assessment of both the available data as well as the regulatory management system and its enforcement, it has been selected to assess Criterion 2 – Effluents.

Factor 2.1: Production system discharge
Factor 2.1 assesses the amount of nitrogenous waste produced by the fish (Factor 2.1a) and then the amount of that waste that is discharged from the immediate vicinity of the farm (Factor 2.1b).

<u>Factor 2.1a – Biological waste production per ton of fish</u>
To calculate the nitrogenous waste produced by the fish, nitrogenous inputs and outputs are calculated. The following data were provided by Intesal, the technical division of the Chilean salmonid farming industry association, SalmonChile, and one Chilean rainbow trout producer. The provided data were found to be aligned with and supported by information from the listed primary literature, and are used in the calculations for this criterion (please see Criterion 5 – Feed for more details regarding these values):

- (a) Protein content of feed – 42% (company data, Hernandez et al. 2016) (Hernandez et al. 2013) (Navarrete et al. 2013)
- (b) Economic Feed Conversion Ratio (eFCR) – 1.52 (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017)
- (c) Protein content of harvested whole fish – 15.7% (Boyd et al. 2007)

The calculations that were carried out using these figures and used in assessing the production and effects of effluents are:

N input per ton of fish produced = a x N content factor (0.16) x b x 10 = 102.14 kg N t^{-1}
N content of harvested fish = c x N content factor (0.16) x 10 = 25.12 kg N t^{-1}
Waste N produced per ton fish produced (2.1a) = N input – harvested N = 77.02 kg N t^{-1}

Therefore, the net excretion of nitrogen in soluble and particulate wastes is 77.02 kg N per ton of rainbow trout production.[5]

<u>Factor 2.1b – Production system discharge</u>
The Seafood Watch Aquaculture Standard considers that 80% of all waste produced by fish in a net pen operation are discharged as effluent from the farm, with 20% remaining within the footprint of the net pen. This provided a discharge score of 0.8.

In arriving at a final numerical score for factor 2.1, the values for 2.1a are multiplied by the value for 2.1b, giving a value for waste discharged per ton of fish of 61.62 kg N t^{-1} and corresponding to a waste discharge score of 3 out of 10.

Factor 2.2: Management and regulation of farm level and cumulative impacts
Factor 2.2a assesses the content of the farm-level and regulatory management measures, and Factor 2.2b assesses the enforcement of those management measures. Combined, they give an

[5] Note this is higher than the value for salmon calculated by SFW (2017), due to the higher protein content and eFCR value used for trout.

indication of the effectiveness of the management system overall to control cumulative impacts from the total tonnage of production of individual sites, and of multiple sites that share one receiving water body, area, or region.

The Chilean government regulates all salmonid aquaculture under the same umbrella; thus, rainbow trout farming in Chile is regulated under the same regulatory landscape as Atlantic salmon, a significantly larger industry. Many of the companies that produce Atlantic salmon also produce rainbow trout, often at the same sites. For these reasons, the following section is mostly duplicated from a Seafood Watch assessment of Chilean farmed Atlantic and coho salmon (SFW 2017).

Factor 2.2a: Content of effluent management measures

It is generally considered that the Chilean salmon industry initially expanded in a poorly organized manner without adequate consideration for the density of farms. For example, Salgado et al. (2015) described it as the fastest growing industry in Chile that developed with very limited regulation. This led to concerns about deleterious environmental changes at the site level, and cumulative impacts from multiple farms in the same area or region; 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 Chilean salmon farming in the late 2000s, and 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 the sector. Quiroga et al. (2013) also expressed the concern that the regulatory framework in Chile has not developed the sophistication to monitor, evaluate, and manage impacts in an effective manner comparable to other regulatory frameworks elsewhere. More recently, Salgado et al. (2015) found that inadequate regulatory institutions and governance continue to be the most important concerns of multiple stakeholders to achieve a sustainable aquaculture industry in Chile.

The industry itself has now become a key proponent for the development of new regulatory standards (Little et al. 2015) (Pozo 2016), and the regulatory system in Chile continues to evolve at a substantial pace; for example, the May 2016 revision[6] of the ACS (*Agrupación de Concesiones*—groups of farm sites [concessions] sharing a similar waterbody or area) area management system, and the October 2016 moratorium on new license applications in Region XII.[7] The system now in place can be considered substantially different from the one driving the concerns expressed in the previous paragraph.

Aquaculture in Chile is regulated by the General Law of Fisheries and Aquaculture (LPGA) of 2001, and although the basic content remains largely static, new resolutions provide practical

[6] Sernapesca (Technical report No 356).
[7] Subpesca Resolution 3264, 28 October 2016.

updates in the management of the industry. According to AquaChile (2015), the main organizations regulating aquaculture activities in Chile are:

- Undersecretariat of Fisheries and Aquaculture (Subpesca), which regulates aquaculture activities and establishes technical conditions under which it can develop.
- Undersecretariat for the Armed Forces, which grants aquaculture and marine licenses and establishes appropriate areas for aquaculture.
- Environmental Assessment Service, which participates in the environmental evaluation of projects.
- National Fisheries and Aquaculture Service (Sernapesca), which monitors compliance with the norms of aquaculture, sanitary management, and provides services to enable their correct implementation.
- General Directorate of Maritime Territory (DIRECTEMAR), which works to monitor activities developed in the sea, rivers, and navigable lakes.

Overall, there is a substantial volume of regulatory burden on the industry. Subpesca and Sernapesca (operating under the Ministry of Economy, Development, and Tourism) have the most relevance to the activities of interest to this assessment. The Sernapesca website (in Spanish) contains a large volume of regulatory information, and includes frequent new resolutions and updates. Isolating the content of relevance to any one impact (e.g., effluent wastes) is challenging.

The key environmental regulation is *Reglamento Ambiental para la Acuicultura* (RAMA) of 2001 and updated 2009 (Sernapesca 2016c). At the site level, the monitoring of soluble nutrient effluents in the water column is not mandated in the regulations, and effluent impact monitoring in salmon farming internationally has generally focused on the discharge of particulate organic matter and the resulting changes in benthic biogeochemistry and biodiversity (Elizondo-Patrone et al. 2015). This is the case in Chile through the INFA environmental assessments and minimum requirements such as mandatory three-month fallowing periods for sea sites.

Under the RAMA regulations, benthic assessments for INFA (under Resolution 3612 updated in 2014) are performed before the start of harvesting (i.e., at maximum biomass). These regulatory measures focus on the immediate allowable zone of effect, but they can be of use to the Effluent Criterion through the demonstrated relationship between near- and far-field ecosystem health metrics. Studies in Chile and elsewhere 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); therefore, the benthic results within the immediate farm area can be used to infer the degree of impacts beyond it. Although there is a suite of measurement parameters, the primary indicator is the aerobic/anaerobic status of the sediments, measured by the presence of dissolved oxygen in the interstitial water in the first three centimeters of sediment (see Criterion 3 – Habitat for more information). An anaerobic result (deficit of oxygen) indicates a moderate to high level of enrichment of the seabed. A farm may not restock fish at a site if it does not have results showing that the center of the site is operating under aerobic environmental conditions.

In regard to cumulative impacts and the scale of production, the primary tool employed is the division of the farming regions (X, XI and XII) into groups of farm sites (concessions) sharing a similar waterbody or area—*Agrupación de Concesiones*, or ACS. Each ACS is legally defined and has a fish health management plan.

Based on a 2009 regulation (Resolution 1449) updated most recently in May 2016 (Technical report No. 356), biomass limits and stocking densities are set according to a classification calculation of the ACS based on the INFA results of the farms (aerobic or anaerobic), the mortality numbers of fish, and the production relative to projections (all from the previous production cycle). For example, if between 75.1% and 100% of the INFA results for sites in the ACS are “aerobic” after the last production cycle, then 100% of the planned stocking can be repeated. This reduces sequentially with increasing numbers of “anaerobic” INFA results, such that only 25% of the fish can be stocked in the next cycle if less than 25% of the INFA results are “aerobic.” Similarly, mortalities above 15.1% have a reduction in stocking of 10%, which increases to a reduction of 60% if mortality is greater than 26%. These factors are weighted and used to give a final score for the ACS, which determines the stocking density (ranging from 11 to 17 kg/m^3 for Atlantic salmon) and the corresponding number of fish stocked. Based on growth projections, this will correspond to a predicted peak biomass before harvesting begins. Thus, although the INFA assessment is conducted at the site level, it is at least partly involved in setting production limits at the area level.

Despite this apparently complex system, questions remain about the applicability and appropriateness of the regulations to the carrying capacity of the waterbodies in which the industry operates. Niklitschek et al. (2013) warn that, though 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 in Chile appears to be a major obstacle to reducing the environmental risks of the industry. These authors (Niklitschek et al. 2013) concluded that the risks of exceeding the ecosystem’s capability of assimilating the industry’s discharge of nutrients into the food web (i.e., the ecosystem’s carrying capacity) are a matter of immediate concern. It is also unclear if the ACS boundaries are set according to relevant hydrographic characteristics of the waterbodies, or if they are primarily defined according to practical production requirements of the industry. Pitchon (2015) questions whether aquaculture policy governing the use of inshore coastal areas for salmon farming in Chile adequately ensures ecological (and social) sustainability. From a regional perspective, much of the information and study has focused on Regions X and XI where the current industry is concentrated. Production has been slowly expanding into Region XII, and as discussed in Criterion 3 – Habitat, less is known about potential impacts there. Recent regulatory changes (Resolution 3264, 28 October 2016) placed a moratorium on new license applications for Region XII; however at that time, approximately 1,000 applications were already in place with Sernapesca. There are currently 106 registered sites in Region XII. It appears the existing 1000 applications will lead to a small number of additional sites (between 7 and 25) while new areas are evaluated and some existing sites are relocated (SFW 2017).

Overall, the aquaculture regulations in Chile are substantial in their volume of content; however, their true effectiveness and applicability to the effluent discharges of the industry as a whole and their cumulative impacts continues to be uncertain. The use of the aerobic status for benthic impacts at peak biomass is considered to address (or at least substantially reduce the risk of) benthic impacts beyond the immediate farm area, and the ACS system is intended to address the cumulative impacts; however, with a focus on fish health, the uncertain effectiveness of the ACS system's management of cumulative impacts is limiting. The score for Factor 2.2a is 3 out of 5.

Factor 2.2b Enforcement of effluent management measures

Clearly, there is substantial enforcement of the aquaculture regulations in Chile. Sernapesca is identifiable as the primary organization, and it presents monitoring data such as INFA results and a large amount of other industry information online (www.sernapesca.cl). Resolution 3612 defines the qualifications and the accredited laboratories for those involved in sampling, and Sernapesca staff are confirmed to be present during INFA sampling (AquaChile, pers. comm. 2016).

The Global Salmon Initiative (GSI) also provides some indication that regulations are enforced by listing the number of non-compliances with environmental regulations. Between 2013 and 2016 inclusive, the eight member companies had an average of 22 environmental regulatory non-compliances per year (i.e., 2.75 per company), with an average fine of USD 3,219 per infringement. The infringements were generally related to maritime laws and the General Law for Fisheries and Aquaculture (and therefore not specifically related to effluent impacts). The specifics of the infringements show that there is some robust scrutiny and enforcement in place.

Regarding the effectiveness of the regulatory system in managing cumulative effluent impacts overall, practical questions remain within the academic literature and within the industry itself. Mayr et al. (2014) studied a doubling in depositional rates of nitrogen and carbon, and a change in the source of carbon from allochthonous[8] to autochthonous[9] over the last twenty years in a fjord in Chile, and concluded an increase in nutrients caused by aquaculture is the most likely explanation. Similar to the conclusion reached by Niklitschek et al. (2013) with respect to soluble wastes (i.e., noting the lack of carrying capacity studies and an ecosystems assessment of accumulated nutrients and its effects), 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.

[8] Allochthonous: material that is formed or introduced from somewhere other than the place it is presently found.

[9] Autochthonous: material formed or originating in the place where found.

The algal bloom in 2016 highlighted another example where insufficient research into the potential contributions of salmon farming to regional nutrient loads hinders effective understanding of the industry's management and enforcement. Many questions were raised in the popular media regarding both the ongoing salmon farming production and key events such as the dumping of thousands of tons of dead fish of Chiloe Island e.g., (Pfeiffer 2016) (Cambero and Slattery 2016). The Chilean Society of Marine Science (*Sociedad Chilena de Ciencias del Mar*) provided an independent overview of the causes (SCHCM 2016), of which an intense El Niño event was a primary one. Average sea surface temperatures were 2 to 4 °C higher than normal off the coast of Chile, and the normal influx of freshwater from rivers and glaciers and rain effect was diminished, which led to increased salinity. Changes in wind and current patterns caused upwelling that "produced algal blooms not seen in the region before" (SCHM 2016). It is not known if nutrients from salmon farms were a contributing factor to the blooms and therefore evidence of a lack of effectiveness and enforcement of the management systems; Elizondo-Patrones et al. (2015) note that these occurrences have been reported since 1993, coinciding with an intensification of salmon culture activity, but this aspect was not mentioned by SCHCM (2016), presumably because it was considered to be minor in comparison to the scale of the other external factors discussed. Regarding enforcement in this regard, two companies (Australis and Salmones Maullín) have been sanctioned for breaching contingency plans for their delayed disposal of dead fish.[10] Despite these examples of enforcement activities, the ongoing uncertainty in the industry's potential cumulative impacts in terms of direct nutrient input, and less well understood changes to nutrient ratios and effects on microbial communities, highlight the need for effective management and enforcement. The industry has been plagued by concerns that production is too densely concentrated in Regions X and XI (e.g., Niklitschek et al. 2013) indicating that the effectiveness of the regulatory systems is limited.

In Chile, the enforcement organizations are identifiable and active, and enforcement is active at the area-based scale through the ACS system. There is evidence of penalties for non-compliances, but questions and gaps in the understanding of the management of the industry's cumulative impacts remain. The score for Factor 2.2b is 3 out of 5.

Factor 2.2 Final Score

Overall, the scoring for Factor 2.2 "Management of farm-level and cumulative impacts" combines Factors 2.2a and 2.2b and results in a final score for of 3.6 out of 10. This reflects the ongoing gaps in knowledge and concerns for the efficacy of cumulative management.

Conclusions and Final Score

The final score combines the waste production score (Factor 2.1) with the management effectiveness score (Factor 2.2) to give an indication of a rainbow trout farm's effluent waste production, the potential impacts beyond the immediate farm area, and Chile's management of

[10] Intrafish Media, Dec 22 2016. Australis, AquaChile hit with sanctions for mishandling massive salmon mortalities. www.intrafish.com

cumulative impacts from multiple farms operating in the waterbody or region. The final score for Criterion 2 – Effluent is thus 4 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		7
F3.2a Content of habitat regulations	3	
F3.2b Enforcement of habitat regulations	3	
F3.2 Regulatory or management effectiveness score		3.6
C3 Habitat Final Score (0-10)		**5.87**
Critical?	NO	**YELLOW**

Brief Summary

The habitat criterion assesses the direct impacts on the farm area which, in the case of marine net pen rainbow trout 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 unique benthic fauna of high ecological value, including sites important for cold-water corals. The floating net pens used in salmonid farming have relatively few direct impacts to conversion of habitat, but the seabed impacts under them can be severe. It is apparent that there is a high degree of overlap between sites highlighted as ecologically important and the sites of farm operations; however, there is no consensus on the actual effects of such operations on the benthos; some authors suggest there are several effects with a wide area of impact, and others suggest the effects are minimal and restricted to a small area around the net pens.

Benthic monitoring data show that the majority of Chile's salmonid sites are rated as being in good condition (i.e., aerobic), but a significant proportion (23%) do not meet these requirements. The total impacts of all salmonid farm areas are limited to a relatively small spatial extent (approximately 1,300 ha or 0.1% of the region's coastal border), and are shown to be rapidly reversible, but the industry's southward expansion, albeit slow, has been, and continues to be, a cause for concern. Also, there is still uncertainty in the capability of the regulatory system, which has developed since the ISA outbreak in the salmon industry, to effectively monitor and control the impacts of the industry. The final score for Criterion 3: Habitat is 5.87 out of 10.

Justification of Ranking

The floating net pens used in salmonid farming have relatively few direct habitat impacts, but the operational impacts on the benthic habitats below the farm and/or within an Allowable Zone of Effect (AZE) can be profound (Buschmann et al. 2009).

According to Niklitschek, Soto et al. (2013), the southward expansion of the Chilean salmon industry in the Patagonian Fjords has caused increasing 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. The Habitat Criterion assesses any 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 in both cases is the same (i.e., uneaten feed and fish waste).

Factor 3.1. Habitat conversion and function

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

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 influence the abundance and diversity of infaunal communities; however, the exact environmental impacts of net pen aquaculture are varied and interactions between different factors may produce complex changes in coastal ecosystems (Buschmann, Cabello et al. 2009). Primarily, changes can be anticipated in total volatile solids, redox potential, and sulfur chemistry in 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). As noted in the Effluent Criterion, however, 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, but 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, Cromey et al. 2013).

Soto and Norambuena (2005) 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 net pens compared with control sites. Kowalewski (2011) documented a catastrophic decline in local benthic productivity triggered by fish farming, and Aranda, Paredes et al. (2010) recorded mats of filamentous bacteria covering the substrate below net pens and within the near field area from 10 to 60 m away. Niklitschek, Soto et al. (2013) also note conflicting studies that have shown increased species richness around farm sites in Chile (Soto and 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 in a simple form of "Aerobic" (i.e., good condition) or "Anaerobic" (i.e., poor condition). Classification of the two states is dependent on the results of a suite of indicators included in the Informes Sanitarios y Ambientales Acuicultura (INFA) assessment conducted at the time of peak biomass of feeding in the production cycle. The parameters include pH, dissolved oxygen, redox potential, organic matter, macrofauna abundance, and the presence of gas bubbles or bacterial mats (depending on the nature of the substrate type e.g., soft or rocky). The results from Sernapesca are not specified by species, and an analysis of all marine "salmonid" sites (Figure 5) shows the majority are in "Aerobic" condition at peak production, and the proportion has been rising since 2013; the 2016 data year is incomplete (includes data to August 2016).

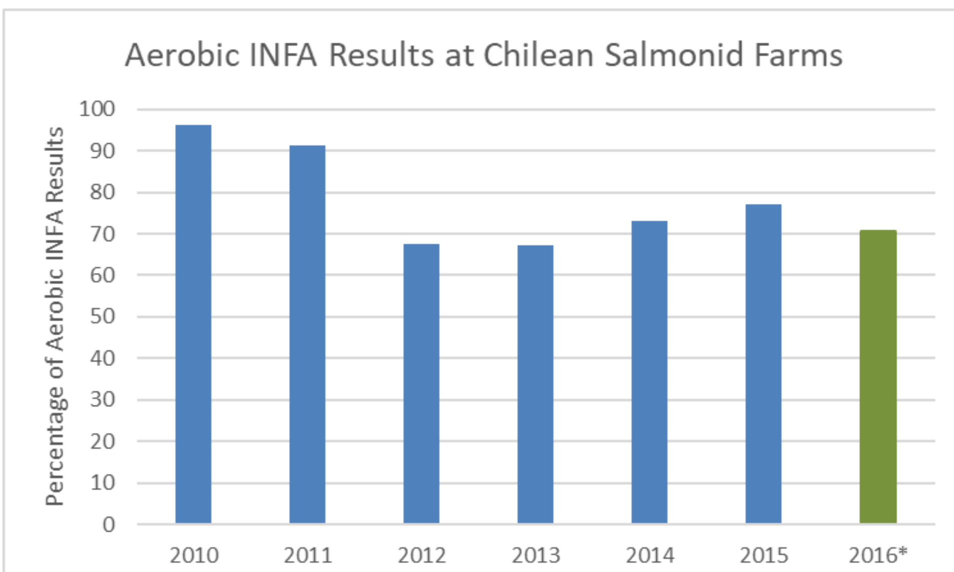

Figure 5: Percentage of aerobic sites in Chile. Data from Sernapesca. The 2016 data year is not complete at the time of assessment[11] and represents INFA results to 31 August. (Bridson 2014).

