Rainbow Trout

Oncorhynchus mykiss

Chile

Raceways

Report ID 28292

July 10, 2023

Seafood Watch Standard used in this assessment: Aquaculture Standard v4

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About Seafood Watch

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

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

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

Guiding Principles

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

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

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

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

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

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

Best Choices/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

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

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	8.86	Green	n/a
C2 Effluent	8.00	Green	No
C3 Habitat	8.67	Green	No
C4 Chemicals	10.00	Green	No
C5 Feed	3.43	Yellow	No
C6 Escapes	5.00	Yellow	No
C7 Disease	8.00	Green	No
C8X Source	0.00	Green	No
C9X Wildlife	–1.00	Green	No
C10X Introduction of Secondary Species	–3.00	Green	n/a
Total	47.96		
Final score (0–10)	6.85		

OVERALL RANKING

Final Score	6.85
Initial rating	Green
Red criteria	0
Interim rating	Green
Critical Criteria?	0

Final Rating
Green

Scoring note: scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of –10 reflects a very significant impact. Two or more Red criteria, or one Critical criterion (highlighted with black background and white text) result in a Red final result.

Summary

The final numerical score for rainbow trout (*Oncorhynchus mykiss*) produced in freshwater raceways in Chile is 6.85 out of 10, which is in the Green range. With no Red or Critical criteria, the final recommendation is Best Choice.

Executive Summary

The total production of freshwater rainbow trout (*Oncorhynchus mykiss*) in Chile in 2021 was approximately 2,571 metric tons (mt), which is minor in comparison to the 54,085 mt of the same species produced in marine net pens in 2021. The freshwater production (commonly referred to as "pan-sized" or "portion-sized") of rainbow trout occurs mostly in Chile's Region XIV—Los Rios, with minor harvests recorded in Region VII—Maule, Region VIII—Biobio, Region IX—Araucanía, and Region XVI—Ñuble. The dominant producer is Piscicola Entre Rios Ltda, with annual average production of approximately 2,300 mt. The five farms of this company are used as the primary examples of the industry for this assessment, and the majority (approximately 95%) of production is exported to the United States. All five farms of Piscicola Entre Rios are certified to the Best Aquaculture Practices Farm Standard.[2]

The assessment involves criteria covering the impacts associated with effluent, habitats, wildlife mortalities, chemical use, feed production, escapes, introduction of secondary species (other than the farmed species), disease, the source stock, and general data availability.[3]

Because of the small scale of production and the full engagement of the dominant producer's five farms, the data availability for this assessment was excellent. Using the five farms as examples, large amounts of monitoring and survey data as well as documentary evidence (particularly from the two farms that were most recently constructed or expanded) are publicly available from the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA) and in the Environmental Impact Assessment System (Sistema de Avaluacion de Impacto Ambiental—SEIA). There inevitably continue to be some gaps in the understanding of potential impacts (and the risk of those impacts occurring), but overall, the final score for Criterion 1—Data is 8.9 out of 10.

Raceway trout farms produce substantial quantities of soluble and particulate effluent wastes. Detailed water-quality compliance requirements and monitoring data are publicly available for all farms in the SNIFA database. Extensive supporting information is also available in the farm RCA compliance documents, and in the associated regulations (particularly Decree 90—Emission Standard for the Regulation of Pollutants Associated with Discharges of Liquid Waste to Marine and Continental Surface Waters). Raceway trout farms collect particulate wastes via various sedimentation processes, and (at least for the farms of Piscicola Entre Rios) utilize the dried sludge as an agricultural soil conditioner. Soluble wastes in the effluent water are monitored weekly, and of the parameters of most interest to this assessment, the results show that the concentrations are consistently quite low compared to the maximum permitted values in the D90 regulation. Publicly available enforcement records show some flaws in the management of the farms, with occasional minor and serious infringements of the compliance requirements and one fine (in 2018). Nevertheless, twice-yearly independent aquatic fauna

[2] https://www.bapcertification.org/Standards
[3] The full Seafood Watch Aquaculture Standard is available at: http://www.seafoodwatch.org/seafood-recommendations/our-standards

surveys at the farms show that their operations (including any infringements) do not cause any detectable impacts in their associated rivers in the vicinity of the farms. Because of their sparse distribution and relatively small scale of production, there is not considered to be a significant risk of regional or cumulative impacts. The final score for Criterion 2—Effluent is 8 out of 10.

Freshwater raceway trout farms in Chile have a small total footprint and operate primarily in a mixed landscape of agriculture and forestry. Nevertheless, somewhat by necessity, the farms are also located in riparian locations near their water supply, and some impacts to these habitats are inevitable with farm construction. Using the examples of the five farms of Piscicola Entre Rios, the score for Factor 3.1—Habitat Conversion and Function is 8 out of 10. The earlier farm constructions may have had less regulatory oversight, but for the past 20 years, there has been a substantial regulatory system in place, with transparent regulations. There is also a highly transparent enforcement process through the Superintendence of the Environment (SMA), the Environmental Impact Assessment System (SEIA), and the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA). If the raceway trout industry were to expand, it would likely utilize existing land-based freshwater facilities that are no longer used for the freshwater stage of the larger marine salmonid grow-out industry, with minimal further habitat impacts. With a comprehensive and transparent system in place, the score for Factor 3.2—Farm Siting Regulation and Management is 10 out of 10. Overall, although there are considered to have been some impacts to riparian habitats, the farms have primarily been converted from agricultural land, and because of their small size and effective regulatory system, Factors 3.1 and 3.2 combine to give a final score for Criterion 3—Habitat of 8.67 out of 10.

Of the 463.4 mt of antimicrobials used in salmonid aquaculture in Chile in 2021, 1.26% or 5.84 mt were used in freshwater facilities (for any species). Data provided by Piscicola Entre Rios showed that no antimicrobials were used in their five farms in 2021–22, with a last application in September, 2020. The data provided showed that antimicrobials were used at up to 33.3 g/mt of production (compared to 138 g/mt for rainbow trout in marine net pens in the neighboring Region X), but after a change of management practices to stock larger fingerlings in the on-growing raceways, the antimicrobial use declined to zero. Occasional salt baths are the only other treatment used. The aquatic faunal surveys at locations both upstream and downstream of the farms show that the rivers are not significantly affected in abundance or diversity by the discharges of salts and nutrients, or by other activities of the farms. The final numerical score for Criterion 4—Chemical Use is 10 out of 10.

A substantial amount of feed data was made available by two feed companies in Chile, and was used anonymously on request. In addition, detailed feeding records were provided for the five farms of Piscicola Entre Rios. Nevertheless, some estimation of the nonmarine ingredient inclusion levels was needed, based on an academic review of rainbow trout nutrition. The feeding records showed that the economic feed conversion ratio in 2022 was 0.99, and with moderate levels of fishmeal and fish oil, the Forage Fish Efficiency Ratio was 1.34. This means that, from first principles, 1.34 mt of wild fish would need to be caught to provide the oil in the feed used to grow 1 mt of farmed rainbow trout. Most of the fishery sources for marine ingredients used by one feed company were certified to the Marin Trust, but there was some uncertainty about the second feed company (score of 2.35 out of 10 for Factor 5.1). With an average feed protein content of 43.5%, and a whole-body protein content of harvested rainbow trout of 15.7%, there is a net protein loss of 63.54% (score of 3 out of 10 for Factor 5.2). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 14.23 kg CO_2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for Criterion 5—Feed of 3.43 out of 10 (see the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations).

Raceway farms have a high-flow throughput of water, so they have an inherent risk of escape. Nevertheless, the constrained physical structure also provides opportunities for multiple escape prevention measures. No escapes have been reported from freshwater raceway trout farms, and government data show that there have been no reported escapes of rainbow trout in Los Rios or Araucanía Regions since at least 2011. Annual aquatic surveys at two freshwater raceway rainbow trout farms from 2013 to 2022 show only a single detection of a rainbow trout in 2015. Nevertheless, the Fisheries Development Institute (IFOP) shows that rainbow trout represent 29.1% of the fish caught in annual sampling of wild, feral, and escaped fish in rivers and lakes in Los Rio Region (and 24.0% in Araucanía). A genetic analysis (by IFOP) shows that the majority of rainbow trout captured in the Araucanía Region are farm escapees, as opposed to wild-spawned feral fish. Nevertheless, because of the presence of large numbers of freshwater rainbow trout facilities in Araucanía that grow fingerlings and smolts for on-growing in marine net pens, in addition to the widespread establishment of the species from historical stocking, none of the fish detected in the wild can be attributed to escapes from freshwater raceway grow-out farms in Los Rios Region (or elsewhere) covered by this assessment. With multiple escape barriers, and no apparent escapes for >10 years, the Escape Risk score (Factor 6.1) is 7 out of 10.

Although rainbow trout became ecologically established in Chile before aquaculture began, it is considered that escapes from farms have aided the high establishment success and rapid expansion of the species' range. There is contradicting evidence on the potential impacts of escaped rainbow trout on native ecosystems and their biodiversity, and some difficulty in attributing impacts to any one of the several nonnative salmonid species present in Chile. Nonetheless, if there were an escape from a freshwater raceway trout farm, then competition, predation, and impacts to wild species, habitats, or ecosystems may occur, although this would be unlikely to affect the population status of wild species. Therefore, the score for Factor 6.2—Invasiveness is 4 out of 10. Factors 6.1 and 6.2 combine to give a final score of 5 out of 10 for Criterion 6—Escapes.

Detailed data from the freshwater raceway trout farms in Chile show that two pathogens, *Flavobacterium psychrophilum* and the infectious pancreatic necrosis virus (IPNv), are associated with an average annual mortality due to disease of 5.5%. No high-risk pathogens (as defined by SERNAPESCA) have been detected. These farm-specific data closely reflect the annual fish health monitoring data from SERNAPESCA for all freshwater facilities in Chile, where the same two pathogens are dominant. A 2017 risk assessment of pan-sized trout farms in Chile carried out by the University of Valparaíso showed that, because of the high flow rates through the raceways, there is a high risk that wild fish will be exposed to pathogens from farms. But, the assessment also noted that *Flavobacterium*, and to a lesser extent, IPN virus, are ubiquitous in the environment in Chile and concluded that the risk to wild fish was low to moderate. Annual monitoring of the health status of wild fish in Chile by the Fisheries Development Institute (IFOP) shows low detections of fish testing positive for 13 pathogens. Between 2010 and 2022, 0.58% and 0.40% of fish tested positive for *F. psychrophilum* and IPNv, respectively. Detections of parasites in wild fish were also at background levels. Overall, it is considered (as indicated by the mortality disease data, the high flow rates in the raceways, and the risk assessment) that disease transmission may occur, but (as indicated by the risk assessment and the IFOP data), pathogens or parasites In wild fish are not considered to be amplified above background levels nor to cause morbidity. Thus, the score for Criterion 7—Disease is 8 out of 10.