In 2015, 23% of marine sites were in anaerobic (i.e., poor) condition, which subsequently requires remediation to return to aerobic compliance conditions. Anaerobic sites must be

[11] Sernapesca data accessed 25 July 2017 has INFA results to 31 August 2016.

shown to have returned to aerobic status before fish can be restocked at a site (after a compulsory three-month fallow period, or longer if necessary; see Factor 3.2 below). Anaerobic INFA reports, particularly when repetitive, lead to reduced biomass permissions and also affect the stocking of the ACS as a whole. Due to the lack of species differentiation in the Sernapesca results, it is not known if trout sites in Chile perform differently from salmon sites, but for the purposes of this assessment, they are considered sufficiently similar to be assessed in combination.

Focusing on the Aysén region (XI), Niklitscheck et al. (2013) indicate that local impacts can be severe in intensity, but are confined to a relatively small spatial extent; they calculated that the region's 154 salmonid sites covered 1,278 ha of area, or 0.1% of the region's coastal border. Given the 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. The authors note, however, that this optimistic view must be qualified by considering two major issues:

1. As salmonid farms tend to be distributed in operational clusters, the actual proportion of the sea bottom impacted within a bay, fjord, or specific habitat may become much higher than average values.
2. It is necessary to assess the relative importance of such specific habitats, 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 (Haeussermann and Foersterra 2007).

As mentioned previously, when assessing ecological impacts based on undifferentiated salmonid data, it is important to keep in mind the relative contribution of rainbow trout to total salmonid production (10.6%), and the potential relative impact of trout compared to the industry as a whole. Also, from the farm siting information gained, it is impossible to determine exactly where the rainbow trout licenses are situated, although it is fair to assume that they would largely be sited near salmon licenses because many companies produce multiple salmonid species.

More broadly, it is necessary to consider impacts to overall ecosystem functionality as a result of rainbow trout farm siting, beyond the immediate impact to the benthos beneath a farm site. As mentioned above, Chilean fjords are incredibly diverse and productive ecosystems. Of particular concern is a portfolio of forty areas of high conservation value (Áreas de Alto Valor de Conservación, AAVC) shown in Figure 6, primarily established by WWF-Chile.

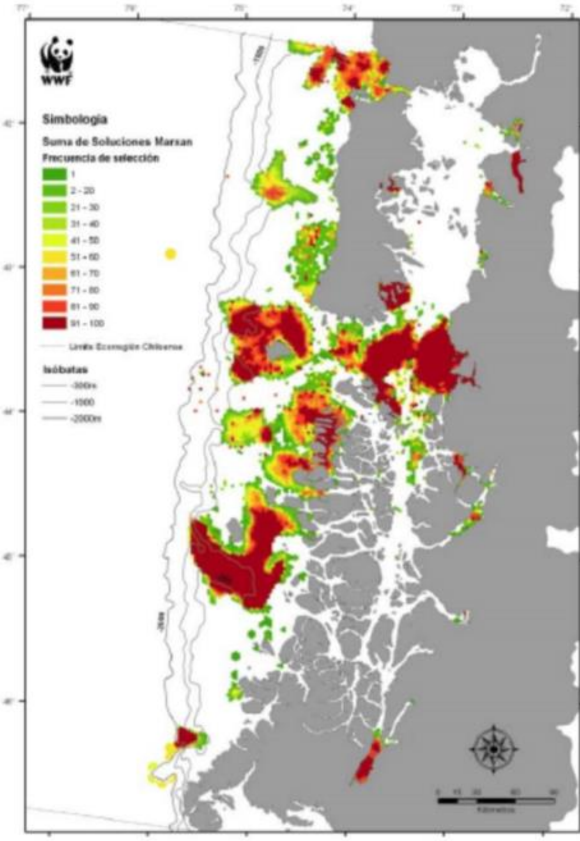

Figure 6: Areas of high conservation value. Darker red colors indicate areas of higher conservation value. Reproduced from (Bridson 2014).

The species involved in defining the AAVC are varied, but this region is known to include cold water corals that may be susceptible to salmonid farm impacts. Figures 7 and 8 show sites in regions X and XI in which cold water corals have been identified.

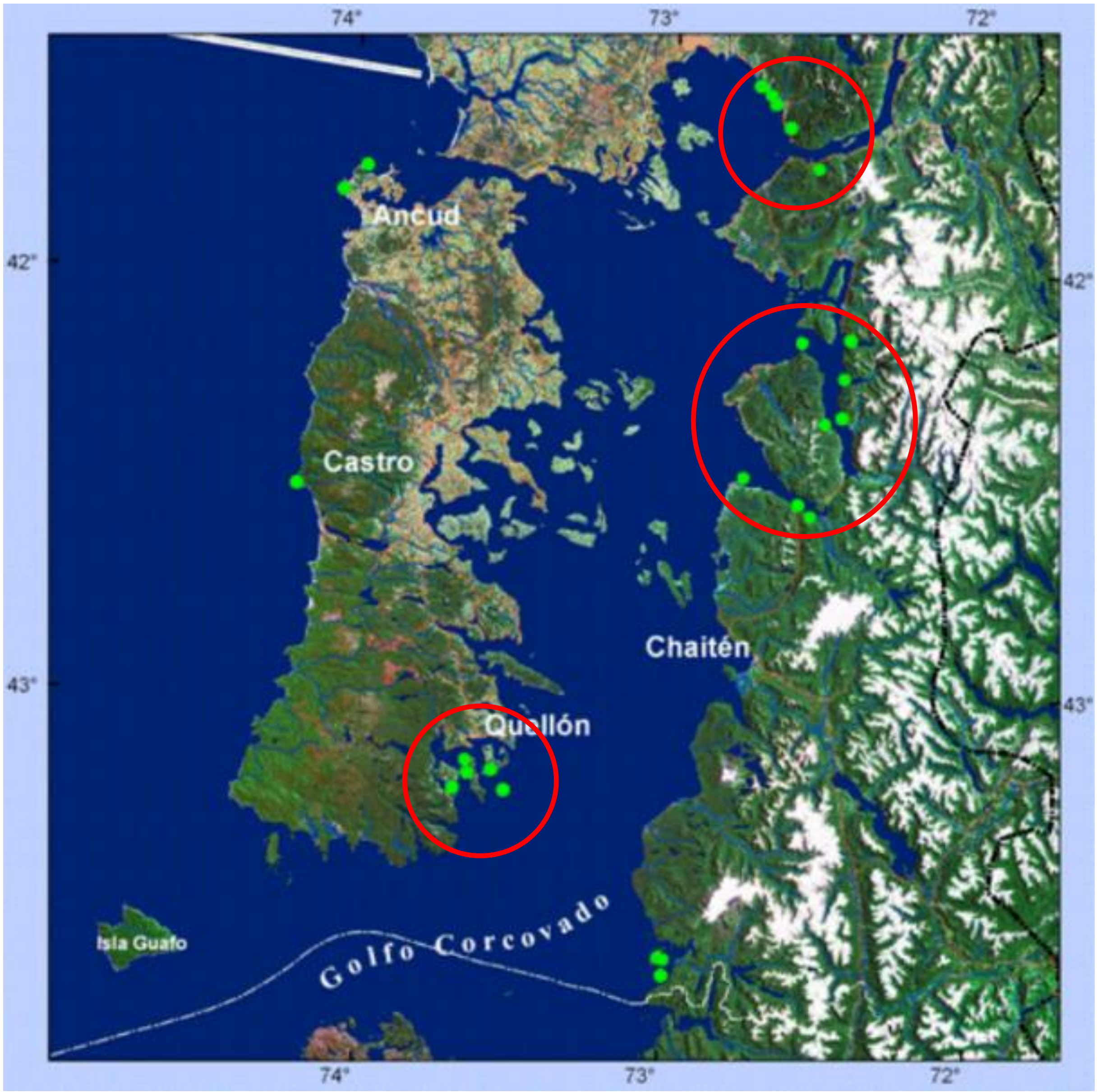

Figure 7: Sites with cold water corals (*Desmophyllum dianthus*, *Caryophyllia huinayensis*, *Tethocyathus endesa*) in Region X. Red circles demonstrate areas where salmonid site licenses overlap with soft coral sites. Reproduced from Miethke and Galvez (2009).

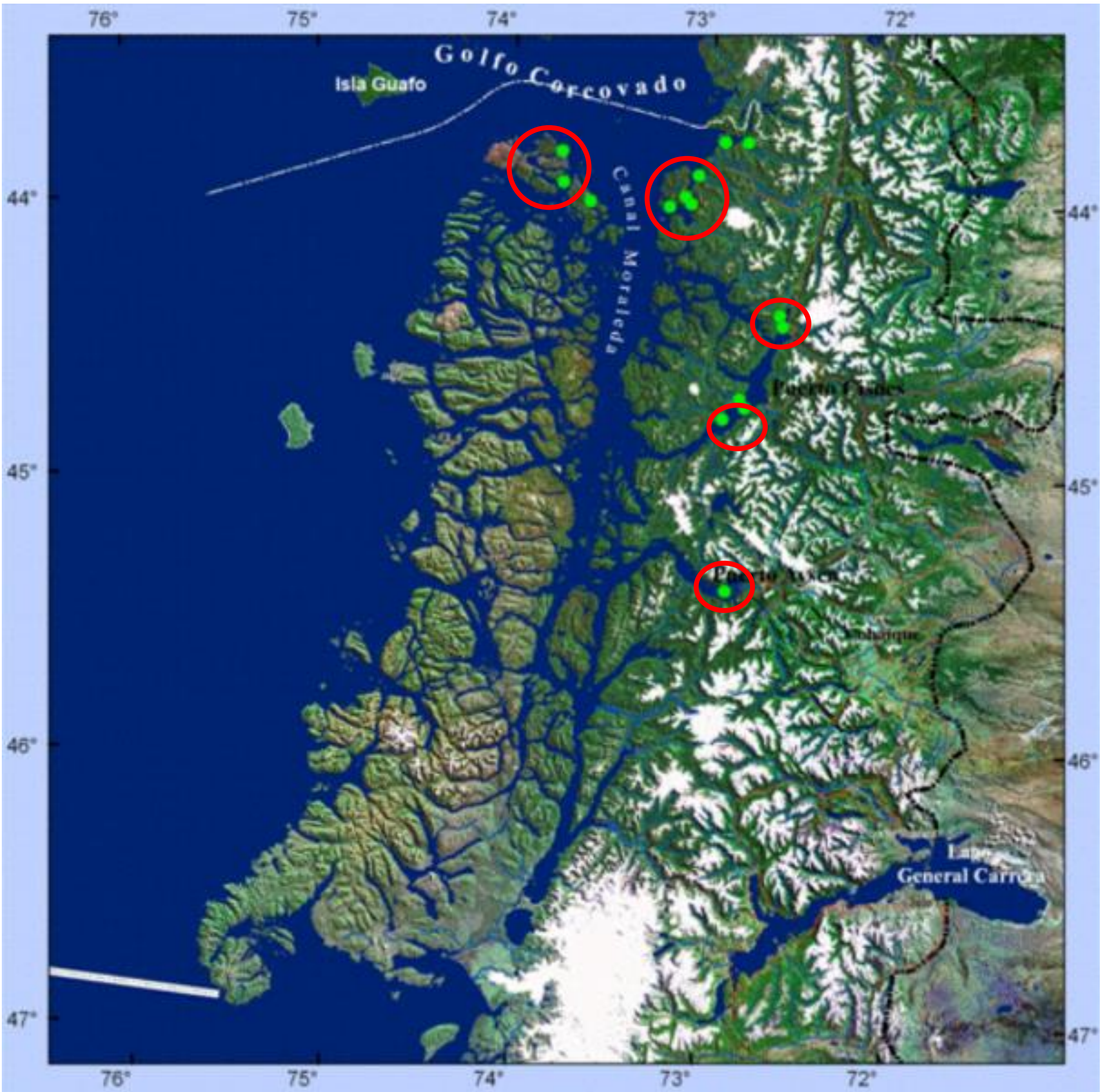

Figure 8: Sites with cold water corals (*D. dianthus*, *C. huinayensis*, *T. endesa*) in Region XI. Red circles demonstrate areas where salmonid site licenses overlap with soft coral sites. Reproduced from Miethke and Galvez (2009).

Although it appears clear that the ecosystem services can be considered to have been lost in the areas below and close to the net pens, the impacts are relatively rapidly reversible compared to many other types of habitat conversion and can be recovered by fallowing and/or removing the farm. Although a return to aerobic status does not imply a full recovery, it is considered that benthic impacts of this nature can be relatively rapidly reversed with cessation of production or fallowing (Keeley et al. 2015). The INFA data from Sernapesca show that recovery times between an anaerobic sample and a subsequent aerobic sample varies between approximately 2 and 18 months. Thus, although localized benthic impacts at existing sites may be severe, due to their 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 while maintaining functionality at any one farm site. Therefore, the final score for Factor 3.1 is 7 out of 10.

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

Husa et al. (2014) noted (in a Norwegian study) that the cumulative effect of numerous impacted areas around multiple farm sites must be taken into consideration when evaluating the total impact from aquaculture on ecosystem functioning, and Factor 3.2 assesses the effectiveness of the regulatory and farm management practices in addressing the potential cumulative impacts from multiple farming sites. As articulated in the Effluent Criterion above (Criterion 2), the Chilean government regulates all salmonid aquaculture under the same umbrella; therefore, the regulations that govern habitat impacts apply to both rainbow trout and salmon production. The following section is again largely duplicated from the most recent Seafood Watch assessment of Chilean farmed Atlantic and coho salmon (2017).

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

Regarding the direct site habitat impacts, Chile's System of Environmental Impact Assessment (*Sistema de Evaluación de Impacto Ambiental*, SEIA) operates within the Ministry of the Environment (*Ministerio del Medio Ambiente*). Since 2001, all farm sites must be licensed, and evidence of their approval—their "Ruling for Environmental Certification" (*Resolución de Calificación Ambiental*, RCA)—is available online at the SEIA database. Sites that were approved before 2001 are not required to submit to the SEIA unless they undergo "important changes" that require them to enter the SEIA evaluation under an RCA. In this case, "important changes" include an expansion of production (under Law 19300, and Resolution 290), which has occurred on many sites.

The SEIA environmental impact assessment takes the form of a preliminary characterization of the site (*Caracterización Preliminar de Sitio*, CPS), and as described in the Effluent Criterion and in previous paragraphs of this Habitat Criterion, the principal regulatory management tool for monitoring seabed habitat impacts is Sernapesca's INFA assessment under the environmental (RAMA) regulations. While the assessments focus on the site level, the results are considered in the ACS area system along with mortality and other performance parameters to predict the stocking numbers and therefore maximum biomass for the next production cycle. Therefore, while the INFA assessment is conducted at the site level, it is at least partly involved in setting production limits at the cumulative multi-site (ACS) level.

Although apparently comprehensive and administratively burdensome on the industry (as described in the Effluent Criterion), the effectiveness of the regulatory content regarding cumulative impacts on ecosystem services in the areas used by the salmon farming industry continue to be questioned. Fallowing requirements can be considered a form of habitat restoration, but their occurrence between production cycles only temporarily improves the benthic conditions (before production begins again); however, they do ensure that long-term local cumulative impacts are minimized. Scheduled fallow periods for all sites in Chile up to the year 2020 are available from Sernapesca's website.[12]

Regarding the broader habitat impacts and disturbances resulting from salmon farming, direct impacts to predators and wildlife as they are understood in Regions X and XI are assessed in Criterion 9X, and Vila et al. (2016) note that the recommendations resulting from their work on conservation areas in Region XII were used by the Chilean government when considering the ACS mapping in the southernmost areas. Vila et al. (2016) worked with multiple stakeholders—representatives from small-scale and industrial fisheries, tourism, government, and aquaculture—to identify high value conservation areas in this region, which contains critical habitats for marine mammals of global conservation concern and is home to rare and endemic species, such as the Chilean dolphin *Cephalorhynchus eutropia*, the southern sea otter *Lontra felina* and the southern river otter *Lontra provocax*. The study identified High Conservation Value Areas in the channels and fjords of the southern Chile ecoregion using 39 conservation features, and noted that the distribution of 12 conservation features overlapped to a certain extent (>10%) with Appropriate Areas for Aquaculture. Nevertheless, all proposed conservation targets could be met with a suggested portfolio of 33 High Conservation Value Areas covering 99,432 km^2 (12% of the ecoregion). The primary impact to aquaculture siting would be the exclusion of salmon farming from Tierra del Fuego island in the southernmost region of Chile.

As noted in Criterion 2 – Effluent, Resolution 3264 (28 October 2016) placed a moratorium on new license applications for Region XII, and although Sernapesca has 1,000 applications already underway, it appears that the number of new sites granted will initially be low (estimated at up to 25; see Criterion 2 – Effluent).

In conclusion, although EIAs are required for new site licenses, and there is some consideration of cumulative impacts through the ACS system, there are ongoing concerns regarding the uncertain carrying capacity of Chile's unique habitats. Ultimately, the management system is generally based on ecological principals, but is not considered to robustly account for cumulative impacts. As such, the score for Factor 3.2a is 3 out of 5.

Factor 3.2b: Enforcement of habitat management measures

With the similarity in regulatory enforcement between the Effluent and Habitat Criteria, the content in Factor 2.2b in the Effluent Criterion above is referred to here. The availability of EIA reports in addition to the INFA results indicates that monitoring and evaluation are taking place. Resolution 3612 defines the qualifications and the accredited laboratories for those involved in sampling, and Sernapesca staff are present for INFA sampling (AquaChile, pers. comm. 2016)

[12] Programacion de Periodos de Descanso de las Agrupaciónes de Concesiones de Salmonideos en las Regiones de Los Lagos, Aysén y Magallanes. http://www.sernapesca.cl/index.php?option=com_content&view=article&id=1220&Itemid=1009

Although the ACS process, in terms of managing production on an area basis, is to be commended, the robustness of the biomass, stocking calculations, and procedures continue to lack some transparency, and their efficacy regarding Chile's unique and ecologically valuable habitats continues to be questioned (see the Effluent Criterion for further details). As noted in the Effluent Criterion, the Global Salmon Initiative also provides some indication that regulations are enforced by listing the number of noncompliances with environmental regulations.

Between 2013 and 2016 inclusive, the eight member companies had an average of 22 environmental regulatory noncompliances per year (i.e., 2.75 per company), with an average fine of USD 3,219 per infringement. Details were not specified, but the noncompliances were related to maritime law and the General Law for Fisheries and Aquaculture (i.e., not related specifically to this Habitat Criterion). These examples clearly demonstrate that some active enforcement takes place.

In conclusion, the information available shows that farm-level regulatory enforcement is generally effective, but with similar concerns articulated in the Effluent Criterion regarding the scale of production and the unique habitats in Chile, the enforcement on a national scale has some limitations. Ultimately, enforcement organizations are identifiable and active, but these limitations mean that cumulative habitat impacts may not be fully addressed. The score for Factor 3.2b is 3 out of 5.