Rainbow trout has been selectively bred for beneficial traits for decades throughout the world. In Chile, the fingerlings used by Piscicola Entre Rios are raised from eggs produced at the Piscicola Huililco[4] breeding center in the Araucanía Region of Chile (Region IX). The company uses a domesticated strain of rainbow trout called Blueback, which it has developed in a selective breeding program since 2005. The facility operates as a closed-cycle breeding center, with no entry of external eggs, fingerlings, juveniles, or adults. Therefore, the production of rainbow trout in freshwater (and seawater) in Chile is considered fully independent of wild stocks for broodstock, eggs, or fingerlings, and the score for Criterion 8X—Source of Stock is a deduction of 0 out of –10.

It is to be expected that the fish in raceway farms attract predators, but the evidence from the farms in Chile, and from similar systems elsewhere, shows that nonlethal exclusionary techniques, such as fences and predator netting, are the primary methods used to manage interactions. Overall, effective management practices are in place for the nonharmful exclusion of wildlife, and deliberate lethal wildlife control is not used or permitted. It is possible that accidental mortalities may occur, but are likely to be limited to exceptional cases and highly unlikely to affect the health of the population. Therefore, the final score for Criterion 9X—Wildlife Mortalities is a small deduction of –1 out of –10.

The five raceway grow-out farms used as an example in this assessment rely on the movement of live eggs, alevins, or fingerlings to and from three separate facilities in the Araucanía and Los Rios Regions of Chile. Although these source and destination locations are broadly similar ecologically, they are on different rivers and watersheds, so the farmed trout production is considered to be fully reliant on trans-waterbody movements of live fish. The final destinations

[4] https://www.ovasdetrucha.cl/

of the movements (i.e., the raceway grow-out farms) have biosecurity limitations because of their flow-through nature; however, the egg and fingerling producers in indoor tank-based facilities have greater biosecurity potential. For example, the egg provider operates as a closed-cycle breeding center, with no entry of foreign eggs, fingerlings, juveniles, or adults, and along with the fingerling producers, it has the ability to treat and disinfect the water, eggs, and facilities. There are also several documentary and testing requirements from SERNAPESCA regarding permissions to move fish, veterinary health certificates, and testing for specific high-risk pathogens. The emergence of a novel pathogen is always a possibility, but overall, during live fish movements, there is a relatively low risk of introducing species that are not native to or present in the destination rivers (e.g., a pathogen). The final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3 out of –10.

The final numerical score for rainbow trout produced in freshwater raceways in Chile is 6.85 out of 10. With no Red or Critical criteria, the final rating is Best Choice.

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
Freshwater raceways

Species Overview

Brief Overview of the Species
Rainbow trout (*Oncorhynchus mykiss*) is native to the western seaboard of North America from Alaska, United States to Baja California, Mexico, as well as the upper Mackenzie River drainage (Arctic basin), Alberta, and British Columbia in Canada. It has been intentionally introduced as a sport fish worldwide and is now naturalized on all continents except Antarctica. It is highly adaptable and capable of inhabiting many different habitats, from an anadromous lifestyle in coastal waterways to permanent residence in freshwater lakes. From an aquaculture perspective, it is 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 it is nonnative to Chile, the species was introduced between 1805 and 1920, and it now has widely distributed self-sustaining populations in the wild (FAO 2005)(Carrera 2020)(Luna and Torres 2011)(Monzón-Argüello et al., 2014).

Production Method
Commercial production of rainbow trout in Chile began in 1975, and grew slowly to six companies in the 2000s, but one company (Piscícola Entre Ríos Ltda) now dominates production (Estay 2017)(pers. comm., Juan Villasante, Piscicola Entre Rios January 2023). Freshwater raceways are the primary on-growing system, and although this is predominantly a rapid-turnover, flow-through system, some of the raceway and tank systems covered in this assessment may partly or temporarily recirculate water, particularly during periods of reduced river flows in the austral summer (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023). Figure 1 provides an overview of a raceway rainbow trout farm in Chile (Pichico farm in Los Rios Region).

Figure 1: Aerial view of a freshwater raceway trout farm in Chile: 1) water supply channel from upstream water intake in the river; 2) raceways; 3) settling ponds; and 4) water return to river. Image reproduced from Google Earth.