Factor 3.2 Final Score
Combining Factors 3.2a and 3.2b results in a low score for the overall efficacy of the management and regulatory control of cumulative habitat impacts in Chile. This reflects similar concerns articulated in the Effluent Criterion regarding the scale of production and the unique habitats in Chile. The final score for Factor 3.2 is 3.6 out of 10.

Conclusions and Final Score
Though the installation of net pens has little direct impact on the habitat where they are sited, the discharge and deposition of particulate organic matter during production can create poor sediment conditions near the sites and impact the functionality of the ecosystem. This reflects a moderate concern regarding the direct habitats at the site level, but the overall score is impacted by uncertainties in the effectiveness of the regulatory system to manage potential cumulative impacts from the industry at the ACS and broader regional scales. Factors 3.1 and 3.2 combine to result in a final score for Criterion 3 – Habitat of 5.87 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments.*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**2**	
Critical?	NO	**RED**

Brief Summary

Chilean rainbow trout production used 17.59 t of antibiotics in 2016, or 240 grams per MT (compared to 690 g per MT for salmon) and ranks as one of the highest users in aquaculture in the world. Current data on the frequency of antibiotic use are not available, though it is estimated to be more than once per production cycle. There are no regulatory limits on the frequency or total quantity used should a disease outbreak occur, but various initiatives are underway to attempt to address the problem (e.g., the Pincoy project, and the promising testing of new vaccines for *P. salmonis*). Nevertheless, there is evidence of developed resistance to florfenicol, the most commonly used antibiotic in Chile, and a treatment considered “highly important” for human medicine by the WHO.

Current data on the volume and frequency of antiparasite chemical use in rainbow trout production in Chile (primarily for the sea louse *Caligus rogercresseyi)* are scarce, with incomplete reported use data specific to rainbow trout production published by three member companies of the GSI. The most recent complete data (from 2013) show high volumes of use and, coupled with evidence of developed resistance for some treatments, are cause for significant concern. Studies examining the impact on benthic invertebrate communities are lacking, but given the open nature of net pen production systems, the potential risk of impact is high.

The high volume and frequent use of antibiotics, the confirmed cases of resistance to both antibiotic and pesticide treatments, and potential wider scale impacts to environmental microbial communities is balanced with the understanding that rainbow trout culture represents a small portion of total antibiotics used in salmonid culture (4.6% of the total, dominated by Atlantic salmon) and substantially lower relative usage of antibiotics (64.5% lower) than Atlantic salmon. As such, this results in a "moderate" to "high" concern in this Seafood Watch assessment and the final score for Criterion 4 – Chemical Use is 2 out of 10.

Justification of Ranking

The primary chemicals of concern used in aquaculture are mainly divided into antibiotics and antiparasite treatments. The use of such chemicals in aquaculture is widespread in reducing the impacts of pathogens and parasites on production. In open systems, such as net pens, controlling the release of chemicals into the environment is virtually impossible.

Antibiotics

Salmonid rickettsial syndrome (SRS), also known as piscirickettsiosis, is caused by the bacteria *Piscirickettsia salmonis* and is the primary disease affecting Chilean rainbow trout production (82.9% of rainbow trout disease mortality; Sernapesca 2016c). Vaccines to treat SRS in rainbow trout production have not been particularly effective in mitigating mortality, and antibiotics are frequently used as treatment: 89.3% of Chilean antibiotic use (for all species) is toward treating SRS (Otterlei et al. 2016) (Jakob et al. 2014) (Sernapesca 2017).

The dominant antibiotic treatment for SRS in all species is florfenicol (89.9%), while oxytetracycline is occasionally used (9.7%); these are the two most widely used antibiotics in Chilean aquaculture (Sernapesca 2017). The use of other antibiotics has significantly decreased in the past decade; since 2008, the use of quinolones has reduced markedly, with oxolinic acid (last reported use of 0.488 MT in 2014; Sernapesca 2014a) and flumequin is now being used very sparingly (Sernapesca 2017).

In 2016, rainbow trout aquaculture accounted for 4.6% (17.59 t) of the total 382.5 t of antibiotics (Figure 9) administered by the Chilean net-pen salmonid industry (Sernapesca 2017, F. Cabello pers. comm. 11 June 2014). With 71,381 t of trout production, the relative antibiotic use (i.e., when measured as grams of therapeutant used per MT produced) is 240 grams per MT production (compared to 690 grams per MT for salmon). This means that the relative antibiotic use for rainbow trout was 64.5% less than Atlantic salmon; however, based on this data, the Chilean rainbow trout industry used 83 times more antibiotics in terms of gross volume[13] than the Norwegian salmon production industry (despite producing just 6% as many fish) and 12 times more than the USA while producing roughly three times the fish (Fiskeridirektoratet 2017; SFW 2016).

Chile's relative use of antibiotics in rainbow trout culture was 1,500 times higher than in Norwegian salmonid culture (inclusive of rainbow trout) and 3.5 times that of the (freshwater) rainbow trout farming industry in the USA. Data show (Figure 10) that relative antibiotic use has

[13] It must be noted that, due to highly variable dose rates of different antibiotic treatments, these comparisons between antibiotic use in different countries (where different types of antibiotics may be used), must be used with caution.

fluctuated between 2005 and 2016 in Chile, though has steeply fallen since 2014 and is currently the lowest in over ten years; however, farmed biomass is also at its lowest in over ten years and relative use is still quite high, despite the improvement. In contrast, although farmed biomass in Norway has increased massively, antibiotic use has not increased (Figure 11) due to effective vaccination programs (Wegener 2012).

In addition, though Sernapesca does not report frequency of treatments, it appears that antibiotics are applied on average more than once per production cycle. The dosages of the two primary antibiotics used—florfenicol, 10mg/kg rainbow trout for 10 days; and oxytetracycline, 82.7 mg/kg rainbow trout for 10 days—as well as the percent of total treatments each represents (89.9% florfenicol, 9.7% oxytetracycline as mentioned above) were used to estimate a weighted "average antibiotic dose per treatment," which resulted in 169.5 g antibiotic per MT rainbow trout per treatment. Compared to the annual relative antibiotic use of 240 g antibiotic per MT rainbow trout (see above), this estimate indicates that antibiotics are likely used more than once per production cycle (10 to 12 months at sea), though official treatment frequency data are not available.

It should also be noted that these figures are based on *reported* antibiotic use, but potentially unauthorized and unreported use may push these figures even higher (Millanao et al. 2011).

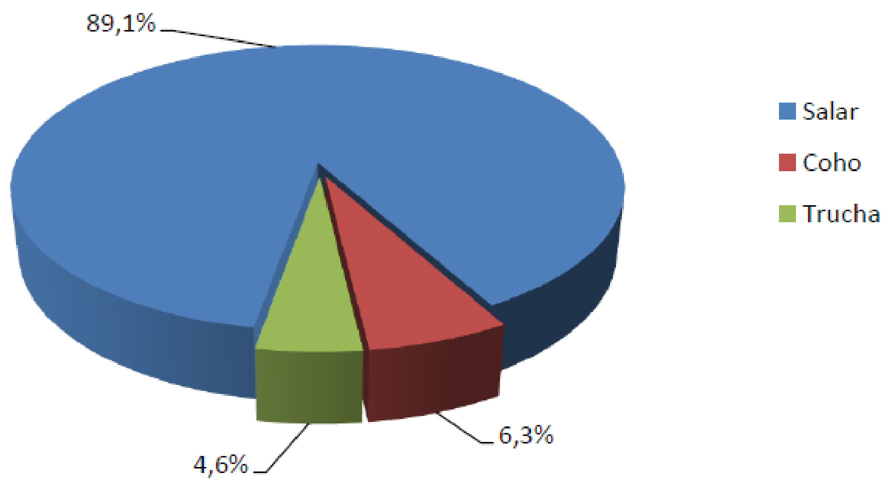

Figure 9: Use of antibiotics in Chile by species in 2016. Data from Sernapesca (2017). *Translations: Salar (Atlantic salmon); coho (coho salmon); trucha (rainbow trout).*

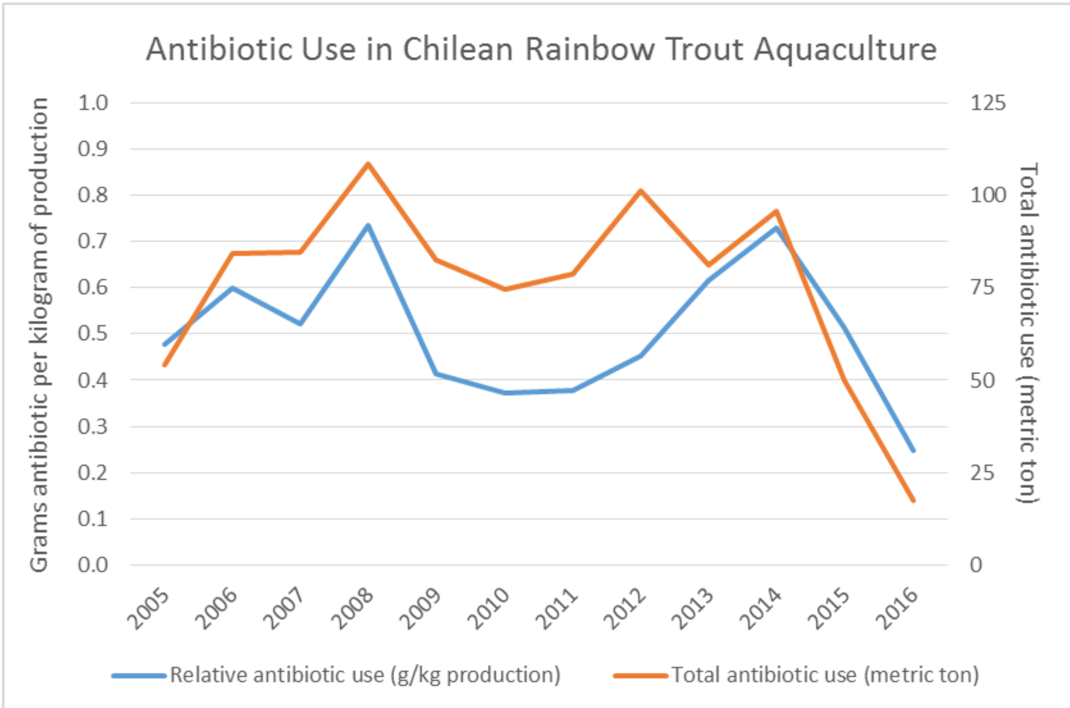

Figure 10: Blue line shows relative antibiotic use in rainbow trout aquaculture in Chile in grams per kilogram of production. Red line shows total antibiotic use for rainbow trout in metric tons. Data from Sernapesca (2017).

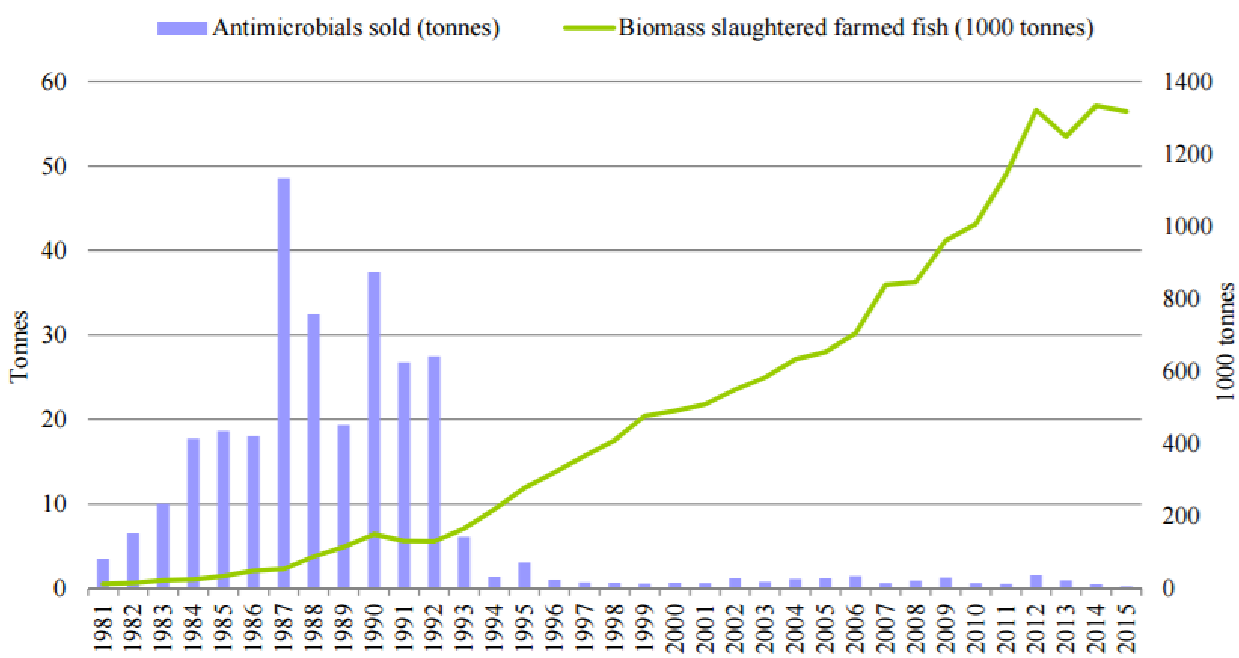

Figure 11: Annual total antibiotic use in Norwegian aquaculture (all species) up to 2015. Graph copied from NORM/NORM-VET (2015).

Both oxytetracycline and florfenicol are listed as being highly important for human medicine (WHO 2011); although florfenicol is not used in human medicine, it is considered highly important for human medicine due to the potential for human pathogens to acquire resistance genes from non-human sources that have been treated with the drug.

Both antibiotics are orally administered through feed, and once in water, there is ample opportunity for active compounds to leach from feeds (Cabello et al. 2013). In addition, some antibiotics such as oxytetracycline are poorly absorbed by fish, and Cabello, Godfrey et al. (2013) estimate that up to 80% of applied treatments can pass through the fish into the environment where they will accumulate under and around net pens, or be carried to distant sites. Despite the sustained high use of antibiotics in Chilean aquaculture, the effects on the ecosystem are still poorly understood; however, there is enough evidence to show that there is a measurable effect in terms of the development of resistance in microbial populations.

Antibiotic resistance

Recent literature (Price et al. 2016) (Henriquez et al. 2016) note a growing concern about the poor response to antimicrobial therapeutants used to treat SRS on some Chilean salmonid farms. Henriquez et al. (2016) demonstrated resistance to quinolones (92% of samples) and florfenicol (4% of samples) among samples of *P. salmonis* taken from diseased rainbow trout in Chile. Indeed, the displayed clinical resistance to quinolones is likely the primary reason for the decline in their usage.

Other studies in Chile have shown bacterial resistance to one or more commonly used Chilean antibiotics (including florfenicol and oxytetracycline) in the environment (Henriquez et al. 2016) (Price et al. 2016) (Tomova et al. 2015) (Shah et al. 2014) (Buschmann et al. 2012). Notably, Shah et al. (2014) found bacteria resistant to florfenicol and oxytetracycline were present in 81% of samples up to 8 km from a farm site, but noted the difference in resistance rates between aquaculture and non-aquaculture sites was insignificant. Furthermore, Buschmann, Tomova et al. (2012) showed that although sediments 20 m from a salmon farm did not test positive for commonly used Chilean antibiotics (the same as above), there were significant increases in bacteria resistant to the chemicals at the aquaculture site compared to a site 8 km distant. Additionally, data from a four-year monitoring program showed high levels of resistance to florfenicol, oxytetracycline, and flumequine in sediment from salmon farm sites in Chile, with oxytetracycline and flumequine demonstrating the greatest incidences of resistant pathogens (Lynch and Perez 2011).

It is important to note that the presence of antibiotic-resistant bacteria in the environment is natural. Henriquez et al. (2016) express that their findings of *P. salmonis* isolates resistant to florfenicol “may reflect adaptation due to a continuous exposition to enhanced levels of [florfenicol], instead of an acquisition of a resistant mechanism.” The authors continue, though, hypothesizing that *P. salmonis* isolates that “exhibit an impaired susceptibility to [florfenicol] may have evolved from those that were shown to be resistant to quinolones” (Henriquez et al. 2016). The authors conclude that clinical resistance to florfenicol is still in the onset (Henriquez et al. 2016); given the high usage of florfenicol in Chilean rainbow trout production, it appears that the development of clinical resistance in the environment may only be a matter of time.

In understanding the effects of antibiotics on resistance, of most concern is that there is presently no evidence of routine resistance monitoring in the environment in Chile, even though it is understood that the release of chemicals, their fate and their effects, are very complex issues due to differences between treatments, hydrodynamics, and inhibition by environmental parameters, among other things (Miranda 2012). Such monitoring needs to be carried out continuously and the risk updated regularly. It should also be noted that the overuse of antibiotics could potentially be selecting for the emergence of new microbial fish diseases as well as causing resistance in already established pathogenic species. This is a situation that is concerning for the aquaculture industry at present, but also one which may in time become a concern for human health (F. Cabello, pers. comm. 2014).

Recent literature has demonstrated the transfer of antibiotic resistance genes from pathogens in the aquatic environment to the terrestrial environment, including human pathogens (Cabello et al. 2016) (Cabello et al. 2013) (Laxminarayan et al. 2013). Seafood Watch (2017) states:

> “In the case of florfenicol, the resistance gene is known as the floR gene, and due to the widely-recognized phenomenon of horizontal gene transfer (HGT), florfenicol has the potential to co-select for a diversity of resistances (Fernandez-Alarcon et al. 2010). For this reason, human health as well as animal health can potentially be impacted by the use of antibiotics in aquaculture. The floR gene has been detected in salmon farms in Chile, and many other aquaculture situations (Miranda et al. 2013). The floR gene has also been associated with the HGT of resistance to human pathogens in human patients in hospitals in Chile (Fernandez-Alarcon 2010). While this cannot be directly attributed to salmon farming, the repeated use of florfenicol on salmon farms must be considered as a high concern. Millanao et al. (2011) provide a comparative analysis of the amounts of antimicrobials used by the salmon aquaculture industry 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.”

Regarding the effect of such antibiotics on native fish populations, antibiotics as administered to salmonids in Chile have been reported to be present in commonly consumed wild fish such as *Eleginops maclovinus* (Patagonian blenny) and *Sebastes capensis* (red rockfish) (Fortt, Cabello et al. 2007). Their direct effects on the fish are poorly understood, but it is concerning that several of the fish species affected are routinely consumed by humans, leading potentially to the problems outlined above. There is also the possibility that excessive levels of antibiotics in sediments and in the water column can affect the phytoplanktonic and zooplanktonic community diversity, potentially in turn affecting the health of animals and humans (Burridge et al. 2010).

Sernapesca's Manual of Good Practices for the Use of Antimicrobial and Antiparasitic Agents in Chilean Salmon (*Manual de Buenas Prácticas en el Uso de Antimicrobianos y Antiparasitarios en Salmonicultura Chilena*) includes a list of best management practices relating to antibiotic use. These are articulated under decree 319 of 2001 from the Ministry of Economy, Development and Tourism; these include a limited number of authorized treatments, the requirement for veterinary diagnosis and prescription, and a prohibition on prophylactic use, but there are no limits on antibiotic use in terms of frequency or total dose.