Despite the current dominance of Piscicola Entre Rios in commercial production, some other small-scale farms may exist; for example, Campalans et al. (2017) note an (unreferenced) 2012 survey by SERNAPESCA that reported that some small-scale freshwater trout farms operate without formal registration. Campalans et al. (2017) report that SERNAPESCA initially identified a potential 48 farms in 2012 in Los Rios and Araucanía Regions. Later, a formal search (using various records, interviews, and questionnaires) by Campalans et al. (2017) identified only 12 farms in operation (including those of Piscicola Entre Rios). The nonregistered subsistence farms, primarily in the Araucanía Region, used small numbers of raceways, tanks, or earthen ponds, and produced small volumes of <8 mt per year. Campalans et al. (2017) concluded that there are around 10 small producers of pan-size trout, the total number is declining, and there is only one company that commercially produces and exports this resource (Piscícola Entre Ríos). Since the publication of Campalans et al. (2017), a search of the internet (for the purposes of this Seafood Watch assessment) identified one other small commercial producer of trout, in the Maule Region (Region VII), operating flow-through tanks (Food For Future).[5]

[5] https://truchacircular.cl

This assessment covers the production of rainbow trout to harvest in freshwater, predominantly in flow-through raceways. The use of flow-through or partly recirculating tanks is also considered to be covered by this assessment. The full production cycle to harvest is completed in freshwater, primarily in Region XIV (Los Rios) (see Figure 3). This is distinct from the production of rainbow trout in marine net pens in Regions X (Los Lagos), XI (Aysen), and XII (Magallanes), which also has an initial freshwater hatchery and nursery phase in Regions X, IX (Araucanía), and XIV.

A challenge is noted in distinguishing the general information and data relating to the production of rainbow trout to harvest in freshwater versus the production of fish (fingerlings or smolts) for subsequent grow-out in marine net pens. For example, a 2011 study (Rosenfeld and Manley, 2011) recorded 169 freshwater salmonid production centers in Chile, of which 34% were exclusively for trout production, but the authors also noted that only a small percentage (not specified) were producers of portion-sized fish. Campalans et al. (2017) noted that the pan-size farms of Piscicola Entre Rios share the Valdivia River basin with 37 freshwater salmon hatchery operations.

The production of rainbow trout in marine net pens is not covered in this assessment. Note that Seafood Watch has separate recommendations for fish produced in fully recirculating indoor systems[6] and for rainbow trout grown in marine net pens in Chile.[7] General information about raceways and other aquaculture production systems is available from Seafood Watch.[8]

Production Statistics

According to the National Fisheries and Aquaculture Service (Servicio Nacional de Pesca y Acuicultura—SERNAPESCA),[9] the total production of freshwater rainbow trout in Chile (Regions VII, VIII, IX, XIV, and XVI) in 2021 was approximately[10] 2,571 mt. This is small in comparison to the 54,085 mt produced in marine net pens in 2021. Figure 2 shows the regional freshwater production. The dominant company (Piscicola Entre Rios Ltda) produces an average of approximately 2,300 mt per year (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023).

[6] https://prod.seafoodwatch.org/recommendation/trout/rainbow-trout-30053?species=219

[7] https://prod.seafoodwatch.org/recommendations/search?query=%3Aspecies%3BRainbow%20trout%3Amethods%3BFarmed%3Acountry%3BChile

[8] https://prod.seafoodwatch.org/seafood-basics/fishing-and-farming-methods

[9] Annual aquaculture statistics (Anuarios Estadísticos de Pesca y Acuicultura) - http://www.sernapesca.cl/informacion-utilidad/anuarios-estadisticos-de-pesca-y-acuicultura

[10] There is also one small freshwater trout farm in Region XI for which the production is not separated from marine net pen production in the SERNAPESCA statistics for Region XI. The figures above are therefore referred to as "approximations."

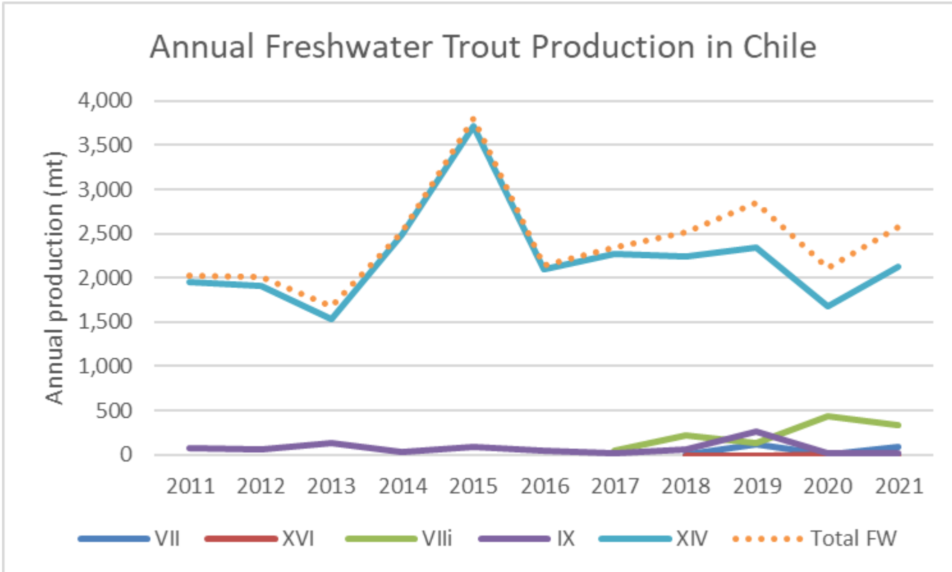

Figure 2: Annual production of freshwater rainbow trout by region in Chile from 2011 to 2021. Region VII—Maule; Region VIII—Biobio; Region IX—Araucanía; Region XIV—Los Rios; Region XVI—Ñuble (see regional map in Figure 3). The dotted line shows the total. Data from SERNAPESCA.