It is apparent that the use of antibiotics in Chilean rainbow trout farming is having an impact on microbial resistance to antibiotics, yet exactly how this affects the environment, wildlife, and ultimately humans is largely unclear. It is, however, clear that there is an urgent need for control, monitoring, and surveillance to ensure that effects are identified and acted upon as soon as they occur; at present this does not appear to be routinely occurring in Chile. With the high relative and frequent use of antibiotics, the level of concern regarding resistance and potential wider scale impacts to environmental microbial communities is high.

<u>Antiparasite agents (pesticides)</u>

Pesticides used on Chilean rainbow trout farms are primarily used to control the sea louse *Caligus rogercresseyi*, a parasite of significant concern in Chilean salmonid aquaculture (Helgesen et al. 2014). Both rainbow trout and Atlantic salmon (*Salmo salar*) are significantly affected by sea lice, but other salmon species, like coho, appear to be more resistant (Bravo et al. 2011).

Although complete data on pesticide use quantities by the salmon farming industry are available by company and in aggregate from SalmonChile[14] and the Global Salmon Initiative (GSI),[15] data are incomplete for rainbow trout. Data from SalmonChile are not distinguished by species, and data from the eight member companies in GSI are incomplete. Using the available data from GSI, the average relative pesticide use in Chile in 2016 was 2.7 g of pesticide active ingredient per ton of rainbow trout production. The average use over 2014 and 2015 was 5.2 grams per ton of rainbow trout production and appears similar to that of salmon production over the same period (6.2 grams per ton). Unfortunately, no data on treatment frequency could be obtained or accurately estimated.

Given Atlantic salmon's dominance in volumetric production and economic importance, the majority of literature studying sea lice and their control is focused on Atlantic salmon; thus, considering the paucity of data specific to rainbow trout production, and given their similar susceptibilities to the parasite and treatment rates, information regarding the environmental impacts of chemical sea louse control is drawn from literature examining pesticide application in salmon farming operations.

[14] http://www.salmonchile.cl/es/sustentabilidad.php

[15] http://globalsalmoninitiative.org/

Chile has authorized four pesticide treatments[16] for use in net pen salmonid aquaculture: emamectin benzoate, delivered orally in feed, and azamethiphos, deltamethrin, and cypermethrin, delivered as bath treatments. Currently, azamethiphos is the most commonly used pesticide in Chile (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017); chemical rotation, usually with pyrethroids (deltamethrin, cypermethrin), is required by law as discussed shortly. These compounds are not pathogen-specific and are toxic to a wide variety of invertebrates, including nematodes and arthropods, representing a high risk to non-target organisms if they enter the environment (Zagmutt-Vergara et al. 2005). Large volumes of both treatments can enter the environment through the water column either in uneaten feed and fecal particles (orally-applied emamectin) or as plumes in the water column after bath treatments (Macken et al. 2015) (Burridge et al. 2010). Once particulate matter containing pesticide is settled, it can persist in the sediments; although studies have shown toxicity to non-target organisms to be chronic at low concentrations, sediments containing detectable levels of pesticide residues have been found over 1km from salmon farms (Macken et al. 2015) (Lillicrap et al. 2015) (Samuelsen et al. 2015). In contrast, pesticides applied as bath treatments are primarily acutely toxic with minimal risk for chronic impacts, as they rapidly disperse and are diluted in the water column (Macken et al. 2015). Previously, however, Burridge et al. (2010) suggested that "bath treatments are released as a water column plume that may retain toxicity for a substantial period after release." Lending credence to this, Tucca et al. (2016) found concentrations of cypermethrin in sediments near salmon pens to be at levels that pose a risk to benthic invertebrates; however, other studies on azamethiphos dispersion show it is not detected at more than 10 m of depth, and therefore unlikely to occur in substantial amounts in sediments (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017). Overall, few studies have shown pesticide residues found in the environment to be at a level capable of causing major impacts, yet the ongoing, high volume use of pesticides is of significant concern and continues to be researched.

Volumes of pesticides used in Chile in 2013 (reported use for both rainbow trout and Atlantic salmon) were obtained by request from Sernapesca in 2014 and are shown in Table 4. Recent requests to Sernapesca for updated information were not fulfilled by the time of publication; therefore, these volumes are the most recent information available.

Active agent	Region	Kg of active agent used in 2013
Emamectin benzoate	X	66
	XI	99
Cypermethrin	X	238
	XI	346
Deltamethrin	X	62
	XI	90
Diflubenzuron	X	2848
	XI	656
Azamethiphos	X	1455
	XI	1752

[16] http://www.sernapesca.cl/index.php?option=com_content&view=article&id=976&Itemid=903

Table 4: Amounts of parasiticides used in Regions X and XI in 2013 (Sernapesca 2014e).

In addition to the reported use, there has also been evidence of "off-label" products being used, such as diflubenzuron (mentioned above), teflubenzuron and dichlorvos (Zagmutt-Vergara, Carpenter et al. 2005). It is believed that diflubenzuron use is considered rare today due to reduced efficacy and the availability of better alternatives, though there is no publicly available data to support this (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017).

Because of the high frequency of treatments, resistance to pesticides is a major concern in Chilean aquaculture, and has been an issue for the past ten years (Yatabe et al. 2011) (Bravo et al. 2013) (Jones et al. 2013). Emamectin benzoate was historically the primary pesticide used in Chile; however, the overuse of this chemical led to the development of resistance in sea lice and a reduction in its effectiveness (Hamilton-West, Arriagada et al. 2012), which was reported as early as the end of 2005 (Yatabe, Arriagada et al. 2011). To counter this, pesticides of other classes such as pyrethroids (cypermethrin and deltamethrin), organophosphates (azamethiphos) and diflubenzuron have been used as treatments for lice (M. Vera, PHARMAQ AS Chile, pers. comm. 04 June 2014).

Currently, Sernapesca manages sea lice treatments through the *Programa Sanitario Especifico de Vigilancia y Control de Caligidosis*, which mandates a rotation of the four approved treatments with a maximum of three consecutive treatments within the same chemical family (Sernapesca 2016b). Regulations also prohibit prophylactic application and require veterinary oversight for use, without limiting total dosage or frequency of treatment.

Despite these management measures, the frequent use of sea lice pesticides remains a concern. Reduced sensitivity to emamectin, deltamethrin, and cypermethrin is widespread (Aaen et al. 2015) (Helgesen et al. 2014) (Bravo et al. 2013). Given the pattern of use, there is high risk of the development of resistance to azamethiphos (Kuar et al. 2015). Also, it is not yet known what the cumulative acute and chronic effects of treatment in wide geographical areas might be.

Conclusions and Final Score

The usage of antibiotics and pesticides in Chilean rainbow trout farming is high, and a large body of literature indicates growing concern about the development of clinical resistance to chemicals highly and critically important to human health. A small percentage of isolates of *P. salmonis* taken from diseased rainbow trout have been found to be resistant to florfenicol, and a variety of bacteria in the environment surrounding Chilean rainbow trout sites have been found to be resistant to multiple antibiotics. The sustained high and repetitive use of florfenicol is likely to lead to the development of clinical resistance. The high volume and frequent use of antibiotics, the confirmed cases of resistance to both antibiotic and pesticide treatments, and potential wider scale impacts to environmental microbial communities is balanced with the understanding that rainbow trout culture represents a small portion of total antibiotics used in salmonid culture (4.6% of the total, dominated by Atlantic salmon) and substantially lower relative usage of antibiotics (64.5% lower) than Atlantic salmon. This results in "high concern" in this Seafood Watch assessment and the final score for Criterion 4 – Chemical Use is 2 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

Feed parameters	**Value**	**Score**
F5.1a Fish In: Fish Out ratio (FIFO)	1.73	5.67
F5.1b Source fishery sustainability score	–6.00	
F5.1: Wild fish use score		3.59
F5.2a Protein IN (kg/100kg fish harvested)	54.75	
F5.2b Protein OUT (kg/100kg fish harvested)	25.07	
F5.2: Net Protein Gain or Loss (%)	–54.21	4
F5.3: Feed Footprint (ha)	7.56	7
C5 Feed Final Score (0-10)		**4.54**
Critical?	NO	**YELLOW**

Brief Summary

The drive to reduce the reliance on wild marine ingredients in salmonid feeds has led to a general decrease in fishmeal and oil inclusion by increasing levels of alternative proteins and oils; however, a paucity of trout-specific data provided by feed companies leaves gaps in the understanding of the exact situation regarding fish meal and oil inclusions, and the use of trimmings or byproducts in feeds.

Current fishmeal and fish oil inclusion levels in Chilean trout feeds are estimated to be 12% and 5.7% respectively, and because of a lack of robust data indicating otherwise, it was assumed that 0% of fish meal and fish oil are derived from byproducts and trimmings. Using these figures, a FI:FO value of 1.73 was calculated, meaning that for every 1 t of fish produced, the oil from 1.73 t of wild fish will be used. In addition to this, a penalty was applied due to the level of sustainability of fish stocks used in the production of fishmeal, which resulted in a final score for wild fish use of 3.59 out of 10.

In terms of protein loss or gain, there was a high net protein loss of –54.21% corresponding to a score of 4 out of 10 for this factor. Additionally, a feed footprint consisting of both total land and ocean area of 7.56 ha was calculated to be required to produce the feed ingredients necessary for one ton of farmed fish, leading to a factor score of 7 out of 10.

The final score for Criterion 5: Feed is 4.54 out of 10.

Justification of Ranking

The Seafood Watch Aquaculture Standard assesses three feed-related factors: wild fish use (including the sustainability of the source), net protein gain or loss, and the feed "footprint" or global area required to supply the ingredients. For full detail of the calculations, see the Seafood Watch Aquaculture Standard document.[17]

The following assessment is based on data provided by Intesal and anonymously by one major rainbow trout producer in Chile. Additional partial data are available from feed brochures, reports, peer-reviewed literature, and secondary data for salmon as collected by Seafood Watch (2017). Except for eFCR, the values provided by the Chilean rainbow trout producer are largely in accordance with the range of values found in the additional sources; as such, they are considered representative of the rainbow trout industry in Chile for the purposes of this assessment.

Factor 5.1. Wild fish use

<u>Factor 5.1a - Fish In:Fish Out</u>

The data provided by the major rainbow trout producer in Chile show total fishmeal and fish oil inclusion levels are 12% and 5.7%, respectively. A five-year average (2012 to 2016) annual economic feed conversion ratio (eFCR) of 1.52 was used (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017).

To assess how representative of the industry these data are, the following literature was reviewed in addition to consultation with Chilean aquaculture experts.

Tacon, Hasan et al. (2011) reported fishmeal and oil use in Chilean rainbow trout feeds (in 2008) to be on average 20 to 25% and 12 to 15% respectively, with 25% inclusion of plant protein sources, and 10 to 20% animal byproducts. These are average figures; the actual contents vary from around 60% fishmeal in starter feeds to only 9% in late grower feeds (C. Lobos, Troutlodge Chile, pers. comm. 19 June 2014). Skretting (2012) reported that in 2011

[17] http://www.seafoodwatch.org/seafood-recommendations/our-standards

Chilean salmon feeds contained 18.3% fishmeal (weighted average, range 26.7% to 12.4%) and 11.4% fish oil (weighted average, range 19.9% to 10.1%). It should be noted that there is significant effort within the industry to reduce fishmeal and fish oil levels in aqua feeds. One such initiative was Aquamax, the objective of which was to reduce fishmeal and fish oil inclusion to only 5% for rainbow trout (Skretting 2011[2]) by using alternative ingredients derived from terrestrial plants. The data provided by the trout producer agree with this trend, with lower levels of fishmeal and fish oil currently used relative to the relatively dated literature.

The use of fishery byproducts in trout feeds is difficult to estimate because data were provided by only one rainbow trout producer in Chile. According to the International Fishmeal and Fish Oil Organization (IFFO), about 25% of the global fishmeal supply originated from byproducts in 2009 with estimated growth of 1 to 2% annually (Jackson and Shepard 2012); accordingly, this estimate would place the current (2016) value at roughly 32%. This is in accordance with some available industry statistics, since the EWOS group reported that 32.2% of their marine raw materials were made up of such trimmings in 2015 (Cermaq 2013), up from 18% in 2011 (Cermaq 2011). Yet, there is no reason to assume that these levels directly reflect ingredients in rainbow trout feeds in Chile. Feed companies operating in Chile were not able to be contacted during the writing of this report, though the data obtained from the Chilean rainbow trout producer indicate no use of byproducts in the feed used. Although this is unlikely to represent all Chilean rainbow trout feeds, there is not enough information to accurately estimate byproduct inclusions beyond what was given by the producer; as such, fishmeal and fish oil byproduct inclusions are assumed to be 0% for the purposes of this assessment.

Globally, trout production has historically seen eFCRs in the range of 0.7 to 2.0, with Chile falling at 1.4 in 2007, slightly above the global average (1.3) (Tacon and Metian 2008). More recently, Gonzalez et. al (2013) indicated the economic feed conversion ratio in a Chilean rainbow trout farm was 1.9, but the industry applicability of this value is limited due to the small scale (4 pens) and single growout season (2010). Other regions where rainbow trout are farmed in net pens have recently indicated economic feed conversion ratios between 1.3 and 1.6 (Fiskeridirektoratet 2017) (McGrath 2015). The Chilean rainbow trout producer reported an average eFCR of 1.35, which is in line with both the previous Chilean value (Tacon and Metian 2008), as well as within the range of global values obtained from literature. Intesal, the technical division of SalmonChile, the Chilean salmonid farming industry association, provided eFCR data for the previous five years (2012 to 2015) which averaged to 1.52; this value falls squarely within the range of values found in the literature and is considered to be largely representative of the Chilean rainbow trout farming industry. As such, an eFCR of 1.52 is used for the purposes of this assessment.

Table 5. The parameters used and their calculated values to determine the use of wild fish in feeding farmed Chilean rainbow trout.

Parameter	Data

Fishmeal inclusion level (%)	12.0
Percentage of fishmeal from byproducts	0.0
Fishmeal yield (from wild fish) (%)	22.5[18]
Fish oil inclusion level (%)	5.7
Percentage of fish oil from byproducts	0.0
Fish oil yield (%)	5.0[19]
Economic Feed Conversion Ratio (eFCR)	1.52
Calculated Values	
Feed Fish Efficiency Ratio (FFER) (fishmeal)	0.81
Feed Fish Efficiency Ratio (FFER) (fish oil)	1.73
Seafood Watch FFER Score (0-10)	**5.67**

Using the above values, calculations show a $FFER_{FISHMEAL}$ value of 0.81 and a $FFER_{FISHOIL}$ value of 1.73, and as the final FFER value is the greater of the two, the final FEER value is driven by fish oil use and is 1.73. This value translates to an initial score of 5.67 out of 10 in the Seafood Watch criteria for factor 5.1a: Feed Fish Efficiency Ratio.

Factor 5.1b - Sustainability of the source of wild fish

The initial FFER score is adjusted based on the relative sustainability of the source fisheries from which fishmeal and fish oil are derived. Seafood Watch attributes a penalty for decreasing sustainability of the source of wild fish, from 0 penalty for sustainable, certified sources to –10 for demonstrably unsustainable sources.

Due to the limited data availability on the particular fishery sources used by Chilean feed companies, the feed information supplied by a Chilean rainbow trout producer is bolstered by feed information compiled by Seafood Watch (2017) for salmon as a proxy.

Data received by the trout producer indicates all fishmeal and fish oil are sourced from IFFO RS fisheries from Chile, Peru, Ecuador, China, Mexico, India, and Morocco. This information is largely in accordance with the information compiled by Seafood Watch (2017). It states:

> "Fishery information provided by the feed companies show sources of fishmeal and fish oil are somewhat global in nature (Chile, Peru, China, India). The feed companies report that the large majority of fisheries are certified to the IFFO RS[20] responsible sourcing scheme with minor amounts from fisheries certified by the Marine Stewardship Council (MSC). An assessment of the fisheries using FishSource shows while some fisheries have all scores >6, the majority of both fishmeal and oil are from

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

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

[20] http://www.iffo.net/iffo-rs

fisheries where at least one score is either unknown or <6. The sustainability score, therefore, is –6 out of –10."

Therefore, a sustainability score of –6 out of –10 is applied. This results in a Factor 5.1b – Sustainability of the Source of Wild Fish score of –2.08 out of –10. This is deducted from the initial FFER score in 5.1a, and results in a final score of 3.59 for Factor 5.1 – Wild Fish Use.

Factor 5.2. Net protein gain or loss

According to the information provided by the trout producer, feed protein in Chile comes from fishmeal, and terrestrial crop and land animal sources. The feed protein content is 42%, which is in accordance with the literature (Hernandez et al. 2016) (Hernandez et al. 2013) (Navarrete et al. 2013); 19.0% of total protein comes from fishmeal, and 66.76% from terrestrial crop sources that are all considered "edible." The remaining 14.24% comes from land animal byproduct sources. Using an eFCR of 1.52 results in an edible protein input of 547.5 kg per ton of rainbow trout produced.

Table 6. The parameters used and their calculated values to determine the protein gain or loss in the production of farmed Chilean rainbow trout.

Parameter	Company feed data
Protein content of feed	42%
Percentage of total protein from non-edible sources (byproducts etc.)	14.24%
Percentage of protein from edible sources	85.76%
Percentage of protein from crop sources	66.76%
Feed Conversion Ratio	1.52
Protein INPUT per ton of farmed trout	547.5 kg
Protein content of whole harvested trout	15.7%
Percentage of farmed salmon byproducts utilized	100%
Utilized **protein OUTPUT** per ton of farmed trout	250.7 kg
Net protein loss	54.21%
Seafood Watch score (0-10)	4

The protein content of whole rainbow trout is estimated to be 15.7% with yield of fillet estimated at 56.7% (Dumas et al. 2007). All byproducts from harvested trout are considered utilized (Ramirez 2007) (SFW 2017). The calculated protein output is 250.7 kg per ton of farmed rainbow trout, and results in a net edible protein loss of 54.21%. This results in a score of 4 out of 10 for Factor 5.2 – Net Protein Gain or Loss.

Factor 5.3 - Feed footprint

The data provided show that approximately 17.7%, 66.9%, and 10.7% of total feed ingredients come from aquatic sources, terrestrial crop, and terrestrial animal sources respectively. Using fixed values in the Seafood Watch Aquaculture Standard, the area of aquatic and terrestrial primary productivity required to produce these ingredients (for production of 1 ton of rainbow trout) is calculated to be 7.00 ha and 0.56 ha respectively.

Table 7: The parameters used and their calculated values to determine the ocean and land area appropriated in the production of farmed Chilean rainbow trout.

Parameter	**Data**
Marine ingredients inclusion	17.7%
Crop ingredients inclusion	66.9%
Land animal ingredients inclusion	10.7%
Ocean area (ha) used per ton of farmed trout	7.00
Land area (ha) used per ton of farmed trout	0.56
Total area (ha)	7.56
Seafood Watch Score (0-10)	**7**

The total feed footprint is calculated as 7.56 ha, and corresponds to a score of 7 out of 10 for Factor 5.3 – Feed footprint.

Conclusion and Final Score

The final score is a combination of the three factors; Factors 5.1 (3.59 out of 10), 5.2 (4 out of 10), and 5.3 (7 out of 10) resulting in a final score of 4.54 out of 10 for Criterion 5 – Feed. It is acknowledged that this value is in part based on limited data from a single producer in Chile; however, given the similarities to values found in literature and biologically/operationally similar Chilean salmon production, the value is considered largely representative of the average rainbow trout producer in Chile.