Given the dominance of production in Los Rios Region, this assessment of freshwater trout in Chile focuses on this region and uses data primarily from the dominant producer, Piscicola Entre Rios. Figure 3 shows the approximate locations of the five farms operated by the company. All five farms of Piscicola Entre Rios are certified to the Best Aquaculture Practices Farm Standard.[11]

[11] https://www.bapcertification.org/Standards

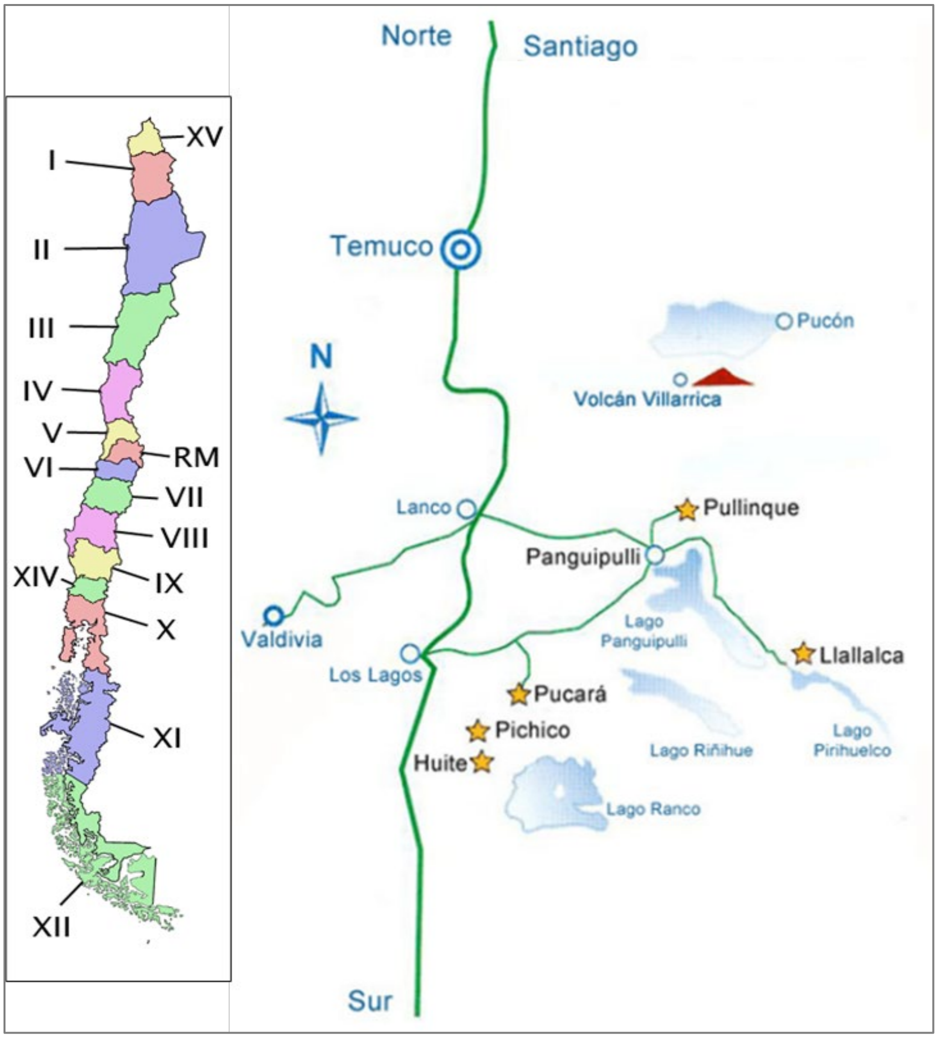

Figure 3: Map of freshwater raceway farm sites operated by Piscícola Entre Ríos Ltda in Los Rios Region (XIV) of Chile (yellow stars). Map reproduced from Piscícola Entre Ríos, and Wikipedia (inset). Note: the inset regional map does not include Ñuble (Region XVI), which was separated from the northern part of Region VII in 2018.

Import and Export Sources and Statistics

Chile exports large volumes of rainbow trout—52,578 mt in 2019 (FAO 2021)—but this figure does not distinguish the minor amounts grown in freshwater from the much larger production in marine net pens. The freshwater raceway production of rainbow trout in Chile is primarily focused on export to the United States, and the dominant company (Piscicola Entre Rios) exports 95% of production, or approximately 2,200 mt per year (pers. comm., Juan Villasante, Piscicola Entre Rios February 2023).

Common and Market Names

Scientific Names	*Oncorhynchus mykiss*
Common Names	Rainbow trout
Spanish	Trucha arcoiris
French	Truite arcenciel

Japanese	虹鱒 (Torauto)

Product Forms

Rainbow trout from Piscicola Entre Rios is exported mostly as butterfly fillets or single fillets (Figure 4).

Figure 4: Examples of single fillets (left) and butterfly fillets (right). Pictures provided by Piscicola entre Rios.

Criterion 1: Data Quality and Availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

C1 Data Category	Data Quality
Production	10.0
Management	10.0
Effluent	10.0
Habitat	7.5
Chemical Use	10.0
Feed	7.5
Escapes	7.5
Disease	7.5
Source of stock	10.0
Wildlife mortalities	7.5
Introduction of secondary species	7.5
C1 Data Final Score (0–10)	**8.9**

Brief Summary

Because of the small scale of production and the full engagement of the dominant producer's five farms, the data availability for this assessment was excellent. Using the five farms as examples, large amounts of monitoring and survey data as well as documentary evidence (particularly from the two farms that were most recently constructed or expanded) are publicly available from the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA) and in the Environmental Impact Assessment System (Sistema de Avaluacion de Impacto Ambiental—SEIA). There inevitably continue to be some gaps in the understanding of potential impacts (and the risk of those impacts occurring), but overall, the final score for Criterion 1—Data is 8.9 out of 10.

Justification of Rating

Given the small scale of freshwater rainbow trout production in raceways in Chile, there is relatively little specific published information. In a literature review, Campalans et al. (2017) observed that information regarding freshwater production of trout in Chile is scarce, and that there were no specific studies on portion-sized or "pan-sized" rainbow trout farming in freshwater in Chile. Campalans et al. (2017) also noted that some studies on other salmonids were applicable, but within the broader topic of freshwater aquaculture in Chile, this Seafood Watch assessment has often found it challenging to distinguish farms producing portion-sized trout for harvest in freshwater from the much greater number of freshwater facilities in the same regions that produce fingerlings of trout and salmon for grow-out in marine net pens farther south in Chile. But, with the engagement of the dominant producer (Piscicola Entre Rios), the small size of the industry became an advantage for data availability, and a large amount of data was provided. To avoid repetition in the following text, when data or information is attributed to the farms or the company, this is referenced by: "(pers. comm., Juan Villasante, Piscicola Entre Rios February 2023)."

In addition, as discussed in the following paragraphs, large amounts of monitoring and documentary evidence for each farm are available in the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA),[12] which is operated by the Environment Superintendency (Superintendencia del Medio Ambiente—SMA),[13] and in the Environmental Impact Assessment System (Sistema de Avaluacion de Impacto Ambiental—SEIA),[14] which is operated by the Environmental Assessment Service (Servicio de Evaluación Ambiental—SEA).[15] The two databases are linked, with SNIFA being the more accessible portal. There is some considerable variability in the amount of information available for each farm from SNIFA and SEIA, depending upon when the farm was built, or when applications were made to modify the farm. Those farms with later developments are associated with a more advanced regulatory system (for example, SEIA was established in 1997) have received greater scrutiny, and generated a larger volume of documentary records.

Industry and Production Statistics

The annual aquaculture statistics from SERNAPESCA (Anuarios Estadísticos de Pesca y Acuicultura)[16] show the total production of rainbow trout by region in Chile. The statistics are not separated by marine or freshwater production, but by focusing on Regions VII, VIII, XI, and XIV (as opposed to Regions X, XI, and XII, where marine net pen production of rainbow trout is practiced), robust estimates of freshwater rainbow trout production can be obtained. Annual production information from Piscicola Entre Rios was also provided by the company. The locations (with satellite images) of all registered aquaculture facilities in Chile are available from SNIFA, and a survey of "pan-sized" trout producers in Campalans et al. (2017) also clarified the approximate number and scale of unregistered subsistence producers. An internet search identified one other small, active, commercial rainbow trout farm (in tanks rather than

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[12] SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)
[13] https://portal.sma.gob.cl/
[14] https://www.sea.gob.cl/sea/que-es-seia
[15] https://www.sea.gob.cl/

[16] http://www.sernapesca.cl/informacion-utilidad/anuarios-estadisticos-de-pesca-y-acuicultura

raceways). Overall, the nature and scale of production is considered to be fully understood, and the Data score for Production Statistics is 10 out of 10.

Management and Regulations

With full engagement from the dominant producer in Chile, all questions were answered about farm-level management processes. In addition, detailed documentary evidence of farm characteristics and operational procedures are available from SNIFA and SEIA, particularly those related to Declarations of Environmental Impacts (Declaración de Impacto Ambiental—DIA) and associated Environmental Qualification Resolutions (Resolución de Calificación Ambiental—RCA). Regulations linked to farm construction, expansion, or operation are typically listed in these documents. The regulatory documents themselves are available from resources such as the Library of the National Congress of Chile (Biblioteca del Congreso Nacional de Chile).[17] The primary enforcement organizations are SEA and SMA, with a highly transparent process; that is, all application and planning documentation, all monitoring data, environmental surveys and audits, and documents relating to infringements and penalties are also publicly available from SEIA and SNIFA. Although the amount and detail of information varies by farm, and there are some gaps in the records (for which the missing reports or data were supplied directly from the farms), the basic management and regulation of the farms is considered to be fully understood. The Data score for Management and Regulations is 10 out of 10.