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.*

Criterion 6 Summary

Escape parameters	Value	Score
F6.1 System escape risk	2	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		2
F6.2 Competitive and genetic interactions		7
C6 Escape Final Score (0-10)		**4**
Critical?	NO	**YELLOW**

Brief Summary

Rainbow trout are farmed in open systems (net pens), and the available data (though incomplete over the time frame) indicate large numbers (>500,000) of fish have escaped each year since the early 1990s, and there is potential for this number to be higher due to undetected or unreported events. Though it is known that escaped rainbow trout have aided in the establishment of feral populations and have impacted native fish by predation, competition for food, and as vectors for disease and parasites, the overall impact on the environment from farm escapes has been tempered, historically, due to historic intentional stocking of the species prior to aquaculture (resulting in established, self-sustaining populations). When combining the score for Factor 6.1 (2 out of 10) with the score for Factor 6.2 (7 out of 10), the final score for Criterion 6 – Escapes is 4 out of 10.

Justification of Ranking

In total there are 23 introduced or exotic fish species living in Chilean waters (Marr, Olden et al. 2013), of which 12 are introduced salmonids (Arismendi et al. 2014). Rainbow trout was one of the first and is considered the most successful (Arismendi et al. 2014), both in Chile and in general (Gozlan, Britton et al. 2010).

Factor 6.1 - Escape risk

Escapes in Chile occur due to range of factors, including: predator attacks on the nets, theft (between 2004 and 2009 theft constituted 21% of reported escapes), vandalism, adverse weather conditions (29%), loss during handling and failure of net pens (18%) and accidental boat collisions (Sepulveda, Arismendi et al. 2013).

It is estimated that between 1994 and 2011, 0.4% of rainbow trout production per annum escaped into surrounding waters (Arismendi et al. 2014). Indeed in 2013, Sernapesca (2014d) reported that just under 0.5% of total production of all fish escaped from farming operations, totaling 1,453,411 individuals; it is important to note that this number is inclusive of Atlantic and coho salmon, and the report does not distinguish or differentiate by species. Very low figures reported in 2011 and 2014 are likely due to lack of data from either one of regions X and XI in the respective year (Sernapesca 2014d). The 2014 report is the most recent government report quantifying salmonid aquaculture escapes. SalmonChile has published aggregated data indicating 655,799 fish escaped in 2015,[21] though this figure is not species specific.

Data presented by Sepulveda, Arismendi et al. (2013) and shown in Figure 12 show that trout escapes are sporadic, and have increased on average from the mid-1990s to the late 2000s in line with the increase in production. This contrasts with a drop in Atlantic salmon escapes, despite a marked increase in production of the latter. The largest reported escape of rainbow trout occurred in 2008, consisting of 1,137,100 individuals. In addition to the reported escapes, undetected or unreported trickle losses may also be significant; escape statistics are usually based on reports by the farmers themselves and are likely to underestimate, significantly in some circumstances, the actual number of fish escaping from farms (Glover et al. 2017).

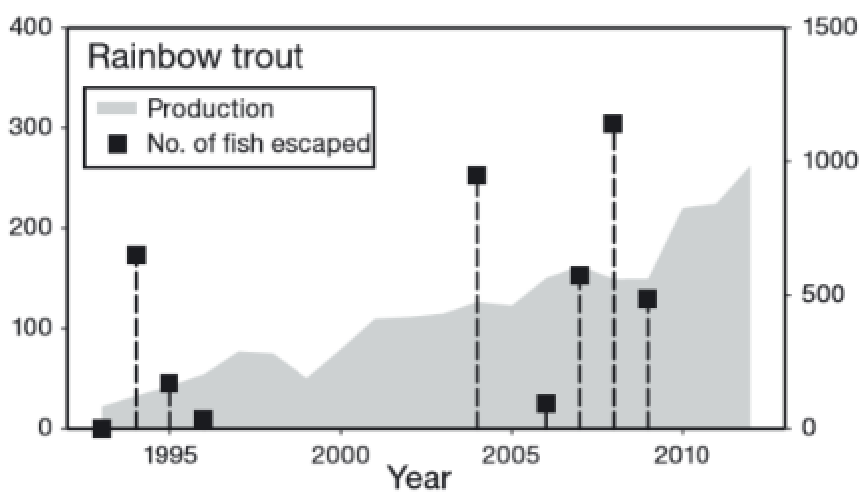

Figure 12: Total rainbow trout production and reported escapes. Left vertical axis = production (x 1000 t); right vertical axis = number of fish escaped (x 1000). No data available between 1996 and 2004. Adapted from Sepulveda et al. (2013).

The incidence of feral trout, which are fish that have escaped from an aquaculture operation or have been deliberately stocked for sport, is widespread in Chile; since it is now relatively easy to distinguish between escaped and free-living fish (Schröder and Garcia de Leaniz 2011),

[21] http://www.salmonchile.cl/en/sustentabilidad_informe.php#A7

studies show one or both groups being recorded from 100% of studied river basins (Figueroa, Bonada et al. 2013). The contribution of escaped rainbow trout to this feral population is substantial, with farm escapees present in 80% of studied rivers and now representing 16% of all free ranging rainbow trout (Consuegra, Phillips et al. 2011). Additionally, in a study by Subpesca (2011) on escapees, it was found that 100% of rainbow trout otoliths (ear bones) from fish captured in the Aysén region showed evidence of escape which, together with other morphological characteristics, led to the classification of all of these specimens as escapees.

Therefore, with the evidence presented regarding scale of rainbow trout escapes in the Chilean industry, coupled with considerable doubt about the accuracy of escape reporting, the initial score given for escapes is 2 out of 10, reflecting a "moderate" to "high" risk.

In mitigating the impact of escaped fish, the immediate mortality and recapture of fish after an escape event is assessed by Seafood Watch as a factor that can improve the overall score for the escape risk; however, there is little to no data to allow a robust review of the likelihood of recapture or mortality in escaped rainbow trout. Some inferences can be made—given the high plasticity of rainbow trout, allowing excellent adaptability to their environment, coupled with the results of studies demonstrating a varied and "normal" diet in feral rainbow trout (Arismendi, Gonzalez et al. 2012, Di Prinzio, Miserendino et al. 2013)—such that it would be unlikely that any significant immediate mortality would occur. There may also be some case to argue that the high aggregation of predatory birds around net pens (Jimenez, Arriagada et al. 2013) along with other predatory animals might cause some mortality after an escape event, or during trickle escapes, but this cannot be quantified.

The evidence does not suggest that there would be any significant mortality of trout after an escape event, and it is unlikely that many, if any, escaped fish are recaptured. Therefore, in terms of recapture and mortality, it is assumed that no escaped fish are either recaptured or are predated upon after escaping. This alters the final score for Factor 6a – Escape Risk to 2 out of 10.

Factor 6.2 – Competitive and genetic interactions

Rainbow trout are thought to have been first introduced to Chile in the early 20th century, well before aquaculture in the region began (Di Prinzio et al. 2009). The species is known to be one of the most successful salmonid invaders in Chile, with its facultative anadromous lifestyle a possible factor in allowing it to disperse into more streams via the sea (Young, Dunham et al. 2010). It became the most widely distributed non-native species in the region (Di Prinzio, Casaux et al. 2009), and is currently considered to be fully established (Arismendi, Brooke et al. 2014). In noting that effects on native assemblages are likely in Mediterranean-climate regions, of which Chile is considered, Marr, Olden et al. (2013) conclude that "the introduction of non-native fish species and the loss of native fish species affected the functional composition of freshwater fish assemblages, which may have important consequences for the functioning of freshwater ecosystems."

Indeed, escaped rainbow trout are believed to pose a significant threat to native Chilean ecosystems because they have the greatest potential to establish naturalized populations due to their high plasticity (Monzón-Argüello, Consuegra et al. 2014). It is thought that escapes from farms have aided the high establishment success and rapid expansion of the species (Ciancio, Pascual et al. 2008) through increased propagule pressure (Young, Dunham et al. 2010, Consuegra, Phillips et al. 2011, Arismendi, Penaluna et al. 2014, Monzón-Argüello, Consuegra et al. 2014). It is also suspected that rainbow trout escapees hybridizing with naturalized populations are serving to maintain or enhance genetic diversity and so accelerate divergence of invasive feral populations (Monzón-Argüello, Consuegra et al. 2014). Nonetheless, although high genetic diversity may initially enhance fitness in translocated populations, it might not necessarily reflect invasion success if part of the functional genetic diversity was rapidly lost when invasive species adapt to novel conditions, a hypothesis that deserves further investigation according to Monzón-Argüello, Garcia de Leaniz et al. (2013).

It is generally agreed that escapes and establishment of populations of non-native salmonids do have detrimental impacts on native fish due to predatory and interference competition (Sepulveda, Arismendi et al. 2013) and widespread ecological damage (Garcia de Leaniz, Gajardo et al. 2010). Rainbow trout are known to be particularly detrimental in Chile due to their greater potential to establish self-sustaining populations, relative to other salmonids (Sepulveda et al. 2013). Escaped rainbow trout have been found to impact native fish through apparent predation and interference competition, resulting in significant decreases in abundance of several species of Galaxiidae (Sepulveda et al. 2013) (Correa and Hendry 2012) (Vanhaecke et al. 2012) (Habit et al. 2010), as well as a variety of native fish species in Argentinian Patagonia (Cussac et al. 2014). In contrast, Young et al. (2010) have demonstrated that native galaxiid species can and do coexist with rainbow trout, although the authors speculate about whether it is possible that local extirpations can occur with time. Although major declines in abundance have been observed, Galaxiid genetic diversity has not been shown to be affected by aquaculture escapees, though more research is required to truly elucidate the impact escaped rainbow trout have on native fish populations (Vanhaecke et al. 2012). Predation pressure imposed by exotic salmonids, particularly on schooling fish, is thought to be high (Niklitschek, Soto et al. 2013), though it is known that predation on native fish species is more commonly associated with brown trout (*Salmo trutta*) than rainbow trout due to their greater ability to hunt in low light conditions. Given the high tannin content and low transparency of many Chilean waterways, predation by rainbow trout may be less of a threat than initially thought (Arismendi, Gonzalez et al. 2012); indeed, stomach content analysis of captured escapees have shown no evidence of piscivory (SubPescA 2011).

Despite the conflicting accounts of piscivory, feral rainbow trout (inclusive of both escaped and intentionally stocked) have been shown to significantly affect native fish populations due to competition for food. Rainbow trout in Chilean streams consume mainly macroinvertebrates and terrestrial insects (Di Prinzio, Miserendino et al. 2013). Thus, there is a high overlap of diets between escaped fish and native species, leading to inevitable competition; however, the scarcity of available information on the state of native fish species before the introduction of salmonids makes analysis of the effect of salmonid introduction and an understanding of their impacts challenging (Garcia de Leaniz, Gajardo et al. 2010). Indeed, negative effects on *Basilichthys australis* (Chilean silverside) have been experimentally deduced as a direct result of rainbow trout competition (Pardo et al. 2013). Significant weight loss was measured in the presence of rainbow trout due to the high niche overlap of the two species and the behavioral aggression exhibited by the trout.

Escaped rainbow trout also pose a disease vector risk because of the potential to transmit non-native pathogens or those of increased virulence to native fish populations, though no conclusive evidence of this occurring exists (Sepulveda et al. 2013). The dynamic between on-farm disease and impacts to the surrounding ecosystem are further detailed in Criterion 7 – Disease.

Although escaped rainbow trout compete for food, predate upon wild species, and can act as vectors for disease and parasites (see Criterion 7), the species was fully ecologically established before aquaculture began (Carcamo et al. 2015). It is believed, though, that escapes from farms have aided the high establishment success and rapid expansion of the species through increased propagule pressure and the maintenance/enhancement of genetic diversity in feral populations. Therefore, the score for Factor 6.2 – Competitive and Genetic Interactions is 7 out of 10.

Conclusion and Final Score

Rainbow trout are farmed in open systems (net pens) and data, while incomplete over the time frame, indicate large numbers (>500,000 fish) of annual escapes have regularly occurred since the early 1990s; because of undetected or unreported events, there is potential for this number to be higher. The impact on the environment from escaped rainbow trout is tempered, historically, because of intentional stocking of the species prior to aquaculture (resulting in established, self-sustaining populations), though it is known that escaped rainbow trout have aided in the establishment of feral populations and impact native fish by competing for food, predation, and acting as vectors for disease and parasites. When combining the score for Factor 6.1 (2 out of 10) with the score for Factor 6.2 (7 out of 10), the final score for Criterion 6 – Escapes is 4 out of 10.

Criterion 7. Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body.*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

Disease Risk-based assessment

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

Brief Summary

The main disease of rainbow trout in Chile is salmonid rickettsial septicaemia (SRS or piscirickettsiosis), which causes nearly 20% of all rainbow trout losses (nearly 83% of all losses related to disease) and affects 12 to 23% of farms. Other minor diseases include those caused by *Flavobacterium* and infectious pancreatic necrosis (IPN) virus, as well as other diseases such as vibriosis, furunculosis, and mycosis. Although no major concerns were found regarding the effect of rainbow trout diseases on wild (feral) rainbow trout populations, some concern has been raised about the potential of spread to other native wild fish.

The main parasite is a sea louse called *Caligus rogercresseyi* and is of primary concern when considering amplification of disease or parasites to native populations. Incidence of salmonid sites on high alert (>3 gravid lice per female) in 2015 peaked at just under 10%. Sea lice are a natural parasite of many native species which inhabit areas around net pens; therefore, the high infection pressure coming from net pens is a cause for concern, with infestation linked to secondary impacts such as a greater risk of predation.

Despite a lack of direct evidence of impact on wild fish, evidence of on-farm disease mortality and parasite infections, and the risk of disease transfer posed by the open nature of net pen rainbow trout farming represents a "moderate" concern; therefore, the final score for Criterion 7 – Disease is 4 out of 10.

Justification of Ranking

Bacterial and viral pathogens

The primary pathogen affecting the rainbow trout industry is the bacteria *Piscirickettsia salmonis*, which causes the disease salmonid rickettsial syndrome (SRS), and is managed under Sernapesca's "Programa Sanitario Especifico de Vigilancia y Control de Piscirickettsia (PSEVC-Piscirickettsia). Though Atlantic salmon showed the most cases of SRS in 2014 (the most recent aggregated statistic available, Figure 13), the mortality related to SRS in rainbow trout was and is extremely high (Figure 14) and the incidence in trout farms is far greater than for any other salmonid species (Figure 15). Figure 16 shows that in 2012, around 18% of active farms tested positive for SRS (Rees et al. 2014) and up to 23.19% in 2013 (Sernapesca 2014c). At any one time its prevalence is around double in rainbow trout than in Atlantic salmon, and is lowest in coho salmon (Sernapesca 2014c). During Q1 2016 (the most recent available data), the weekly incidence rate reached a high of 12.0%, down from a peak of 13.7% in 2015 (Sernapesca 2016c)

In 2015, disease accounted for, in total, 23.8% of all mortality in rainbow trout (Figure 17) compared to 25.6% in Atlantic salmon. Of this mortality due to disease, 82.9% was attributed to SRS equating to 19.7% of all mortality in rainbow trout, compared to 20.2% in Atlantic salmon (Figure 14). These figures show a decreased occurrence rate in rainbow trout and increased rate in Atlantic salmon relative to 2013 and data from SalmonChile provided by Carlos Lobos in 2014 (C. Lobos, Troutlodge Chile, pers. comm. 29 October 2014), which show mortality due to SRS or 35% and 17% of total mortality respectively.

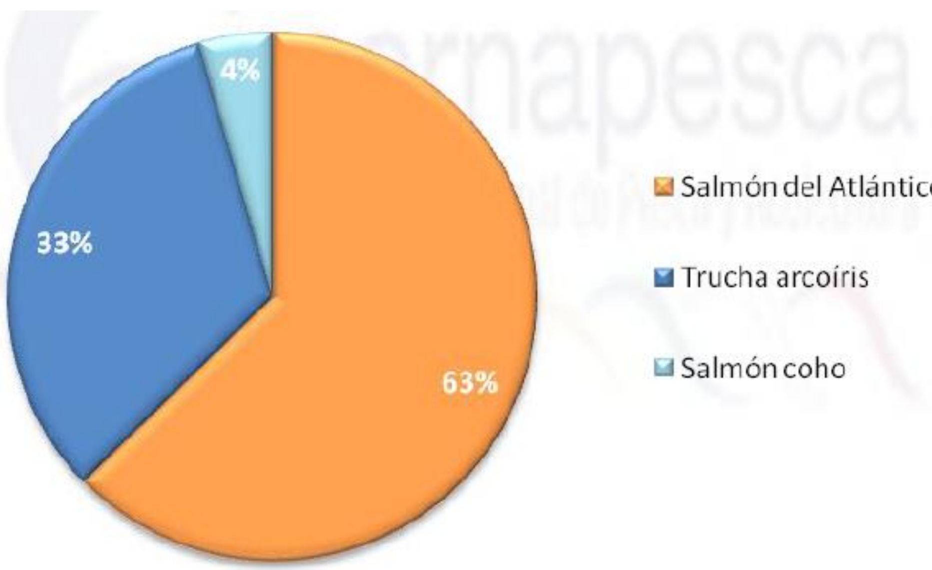

Figure 13: Distribution of SRS among salmonid species, January to December 2014. Data from Sernapesca (2014c). *Translation: salmon del Atlántico, Atlantic salmon; trucha arcoiris, rainbow trout; salmon coho, coho salmon.*

Figure 14: Classification of mortality of rainbow trout due to infection throughout the lifecycle by disease, January to December 2015. Data from Sernapesca (2016c)

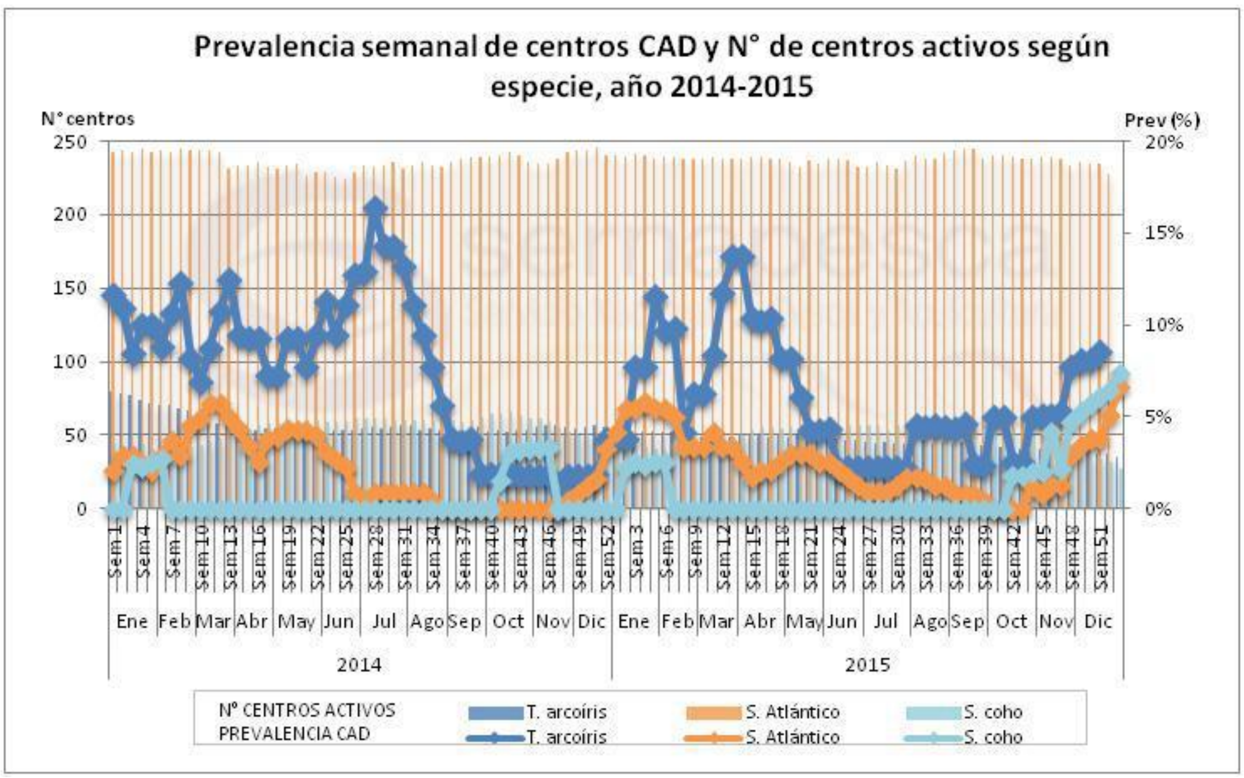

Figure 15: SRS in terms of active centers and prevalence shown by species, January 2014 to December 2015 (Sernapesca 2016c).

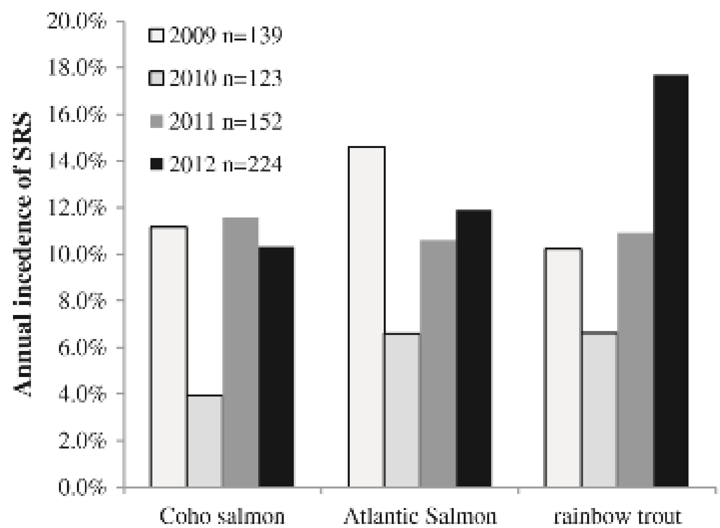

Figure 16: Annual incidence rate of SRS by species from January 2009 to December 2012. The number of active farms during each year, n, is indicated in the legend (Reeset al. 2014).

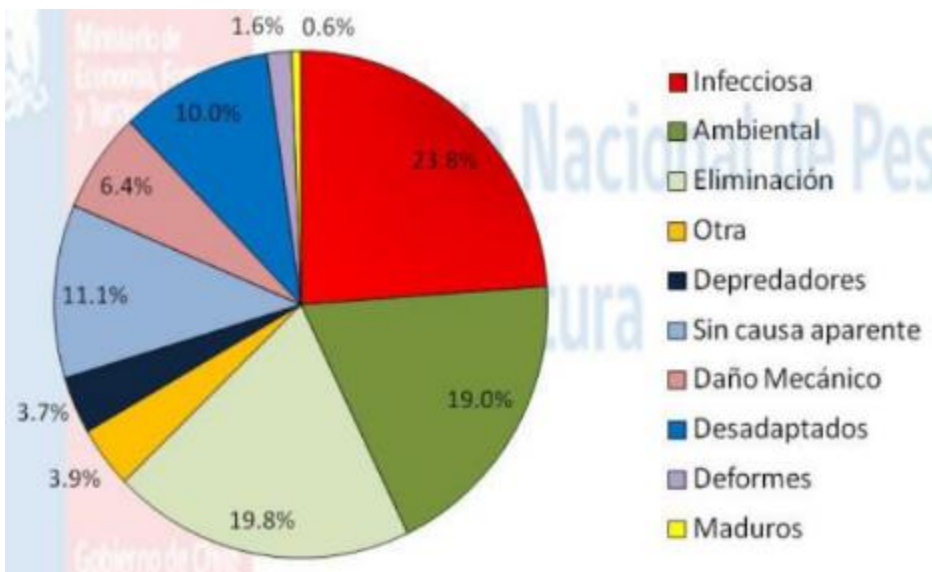

Figure 17: Classification of mortality of rainbow trout by cause and disease, January to December 2015. Data from Sernapesca (2016c). *Translation: infecciosa, infection; ambiental, environmental; eliminacíon, elimination; otra, others; depredadores, predation; sin causa aparente, no apparent cause; daño mecánico, handling damage; desadaptados, poor adaptation; deformes, deformity; maduros, old age.*

The disease has been recorded in other fish species, and was identified as the causative agent of an outbreak with mass mortality among hatchery-reared white seabass in the US, as well as in juvenile European sea bass in sea cages along the French Mediterranean coast (Rozas and Enriquez 2014). It is therefore of theoretical concern for local fish populations in Chile, although no evidence has been found that it is a causative agent in any significant wild fish deaths thus far. Of particular concern is that the extended extracellular survival time of the organism in salt water (several weeks at 5 to 20°C) possibly allows for horizontal transmission between fish without a vector. Although reservoirs of *P. salmonis* are still unknown, studies have demonstrated rapid evolution of increased virulence and outbreak severity over time (Rozas and Enriquez 2014).

Vaccines to treat SRS in rainbow trout production have not been particularly effective in mitigating mortality. Though a field of active research and development, vaccines have historically been ineffective; currently none offer complete protection (Otterlei et al. 2016) (Rees et al. 2014); Jakob et al. (2014) found SRS mortality in vaccinated rainbow trout was not significantly different than that in unvaccinated trout. Otterlei et al. (2016) found that SRS outbreaks among salmon farms in Chile are caused by a minimum of two distinct genetic strains of *P. salmonis*, indicating the difficulty in developing effective vaccines against this bacterium.

A new disease known as idiopathic trout syndrome (SIT, Síndrome Idiopático de la Trucha) first appeared in the industry in 2012, and the causative pathogen is still not known (Aqua 2015b); recent work has failed to link SIT to an infectious agent, suggesting that etiology may not be infectious (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017). In 2015, SIT was responsible for 6.3% of all rainbow trout disease mortality (in previous years, SIT was included in the "other" category, Figure 14). A representative from SalmonChile has said that the presentation of the disease is sporadic with no seasonal or life stage pattern (Aqua, 2015b), and it has primarily manifested in the Los Lagos region, with suspected cases in the more southern Aysén region. It is said that the current status of the disease is not significantly affecting the rainbow trout industry due to decreased production, and Q1 2016 infectious mortality show SIT rates of just 0.6% (Sernapesca 2016c). Regardless, the unknown etiology of the disease is still a major concern for the rainbow trout industry (Aqua 2015b). No information could be found regarding the potential impacts to wild fish, though it is possible that this disease manifested in rainbow trout aquaculture via transmission from wild fish (Aqua 2015b); therefore, it is possible for rainbow trout farms to transmit amplified levels of this pathogen of potentially increased virulence to wild fish.

Flavobacterium (freshwater stage) and infectious pancreatic necrosis (IPN) virus, as well as other diseases such as vibriosis, furunculosis, and mycosis (freshwater stage), make up the remaining 10.8% of disease-related mortality, after SRS and SIT have been taken into account. Though contributing a relatively minor total, *Flavobacterium* is a growing concern for farming in the area. Its spread is attributed to the large-scale importation of eggs prior to the current tightening of biosecurity regulations and the subsequent ban of egg importation from outside Chile (Avendano-Herrera et al. 2014). The authors also note its presence in a native whitebait species, *Galaxis maculatus*, which raises concerns of a spread to native fish, but further work is required to elucidate whether this is a native or an introduced isolate.

<u>Parasites</u>

While bacterial and viral pathogens cause significant mortality in Chilean trout farms, infestation by parasites can also cause significant losses. As with pathogens, the interaction between parasites emanating from farms and wild populations of fish in Chile is poorly studied.

Of the parasites found in salmonid species in Chile, nematodes and sea lice are the most common and prevalent among rainbow trout farms.

Sea lice, in particular *Caligus rogercresseyi*, are by far the most important parasite in Chile, at one point affecting 53.4% of all fish farms (Hamilton-West, Arriagada et al. 2012) with rainbow trout and Atlantic salmon the most susceptible of the farmed salmonid species (Zagmutt-Vergara, Carpenter et al. 2005, Hamilton-West, Arriagada et al. 2012, Bravo, Nunez et al. 2013). It has been noted, however, that the epidemiology of sea lice infestation in southern Chile is complex (Zagmutt-Vergara, Carpenter et al. 2005); thus, the full story is difficult to elucidate, especially when native fish are taken into consideration.

Sea lice infestations are managed in Chile under the "*Programa Sanitario Especifico de Vigilancia y Control de Caligidosis*" (PSEVC-Caligidosis). Although overall prevalence rates are not documented, the number of sites listed as CAD (*Centro de Alta Diseminación*, or sites of high pathogen dissemination) for all salmonids (inclusive of rainbow trout) are reported by Sernapesca (Figure 18). To be classified as a CAD, fish must have three or more gravid lice per female, on average; in 2015, CAD prevalence peaked at just under 10% in late February.

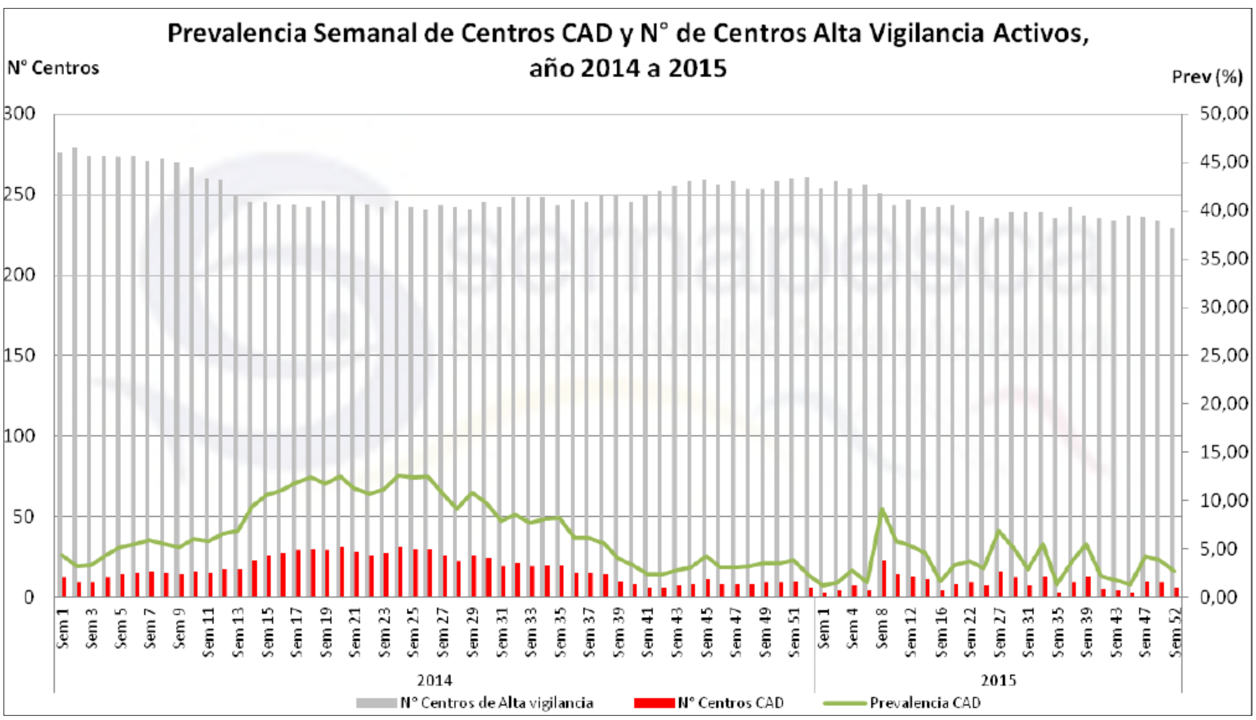

Figure 18. Sites (*Centros*) of high dissemination (CAD) for sea lice and their prevalence in Chile in 2014 and 2015, inclusive of rainbow trout. Graph from Sernapesca (2016c).

In terms of interactions with wild fish populations, a proven overlap with several wild fish species has been demonstrated, and farmed salmonids have now become the main source of the parasite (Sepulveda, Marin et al. 2004). Sea lice is known to be a natural parasite on a range of wild fish found in the vicinity of net pens (Boxshall and Bravo 2000), such as *Eleginops maclovinus* (Patagonian blenny) and *Odontesthes regia* (Chilean silverside), while also infesting the flounder *Paralichthys microps* (Carvajal, Gonzalez et al. 1998). Although unlikely to cause significant direct mortality in wild fish, it has been implicated in significant secondary impacts such as leading to a greater risk of predation (Krkosek, Connors et al. 2011). It should be noted that all studies investigating sea lice abundance show a high geographic variability and have attributed this to a wide range of factors, including water temperature and salinity, species raised, weight of the fish, treatment regimes, pen shape, and farm and fish density, among others (Zagmutt-Vergara, Carpenter et al. 2005, Yatabe, Arriagada et al. 2011, Hamilton-West, Arriagada et al. 2012). There was also a tendency for a reduction in louse prevalence toward the south of Chile (Hamilton-West, Arriagada et al. 2012, Kristoffersen, Rees et al. 2013), again attributed to several possible factors. Sites listed as CAD for sea lice by region are shown in Figures 19 and 20; rainbow trout sites (n=33) account for 24.8% of all CAD sites (n=133).

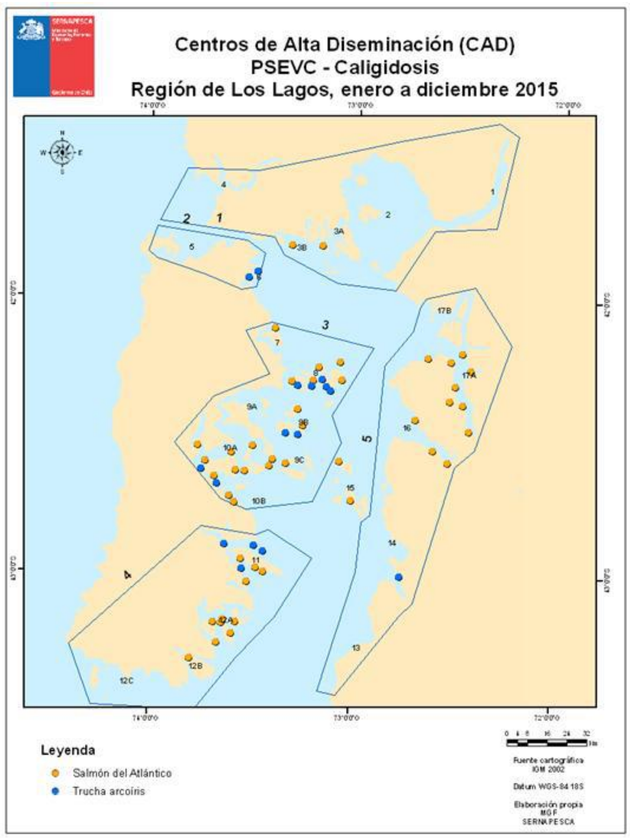

Figure 19: Spatial distribution of *Caligus* outbreak centers according to cultivated species in Region X in 2015. Blue dots represent rainbow trout (n=16, 25.8%), orange dots represent Atlantic salmon (n=45) (Sernapesca 2016c).

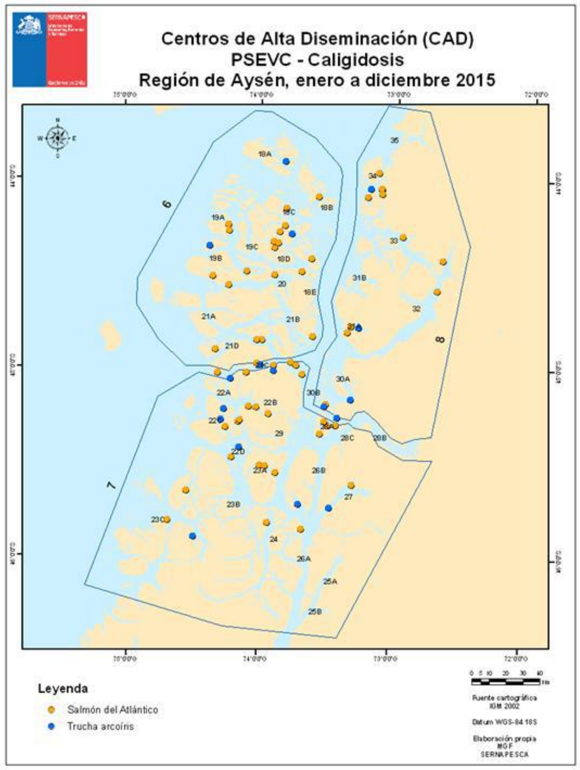

Figure 20: Spatial distribution of *Caligus* outbreak centers according to cultivated species in Region XI in 2015. Blue dots represent rainbow trout (n=17, 23.9%), orange dots represent Atlantic salmon (n=54) (Sernapesca 2016c).

It is not yet clear how the southward expansion of the industry will affect Caligid populations in these areas, and the effects remain to be seen; however, Carlos Lobos (C. Lobos, Troutlodge Chile, pers. comm. 29 October 2014) points out that *Caligus rogercresseyi* demonstrate poor resistance to low salinity, while the intergenerational interval time is driven by temperature; as a result, it appears that the environmental conditions in the south of Chile are currently precluding the establishment of this parasite, since trout production in Region XII has so far showed a general absence of Caligus. In general, rainbow trout are often produced in areas of lower salinity reducing the risk of Caligus infection relative to Atlantic salmon production (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017); despite this reduced risk, sea lice levels are still high and warrant concern (Arriagada et al. 2017).

Nematodes, particularly *Hysterothylacium aduncum*, are an active parasite of rainbow trout, more so than any other salmon species cultured in Chile. The main source of infection of this nematode is via a gammarid amphipod, which harbors the larval stage of the nematode; these amphipods live on the physical structure of net pens and interact with farmed fish (Torres et al. 2010). Therefore, control is relatively easy, requiring a periodical and thorough cleaning of floats and ropes, especially in the spring, and undertaken on land (Gonzalez 1998). The nematode is a known parasite of such wild fish as *Nezumia pulchella* (thumb grenadier) (Salinas, Gonzalez et al. 2008) and their natural and definitive host is *Merluccius australis* (southern hake) (Gonzalez 1998). Though it is known that there is an overlap in *H. aduncum* between native fish species and farmed salmonids (Sepulveda, Marin et al. 2004), the nature of the interaction is poorly studied, so no assertions can be reliably made about this more than stating that there is a likelihood that, as with all other diseases of farmed rainbow trout, the concentration of farms and activities would be likely to provide a greater infestation pressure on native species.

It is again worth noting the contribution of rainbow trout to potential parasite transmission, considering its abundance in relation to salmon farms. Figures 19 and 20 show the recorded incidences of sea lice infestation in Regions X and XI during 2015, and it is clear that, though there are a number of cases on rainbow trout farms, the vast majority are in salmon farms, simply due to the much higher number of salmon farms. So, although the transmission to and from native fish like those described above is occurring as a result of trout production, salmon is expected to have a larger disease-related impact, and rainbow trout, despite being similarly susceptible, are responsible for relatively smaller degrees of impact.