Effluent

Extensive water-quality monitoring results are publicly available for all aquaculture facilities in Chile in SNIFA. Although results were somewhat challenging to analyze in bulk from SNIFA, tabulated results from the five farms of Piscicola Entre Rios were provided for this assessment by the company. Additional water-quality monitoring data associated with certification to the Best Aquaculture Practices standards were also provided by the company. Regulations for water-quality monitoring are also readily available; specifically, Decree D90.[18] The farms' procedures for the management of particulate wastes were similarly provided for this assessment, and are articulated in various documents in the SNIFA and SEIA databases; e.g., (Silob, 2007). Detailed reports from twice-yearly aquatic fauna surveys are also publicly available from SNIFA for two farms (with the most recent reports supplied directly by the farms). Evidence of infringements, penalties, and compliance programs are also publicly available in detail from SNIFA. The management, monitoring, and impact of effluents are considered to be comprehensively understood, and the Data score for Effluent is 10 out of 10.

Habitat

The locations of all aquaculture facilities in Chile are available in SNIFA, including a satellite image and map layer. (See Figure 9 in Criterion 3 for the example screenshot, from which the general habitat types in the area surrounding a farm can be seen.) In addition, a large amount of documentary information is available in the SEIA database (linked from SNIFA) that relates to

[17] https://www.bcn.cl/portal/

[18] Decreto-90 07-MAR-2001 MINISTERIO SECRETARÍA GENERAL DE LA PRESIDENCIA - Ley Chile - Biblioteca del Congreso Nacional (bcn.cl)

the initial construction or expansions of the facilities and ongoing monitoring. As noted above, the amount of documentary information varies considerably by farm. Two of the five farms of Piscicola Entre Rios have detailed construction and modification records (including independent ecological surveys of the former habitat types, tree surveys, and declarations of environmental impacts[19]), and annual aquatic flora and fauna monitoring surveys in the adjacent rivers. The data score for Habitat is 7.5 out of 10.

Chemical Use
SERNAPESCA produces semiannual and annual reports on the use of antimicrobials in aquaculture in Chile. At the time of writing this report (March 2023), antimicrobial reports are available for 2021 and the first half of 2022. These reports provide useful information on antimicrobial use in freshwater aquaculture, and the data are separated by species, but they do not differentiate the raceway-grown, portion-sized trout production from other freshwater facilities producing fish for on-growing in marine farms. Detailed information on antimicrobial use for the five farms of Piscicola Entre Rios was provided by the company, including treatment types, dose, prescription numbers, the total and active ingredient quantities used, and the associated production with which to calculate relative use in g/mt. An example of a veterinary prescription was also provided (Appendix 2). The company declared that low salinity baths were the only other treatments used. The Data score for Chemical Use is 10 out of 10.

Feed
Two feed companies provided data anonymously for the freshwater raceway trout feeds used by Piscicola Entre Rios. They listed the range of feed ingredients used, and provided the inclusion levels of the marine ingredients (fishmeal and fish oil) and their use of by-product marine ingredients. Partial data were available on the sources of marine ingredients, and also their certification status. For the nonmarine ingredients, the generalized feed formulation for rainbow trout in Kamalan et al. (2020)[20] has a close match with the ingredient lists provided by the two feed companies, so it was used to generate a best-fit formulation for the assessment. The protein content of each feed type and size was also provided. Piscicola Entre Rios provided detailed feeding records from 2020 to 2022, from which weighted averages of most parameters (e.g., protein content or the inclusion levels of marine ingredients) could be calculated, in addition to the feed conversion ratio. The Data score for Feed is 7.5 out of 10.

Escapes
Farm-level escape prevention measures were described by the company, and are detailed in various contingency plans, technical drawings, and associated documents in the SEIA database. SERNAPESCA provides data on the reported escapes by region up to 2020, and the Biblioteca del Congreso Nacional de Chile provides a further analysis of these data that includes the species in each region (BCN, 2022). Reports on the twice-yearly aquatic surveys at two of the raceway trout farms are available from SNIFA (as stated above, these were supplied directly from the farms for the most recent examples). Annual sampling by IFOP provides further

[19] Declaración de Impacto Ambiental (DIA) – see Criterion 3 – Habitat for further information.
[20] Kamalan et al., (2020) provided a review of the "Nutrition and Feeding of Rainbow Trout (Oncorhynchus mykiss)"

information on the detection and genetic composition of rainbow trout in the wild in Chile (IFOP, 2023)(IFOP, 2019). There is a robust literature on the impacts of nonnative salmonids in Chile, including rainbow trout, of which the most recent review is Soto et al. (2022). Although it remains impossible to attribute (or robustly refute) the contribution of freshwater raceway trout farms to the impacts of rainbow trout in Chile, the data and information allow a robust indication, so the Data score for Escapes is 7.5 out of 10.

Disease

SERNAPESCA publishes an annual "sanitary report" (also a semiannual interim report) for freshwater and marine aquaculture sites in Chile (Informe Sanitario con Información Sanitaria de Agua Dulce y Mar; SERNAPESCA, 2022c,d). This provides useful information on the typical causes of mortality, including disease, and the most prevalent pathogens; however, freshwater raceway trout farms are aggregated with other freshwater facilities that produce fingerlings for marine grow-out. Piscicola Entre Rios provided detailed mortality data (cause, number, and weight) from 2020 to 2022 for two weight categories of fish. A risk assessment for the potential transfer of pathogens from freshwater raceway trout farms, Campalans et al. (2017), was particularly useful in understanding the prevalence of the most common pathogens in freshwater environments in Chile. In addition, the IFOP (2023) assessment of the health of wild and feral fish in Chile provided data on the detections of relevant pathogens in these fish. The Data score for Disease is 7.5 out of 10.