It is very difficult to determine the exact effects of Chilean trout aquaculture on wild populations of native fish without targeted and detailed studies. Also, though it has not affected the score in this assessment, it is not yet known what effect the southward expansion of the industry will have on the pathogen and parasite interactions between farmed and wild fish. It is also important to keep in mind the relative effects of rainbow trout operations in relation to salmon operations on these factors.

Conclusion and Final Score

Several diseases affect rainbow trout culture in Chile, most notably Salmonid Rickettsial Syndrome (SRS) which accounts for nearly 20% of all rainbow trout losses (nearly 83% of all losses related to disease) and affects 12 to 23% of farms. Though no major concerns were found regarding the effect of rainbow trout diseases on wild rainbow trout populations, some concern has been raised about the potential of spread to other native wild fish.

The main parasite is a sea louse called *Caligus rogercresseyi* and is of primary concern when considering amplification of disease or parasites to native populations. Incidence of salmonid sites on high alert (>3 gravid lice per female) in 2015 peaked at just under 10%. Sea lice are a natural parasite of many native species that inhabit areas around net pens; therefore, the high infection pressure coming from net pens is a cause for concern, with infestation being linked to secondary impacts such as a greater risk of predation.

Despite a lack of direct evidence of impact on wild fish, evidence of on-farm disease mortality and parasite infections, and the risk of disease transfer posed by the open nature of net pen rainbow trout farming represents a “moderate” concern; thus, the final score for Criterion 7 – Disease is 4 out of 10.

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

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms.*
- *Sustainability unit: wild fish populations.*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstock, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Criterion 8X Summary

Source of stock parameters	Score	
C8 Independence from unsustainable wild fisheries (0-10)	0	
Critical?	NO	GREEN

Brief Summary

The rainbow trout industry globally has an established record of selective breeding and domestication. In Chile, the majority of eggs are sourced domestically, and all are derived from hatcheries and established captive populations (as opposed to the wild capture of juveniles). Therefore, there is no reliance on wild fish populations for juveniles or broodstock, and the final score for Criterion 8X: Source of Stock – Independence from wild fisheries is a deduction of 0 out of –10.

Justification of Ranking

Rainbow trout have been selectively bred for beneficial traits, such as growth rate and disease resistance, for decades throughout the world (Carcamo et al. 2015) (Janssen et al. 2015). Chile is no exception, and all stock is sourced from hatcheries (the majority of which are domestic; see Criterion 10X).

Due to ubiquitous use of hatchery raised fingerlings in the marine net pen culture of Chilean rainbow trout, the industry is considered to be completely independent of wild rainbow trout fisheries for the supply of either broodstock or fingerlings.

As the Chilean rainbow trout industry is completely independent of wild populations, the score for Criterion 8: Source of Stock – Independence from wild fisheries is 0 out of -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" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 9X Summary

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

Brief Summary

Aquaculture activities in net pens inevitably interact with wildlife and predators; entanglement, deliberate killing, habitat and space competition, acoustic harassment, environmental contamination, ingestion of debris associated with aquaculture activities, and changes in prey species assemblages are known to occur, but their exact impact on wildlife is largely unknown. This is mainly due to poor reporting and data capture, as well as a general lack of information regarding the scale of impacts and population status of several affected species. For example, the movement and behaviors of the Chilean dolphin, a rare dolphin species whose habitat overlaps with salmonid farm locations, may be affected by the general existence of salmonid farms despite the lack of evidence of direct mortality. Overall, there is significant uncertainty surrounding the impacts to predators and wildlife, though the population statuses of most affected species are known and considered "least concern" and stable. Partnerships between environmental organizations and the salmonid farming industry have been established to monitor and reduce any interactions with key species, further mitigating concern. Thus, though wildlife mortalities may occur beyond exceptional cases, they are not considered to significantly impact affected species' population size; therefore, the final score for Criterion 9X – Wildlife and predator mortalities is –4 out of –10.

Justification of Ranking

It is known that wildlife interacts with rainbow trout farms in southern Chile; this is due to the high concentration of net pens in areas supporting a wide range of species that naturally feed on fish, and the overlap with known areas frequented by dolphins and porpoises (Appendix 2; Figures 21 and 22) as well as fur seals and sea lions (Appendix 2; Figure 23 and 24).

Heinrich (2006) lists the main or potential effects of aquaculture on marine mammals:

1. Competition for space and displacement from important habitats.
2. Exclusion from important habitats through the use of acoustic harassment devices.

3. Harassment from increased boat traffic due to work and maintenance of farms.
4. Changes in abundance and availability of prey species.
5. Environmental contamination and increased marine debris.
6. Incidental entanglement in farming gear.

However, as concluded herein, the author does highlight the fact that potential impacts on, and interaction with, marine mammals have only recently become the focus of discussion and are mainly deduced from anecdotal evidence and incidental observations. Although evidence exists of interference, the impacts need to be fully investigated on a case-by-case basis and in more detail to elucidate their effects and their likelihood of increasing mortality or population decline.

Of those potential interactions listed, it is understood that entanglements do happen in antipredator nets erected to protect the stock, but numbers of mortalities in Chilean trout aquaculture are unknown (Gales, Hindell et al. 2003). Despite current regulations (Reg. 320 of 2001) that require emergency plans for trapped or entangled marine mammals as well as detailed reporting of all incidents, there is no publicly available wildlife mortality data from Sernapesca. Indeed, fatal entanglements were considered frequent in the early 1990s for sea lions and to a lesser extent fur seals (Claude and Oporto 1991; reviewed in Gales et al. 2003). The Southern sea lion populations in both Regions X and XI are currently abundant and appear to be increasing in size (Subpesca 2015) (Sepulveda et al. 2015), and the total population is classified as “least concern” and stable by the IUCN (IUCN 2016). Regulations on predator control in Chile (under RAMA) focus on marine mammals, for which Sernapesca’s Regulations 112 of 2013 and 31 of 2016 prohibit their lethal control (Regulation 31 of 2016 extended Regulation 112 until the year 2021). If small numbers of entanglements do occur, they are not considered likely to affect the population status of the species.

Dr. Daniel Jimenez of Intesal-SalmonChile (D. Jimenez, pers. comm. July 2017) has stated that acoustic harassment devices are no longer used in Chile; sea lions have adapted to the noise, which has effectively become an attractant to a food source, as opposed to a deterrent. Further, aquaculture certification programs such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP), by which many Chilean farms are certified, do not allow acoustic harassment devices.

Avian predators are attracted to aquaculture sites, which are effectively densely aggregated fish stocks that impose a high mortality risk to the birds (Jimenez, Arriagada et al. 2013). The authors also point out that resource concentration might be interpreted as a positive effect for water birds, in terms of increasing total numbers, but that uneven distributions and skewed species abundances demonstrate a largely negative effect, excluding narrow niche species. It is likely that there are some entanglements and drowning, but they are not considered likely to negatively affect population sizes. Floating marine debris (FMD) can also pose hazards to marine wildlife, and entanglement in ropes and free floating nets, ingestion by birds, turtles, fish, and marine mammals is well documented and can be fatal (STAP 2011). A study by Hinojosa and Thiel (2009) in the Internal Sea of Chiloe and Chronos Archipelago found relatively strong evidence that most of the FMD in southern Chile have their origins in aquaculture activities (under which the authors include shellfish production), though the presence of debris and other materials from farms is regulated through the General Law of Fisheries and Aquaculture Article 87[22] and the Supreme Decree No. 320.[23]

Disturbance by increased boat traffic as a result of aquaculture activities has been acknowledged to have an effect on dolphin behavior in Chile, with Chilean dolphins (*Cephalorhynchus eutropia*) reacting negatively to boat encounters (Ribeiro, Viddi et al. 2005), including displaying avoidance responses. The authors suggest that boat disturbance should be considered when developing management plans and policies for coastal areas, especially in areas where widespread industrial activities such as aquaculture take place. Restriction of space by aquaculture activities for biologically important dolphin behaviors has been cited as a possible cause for concern, since dolphins' use of space is concentrated in specific areas suitable for foraging (Ribeiro, Viddi et al. 2007). Although the presence of cage farms doesn't seem to influence or alter movements directly, possibly due to the fact that Chilean dolphins prefer shallow waters with a proximity to the coast and rivers, the alteration of the habitats by aquaculture activities could have potential effects and should be monitored (Vidi et al. 2015). The Chilean dolphin, in particular, may be most at-risk due to an estimated population size of several thousand at the most (IUCN 2016). Several other cetacean species, such as Peale's dolphin (*Lagenorhynchus australis*) and Burmeister's porpoise (*Phocoena spinipinnis*) may be similarly affected, yet their population sizes are unknown. Dr. Daniel Jimenez of Intesal-SalmonChile notes that there are no reports of small cetaceans interacting with aquaculture centers (D. Jimenez, pers. comm. July 2017).

Montecinos (2016) reports on a project established in 2016 to monitor and reduce any interaction between blue whales and salmon aquaculture in Chile. The partnership (which includes the Environmental Ministry, Consejo Nacional de Producción Limpia, WWF Chile, Blue Whale Center, Universidad Austral de Chile and several salmon farming companies) has led to the establishment of two new protected areas that have been established for marine mammals, including the "Tic-Toc" marine protected area within the central red high value conservation area in Figure 21 below (D. Jimenez, Intesal-SalmonChile, pers. comm. July 2017).

[22] http://www.subpesca.cl/portal/615/w3-article-88020.html
[23] https://www.leychile.cl/Navegar?idNorma=192512

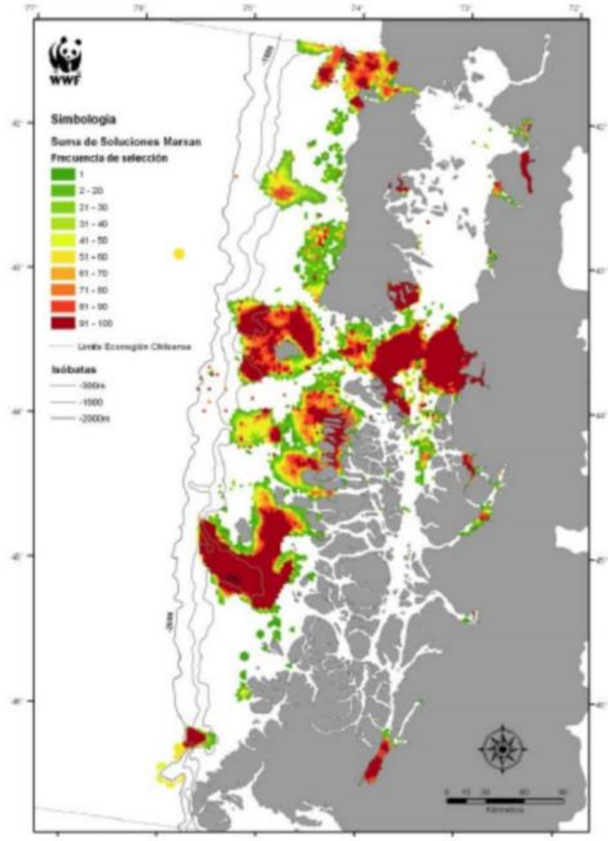

Figure 21: Areas of high conservation value. Darker red colors indicate areas of higher conservation value. Reproduced from (SFW 2017).

Sernapesca has an information sheet of the Chilean dolphin[24] that does not mention aquaculture as one of the "anthropic threats," but notes the risk of commercial fishing activities with gill nets. Similar information sheets for a variety of aquatic Species of Conservation Status in Chile (*Especies Hidrobiológicas en Estado de Conservación en Chile*[25]), including many species of marine mammals, turtles, otters, and fish, also do not implicate salmon farming among their human threats.

Conclusion and Final score

Although there is very little quantitative measure of the predator interaction or wildlife mortality effect by aquaculture activities in southern Chile, it is very likely that there are effects. Though overall impacts to affected population sizes are unknown, it is known that the estimated populations of the primary affected species are considered abundant and stable, indicating that any interactions or mortalities do not significantly impact the affected species' population size. Additionally, disturbances are a concern, but the primary focus of the Seafood Watch standard is on population impacts resulting from direct mortalities. Thus, although mortalities may occur beyond exceptional cases, they are not considered to significantly impact

[24] http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=fileinfo&id=2082
[25] http://www.sernapesca.cl/index.php?option=com_content&task=view&id=671&Itemid=766

the affected species' population size, corresponding to a score of –4 out of –10 for exceptional Criterion 9X: Wildlife and predator mortalities.

Criterion 10X: Escape of Secondary 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.

Criterion 10X Summary

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments (%)		9	
F10Xb Biosecurity of source/destination		9	
C10X Escape of secondary species Final Score		**–0.10**	**GREEN**

Brief Summary

The ISA crisis in the salmon industry led to significant tightening of regulations concerning the movement of fish and fish products into Chile. As a result, a very small portion of eggs are now imported into Chile, considerably reducing the risk of importing unwanted or dangerous organisms. The biosecurity of animal movements within Chile is understood to be high, with strict controls in place to prevent spread of non-target organisms, including pathogens. In terms of broodstock and fingerling biosecurity, broodstock are generally housed in tank-based recirculation systems with high biosecurity, while fingerlings are grown in lakes, introducing some possibility, albeit remote, of biosecurity breaches. Nonetheless, the utilization of health management zones, and the fact that trans-waterbody movements are between fresh and saltwater, dramatically reduce this risk.

The final penalty for exceptional Criterion 10x – Escape of secondary species is –0.10 out of –10.

Justification of Ranking

Factor 10Xa - International or trans-water body live animal shipments

The only discernible movement of live fish or fish products into Chile was, and in a very limited manner still is, the import of eggs. As the import of infected salmon eggs from Norway was believed to be the reason for the ISA outbreak in 2007 (Anderson 2012), the movement of eggs is an important potential vector for the introduction of unintended species, which can include pathogens. For example, the freshwater pathogen *Flavobacterium psychrophilum*, which was first reported in 1993, spread rapidly linked to egg imports and fish movements, as evidenced by the fact that identified isolates in Chile are closely related to European and North American isolates (Avendano-Herrera, Houel et al. 2014). Following the ISA crisis in Chile, a series of voluntarily introduced measures were implemented to improve the biosecurity of fish movement, which were later adopted at the regulatory level. These measures as summarized by Alvial, Kibenge et al. (2012) included:

- A ban on the movement of smolts from zones of poor sanitary conditions to zones of better sanitary conditions.
- Restriction of egg imports.
- A ban on import of eggs from countries with ISA or pancreatic disease.

The import of trout eggs to Chile dropped from 23.5% of the total to 13% of the total between 2011 and 2013 (Table 8), and this trend continued into 2014 (Sernapesca 2014b) with the imports for the first 5 months of 2014 showing a 41.5% decrease over the same period in 2013. An updated version of this dataset could not be obtained, though total egg import statistics (inclusive of salmon, though excluding domestic egg production) from 2011 to 2016 were obtained from Sernapesca (*Estadística de Importación de Ovas por origen*[26]) and indicate a sharp decline in imports (–98.8% since 2011), with less than 1 million rainbow trout eggs imported in 2016. Subpesca reports that roughly 101 million rainbow trout eggs were domestically produced, while 882,000 rainbow trout eggs were imported from Denmark in 2016; thus, imported rainbow trout eggs are <1% of the total eggs used in the industry (DAS/SPA 2017)

Table 8: Egg sources for fingerling production of rainbow trout in Chile, January 2010 to May 2014 (Sernapesca 2014b). Totals in millions of eggs. Origin codes – CL Chile, DK Denmark, US United States of America.

Year	2010			2011		2012		2013		2014	
Month \ Origin	CL	DK	US	CL	DK	CL	DK	CL	DK	CL	DK
Jan		17.40	2.85		10.35		13.95		15.50		6.35
Feb		7.50	0.45		15.72		10.10		5.90		4.80
Mar		8.20	0.56		12.58		0.30		0.55	37.65	0.80
Apr		2.80	0.40		3.60		6.70		0.70		0.80
May		6.40	0.45		2.30		1.40		2.30		1.85
Jun	150.93	1.98	0.45	231.74	2.00	195.94	5.80	171.18	0.00	ND	ND
Jul		0.00	0.45		1.70		0.00		0.00	ND	ND
Aug		0.00	0.00		0.00		0.00		0.00	ND	ND
Sep		0.00	0.00		0.00		0.00		0.00	ND	ND
Oct		0.00	0.00		0.00		0.37		0.00	ND	ND
Nov		0.00	0.00		2.40		2.40		0.75	ND	ND
Dec		11.58	0.00		20.50		1.80		0.00	ND	ND
Totals	150.93	55.85	5.61	231.74	71.15	195.94	42.82	171.18	25.70	37.65	14.60
	212.39			302.89		238.76		196.88		52.25	

In terms of movement of live fish within Chile, this is widespread and is a fundamental part of the production process, as fingerlings hatched in freshwater hatcheries are grown and smolted in lakes before transfer to the marine net pens (Avendano-Herrera, Houel et al. 2014). There is a potential that such movement could cause problems in transmitting non-target organisms, such as the fish tapeworm, between waterbodies and species, including humans (Cabello 2007).

[26] http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=fileinfo&id=4696

However, much stricter controls than existed prior to the ISA crisis in salmon has led to the formation of health management zones (Alvial, Kibenge et al. 2012), which allows for a much more sanitary and safe industry than that which existed previously. Despite the trans-waterbody movement of fish, which could be considered to introduce risk of movement or organisms other than the target fish, this movement is controlled through the use of these health management zones, and thus is now considered highly unlikely to lead to the unintentional introduction of species. The focus of risk in this assessment is therefore on the import of eggs.

As imported eggs represented <1% of the total industry in 2016, a final score of 9 out of 10 is given for Factor 10Xa – International or trans-waterbody animal shipments.

Factor 10Xb - Biosecurity of source/destination

All imported eggs come from Denmark; while it is unknown which suppliers export to Chile, all hatcheries use fully domesticated broodstock, several generations from the wild. The majority of these hatcheries are certified disease-free and operate under strict biosecurity programs.[27] Therefore, the score for Factor 10Xb – Biosecurity of source and destination is 9 out of 10.

Conclusion and final score

The biosecurity of animal movements within Chile is understood to be high, with strict controls in place to prevent spread of non-target organisms, including pathogens. In terms of broodstock and fingerling biosecurity, broodstock are generally housed in tank-based recirculation systems with high biosecurity, while fingerlings are grown in lakes, introducing some possibility, albeit remote, of biosecurity breaches. Nonetheless, the utilization of health management zones, and the fact that trans-waterbody movements are between fresh and saltwater, dramatically reduce this risk. The focus of risk in this assessment is therefore on the import of eggs. Because imported eggs represented <1% of the total industry in 2016, and the majority of eggs are supplied from certified disease-free hatcheries with strict biosecurity programs, the risk is considered minimal.

Based on this, the final penalty for Criterion 10x – Escape of secondary species is –0.2 out of –10.

[27] TroutEx, http://troutex.dk/index-2/quality.html; AquaSearch, http://aquasearch.dk/development/biosecurity/; AquaGen, http://aquagen.no/en/kategori/newsletters/aquagen-egg-update/

Overall Recommendation

The overall recommendation is as follows:

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

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

Criterion	Score	Rank	Critical?
C1 Data	6.36	YELLOW	
C2 Effluent	4.00	YELLOW	NO
C3 Habitat	5.87	YELLOW	NO
C4 Chemicals	2.00	RED	NO
C5 Feed	4.54	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Secondary species escape	-0.10	GREEN	
Total	**26.67**		
Final score (0-10)	**3.81**		

OVERALL RANKING

Final Score	3.81
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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About Seafood Watch®

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

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

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

Disclaimer

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

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[28] or farmed, which 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 broodstock 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

28 "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.

Appendix 1 - Data points and all scoring calculations

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture 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	Data Quality (0-10)
Industry or production statistics	7.5
Management	7.5
Effluent	5
Habitats	5
Chemical use	5
Feed	5
Escapes	7.5
Disease	5
Source of stock	10
Predators and wildlife	5
Secondary species	7.5
Other – (e.g., GHG emissions)	n/a
Total	**70**

C1 Data Final Score (0-10)	**6.363636364**	**YELLOW**

Criterion 2: Effluents

Factor 2.1 - Biological waste production and discharge

Factor 2.1a - Biological waste production

Protein content of feed (%)	42
eFCR	1.52
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	15.7
N content factor (fixed)	0.16
N input per ton of fish produced (kg)	102.144
N in each ton of fish harvested (kg)	25.12
Waste N produced per ton of fish (kg)	**77.024**

Factor 2.1b - Production System discharge

Basic production system score	0.8
Adjustment 1 (if applicable)	0

Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score (0-1)	**0.8**

% of the waste produced by the fish is discharged from the farm

Factor 2.1 Score - Waste discharge score

Waste discharged per ton of production (kg N ton^{-1})	61.62
Waste discharge score (0-10)	**3**

Factor 2.2 – Management of farm-level and cumulative effluent impacts

2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	3
2.2 Effluent management effectiveness	**3.6**

C2 Effluent Final Score (0-10)	**4.00**	**YELLOW**
Critical?	NO	

Criterion 3: Habitat

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	7

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

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

C3 Habitat Final Score (0-10)	**6**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	**Score**	
C4 Chemical Use Score (0-10)	**2**	
C4 Chemical Use Final Score (0-10)	**2**	**RED**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In:Fish Out (FIFO)	
Fishmeal inclusion level (%)	12
Fishmeal from by-products (%)	0
% FM	12
Fish oil inclusion level (%)	5.7
Fish oil from by-products (%)	0
% FO	5.7
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.52
FIFO fishmeal	0.81
FIFO fish oil	1.73
FIFO Score (0-10)	**5.67**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	–6
Calculated sustainability adjustment	–2.08
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**3.59**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	42
eFCR	1.52
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	85.76
Feed protein from NON-EDIBLE sources (%)	14.24
Protein OUTPUTS	
Protein content of whole harvested fish (%)	15.7
Edible yield of harvested fish (%)	56.7
Use of non-edible by-products from harvested fish (%)	100
Total protein input kg/100kg fish	63.84
Edible protein IN kg/100kg fish	54.75
Utilized protein OUT kg/100kg fish	25.07
Net protein gain or loss (%)	54.21
Critical?	NO

F5.2 Net protein Score (0-10)	**4**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	17.7
eFCR	1.52
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	7.00
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	66.9
Inclusion level of land animal products (%)	10.7
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.52
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.56
Total area (Ocean + Land Area) (ha)	7.56
F5.3 Feed Footprint Score (0-10)	7

Feed Final Score

C5 Feed Final Score (0-10)	**4.54**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape risk (0-10)	2	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape Risk Score (0-10)	**2**	
6.2. Competitive and genetic interactions score (0-10)	**7**	
C6 Escapes Final Score (0-10)	**4**	**YELLOW**
CriticaL?	**NO**	

Criterion 7: Diseases

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	4	
C7 Disease Final Score (0-10)	**4**	**YELLOW**
Critical?	NO	

Criterion 8X: Source of Stock

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

Criterion 9X: Wildlife and predator mortalities

C9X Wildlife and Predator Score (0-10)	**–4**	
C9X Wildlife and Predator Final Score (0-10)	**–4**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of secondary species

F10Xa Live animal shipments score (0-10)	9.00	
F10Xb Biosecurity of source/destination score (0-10)	9.00	
C10X Escape of secondary species Final Score (0-10)	**–0.10**	**GREEN**
Critical?	n/a	

Appendix 2 – Wildlife Interactions

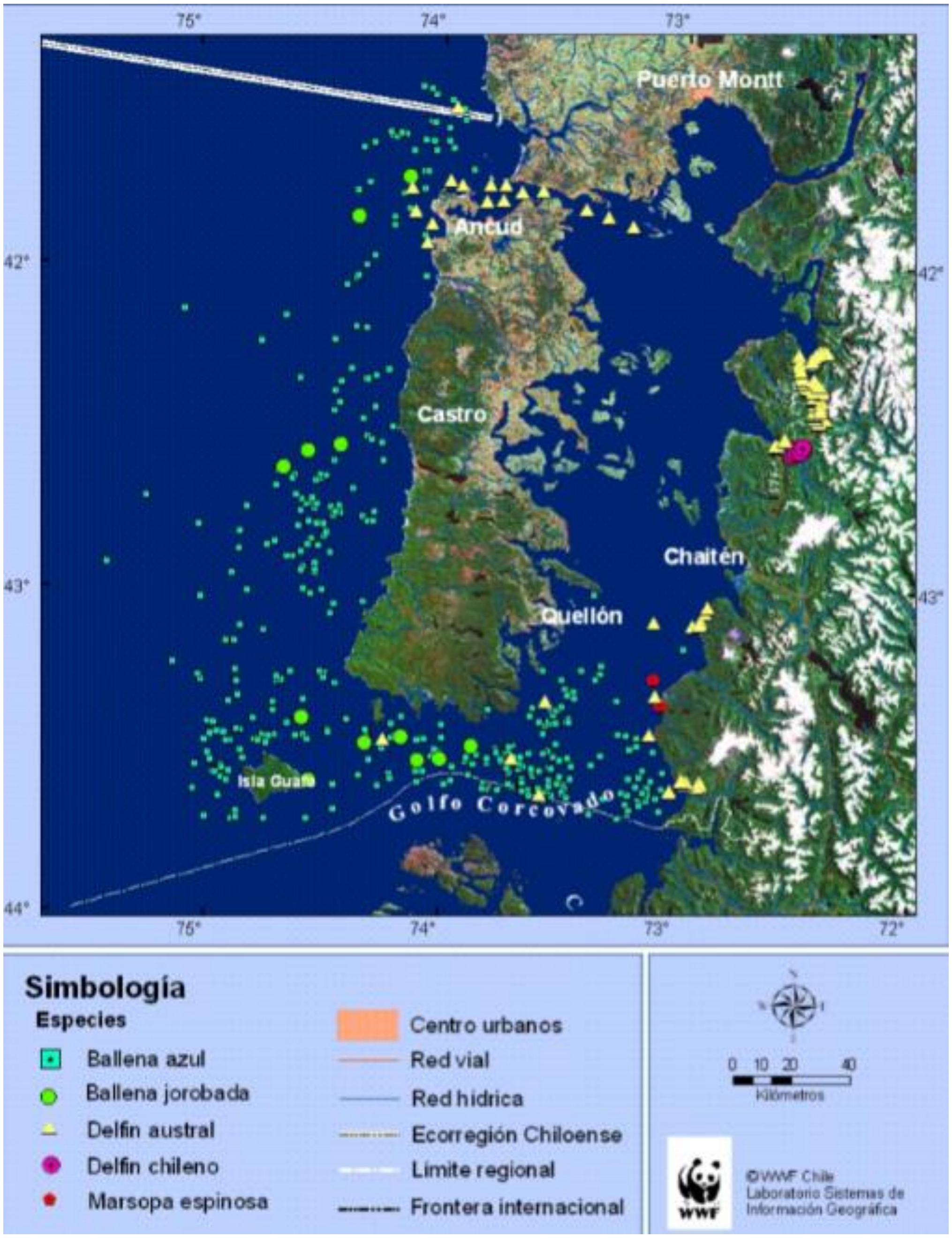

Figure 21: Sightings of blue whale (ballena azul), humpback whale (ballena jorobada), Peale's dolphin (delfin austral), Chilean dolphin (delfin chileno) and Burmeister's porpoise (marsopa espinosa) in Region X (Miethke and Galvez 2009).

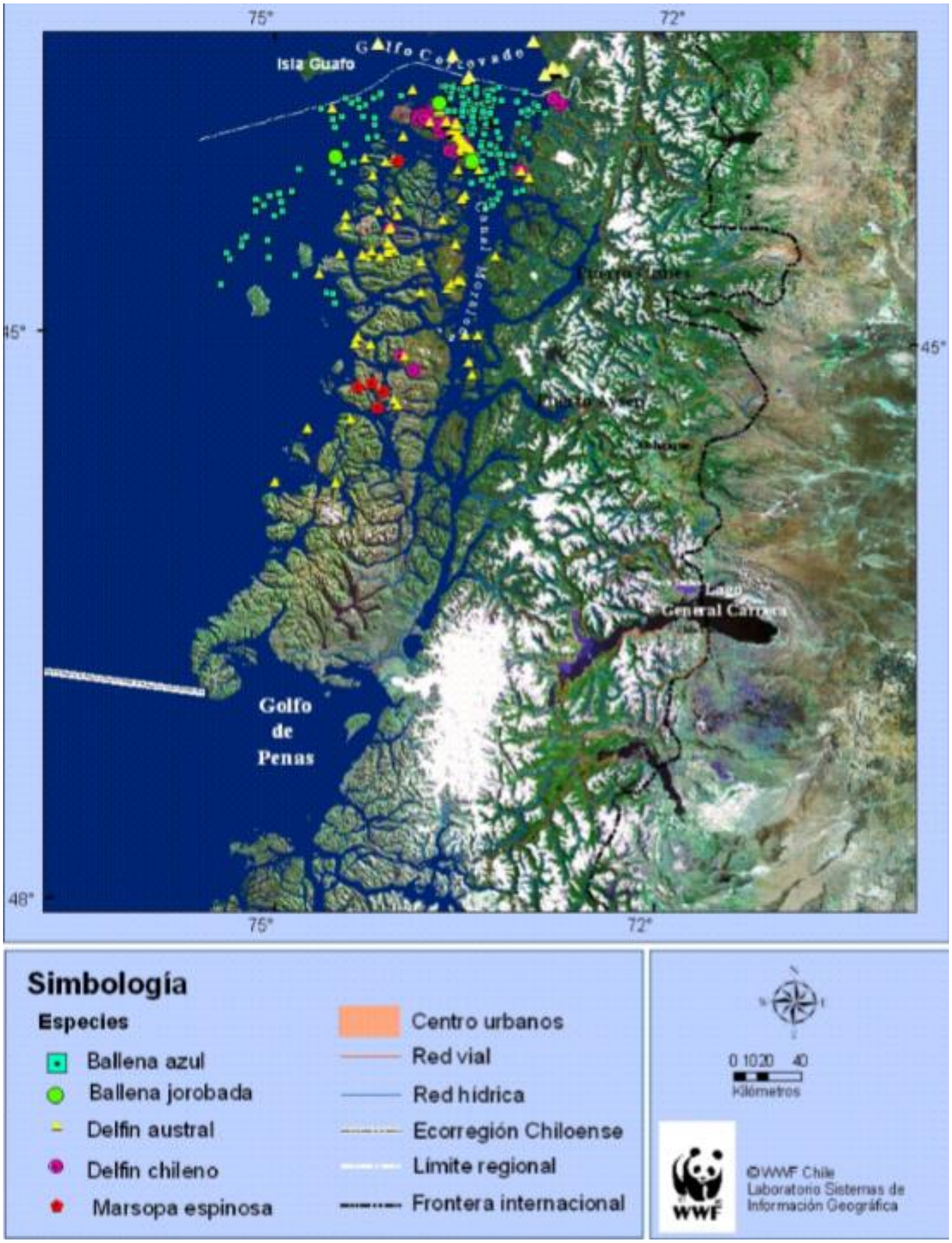

Figure 22: Sightings of blue whale (ballena azul), humpback whale (ballena jorobada), Paele's dolphin (delfin austral), Chilean dolphin (delfin chileno) and Burmeisters porpoise (marsopa espinosa) in Region XI (Miethke and Galvez 2009).

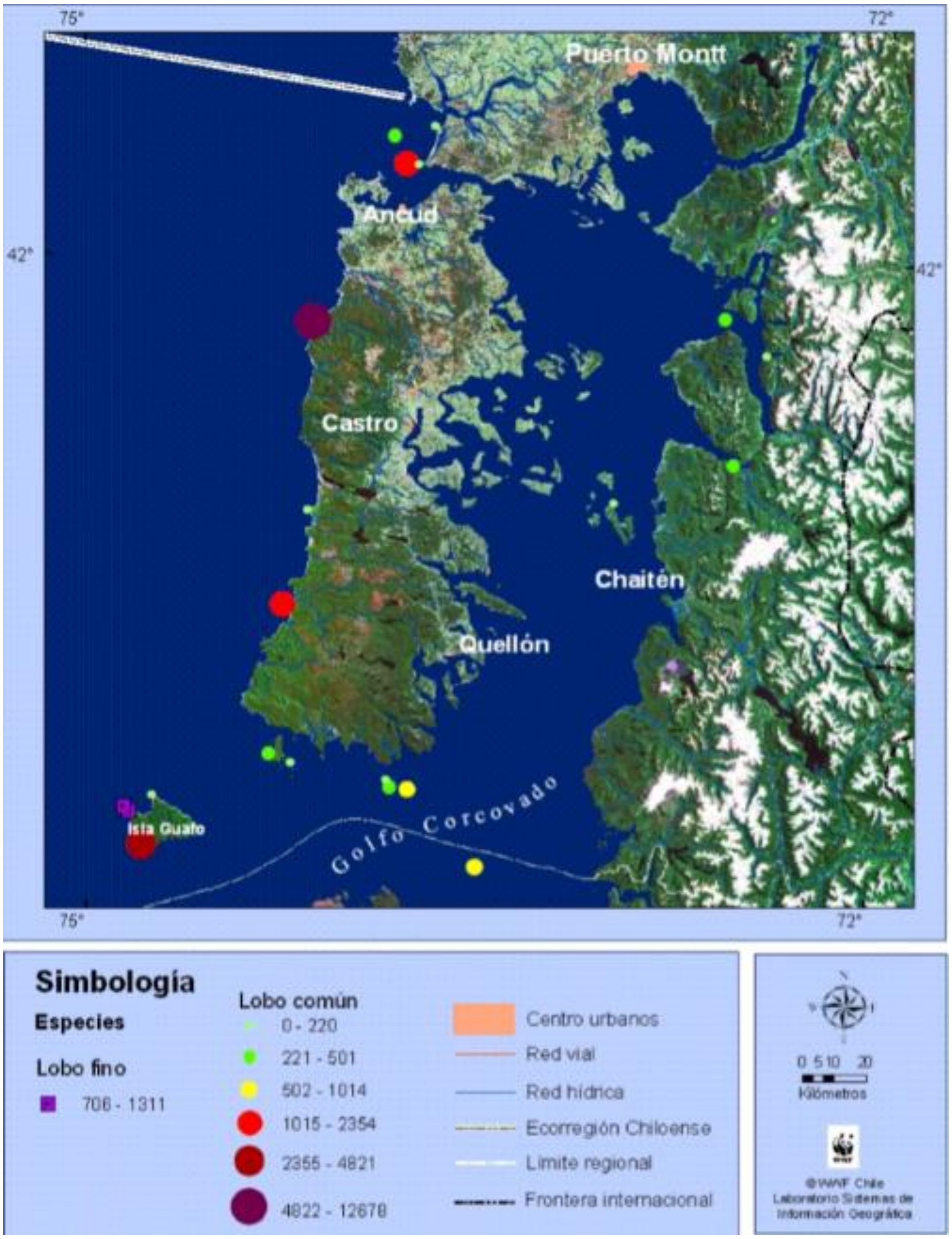

Figure 23: Colonies of South American fur seal and South American sea lion (collectively lobo fino) in Region X (Miethke and Galvez 2009).

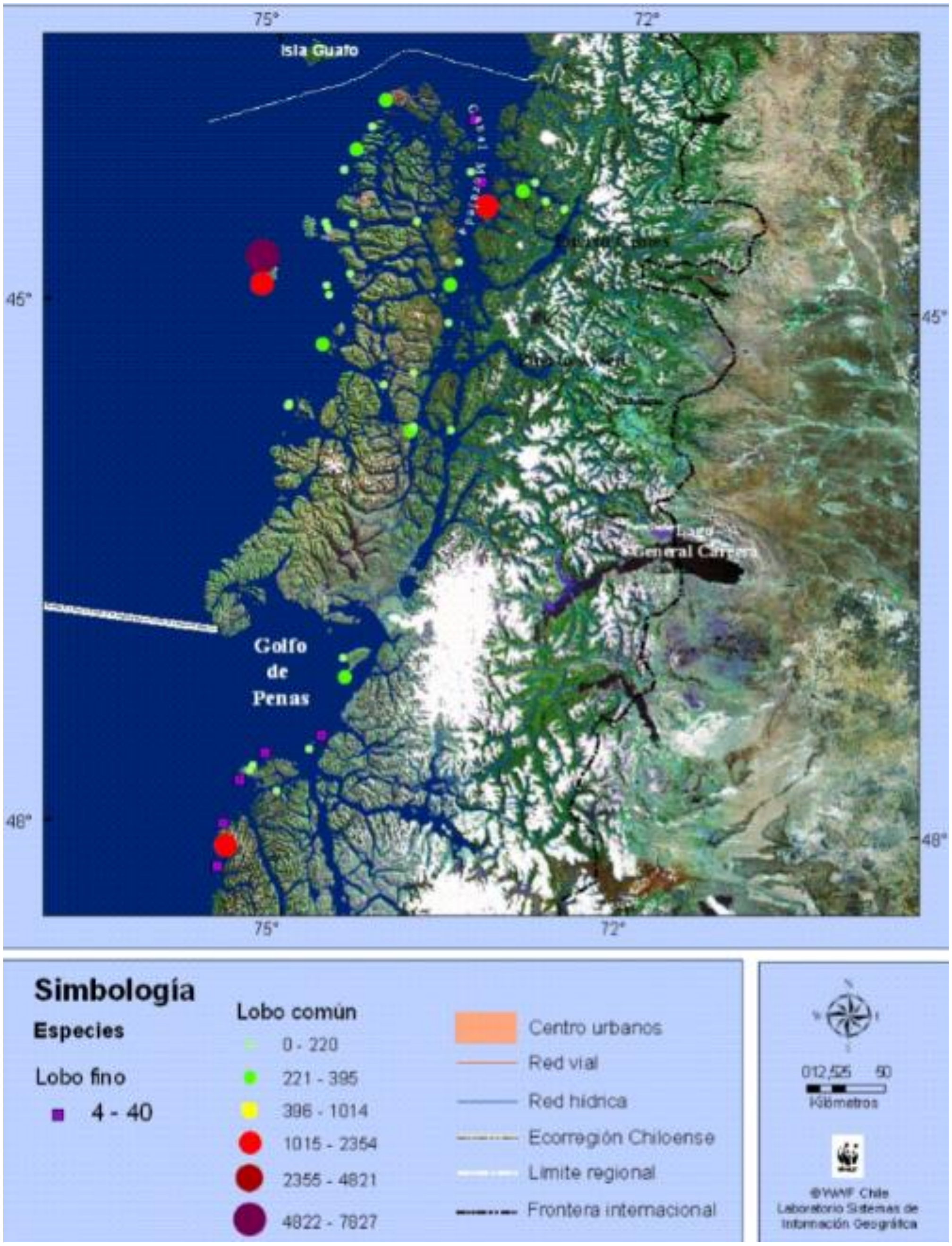

Figure 24: Colonies of South American fur seal and South American sea lion (collectively lobo fino) in Region XI (Miethke and Galvez 2009).