Source of Stock

There is robust literary confirmation that rainbow trout has been domesticated for many generations; e.g., Carcamo et al. (2015), Janssen et al. (2015), and Reis Neto et al. (2019). In addition, the website of the sole egg producer used by Piscicola Entre Rios (Piscícola Huililco[21]) provides substantial information on its closed-cycle breeding program. The Data score for Source of Stock is 10 out of 10.

Wildlife and Predator Mortalities

A description and photographic evidence of the use of predator nets were provided by the company. They also reported a legal prohibition on lethal control and on any harm to wildlife. The independent aquatic survey reports available from SNIFA for two of the farms note that the endangered southern river otter is present in the region, but has not been detected at the farms. Although no specific data are available (e.g., on occasional entanglements in the predator nets), the information provided by the farms gives a reliable representation of the operations, and the Data score for Wildlife and Predator Interactions is 7.5 out of 10.

Introduction of Secondary Species

The company provided detailed data on the numbers of eggs and fingerlings produced, plus their movements between the hatchery, three fingerling facilities, and the five grow-out farms. The locations of the facilities and satellite images are available in SNIFA, and the rivers into which they discharge water can be identified. The Huililco hatchery website (see footnote 21)

[21] https://www.ovasdetrucha.cl/

provides substantial information about the company's biosecurity practices. Examples of movement permission documents, health certificates, pathogen testing laboratory results, veterinary certificates, and transport tank cleaning certificates were provided by Piscicola Entre Rios. The Data score for Introduction of Secondary Species is 10 out of 10.

Conclusions and Final Score

Because of the small scale of production and the full engagement of the dominant producer's five farms, the data availability for this assessment was excellent. Using the five farms as examples, large amounts of monitoring and survey data as well as documentary evidence (particularly from the two farms that were most recently constructed or expanded) are publicly available from the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA) and in the Environmental Impact Assessment System (Sistema de Avaluacion de Impacto Ambiental—SEIA). There inevitably continue to be some gaps in the understanding of potential impacts (and the risk of those impacts occurring), but overall, the final score for Criterion 1—Data is 8.9 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

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

Criterion 2 Summary

Effluent Risk-Based Assessment

C2 Effluent Final Score (0–10)	**8**	Green

Brief Summary

Raceway trout farms produce substantial quantities of soluble and particulate effluent wastes. Detailed water-quality compliance requirements and monitoring data are publicly available for all farms in the SNIFA database. Extensive supporting information is also available in the farm RCA compliance documents, and in the associated regulations (particularly Decree 90—Emission Standard for the Regulation of Pollutants Associated with Discharges of Liquid Waste to Marine and Continental Surface Waters). Raceway trout farms collect particulate wastes via various sedimentation processes, and (at least for the farms of Piscicola Entre Rios) utilize the dried sludge as an agricultural soil conditioner. Soluble wastes in the effluent water are monitored weekly, and of the parameters of most interest to this assessment, the results show that the concentrations are consistently quite low compared to the maximum permitted values in the D90 regulation. Publicly available enforcement records show some flaws in the management of the farms, with occasional minor and serious infringements of the compliance requirements, and one fine (in 2018). Nevertheless, twice-yearly independent aquatic fauna surveys at the farms show that their operations (including any infringements) do not cause any detectable impacts in their associated rivers in the vicinity of the farms. Because of their sparse distribution and relatively small scale of production, there is not considered to be a significant risk of regional or cumulative impacts. Thus, the final score for Criterion 2—Effluent is 8 out of 10.

Justification of Rating

As a result of the incomplete digestion of their feeds and natural metabolic processes, rainbow trout excrete soluble and particulate wastes, which will be discharged (at least in part) to the natural receiving waters of the farm because of the flow-through nature of the production system (Aubin et al. 2011). With monthly water-quality testing results for each farm publicly available from SNIFA[22] (and provided in a spreadsheet format for the five farms of Piscicola Entre Rios from 2017 to 2022), in addition to the results of biannual aquatic fauna surveys for two farms, the evidence-based assessment has been used (i.e., the Data score for Effluent in Criterion 1—Data is >5 out of 10).

Evidence-Based Assessment

Campalans et al. (2017) noted the high rates of water exchange in freshwater raceway rainbow trout farms in Chile (between five and eight cycles per hour for fingerlings, and three to five cycles per hour for fattening). With these high flows through the raceways, the effluent wastes typically include high volumes that contain low concentrations of dissolved metabolites and suspended particulate wastes (fecal matter and unconsumed feeds) (Fornshell and Hinshaw 2008)(Fornshell et al. 2012). The majority of wastes in raceway effluents are dissolved metabolites, such as ammonia, nitrite, nitrate, and phosphate, and are discharged directly into receiving waterbodies; however, between 7% and 32% of total nitrogen and between 30% and 84% of total phosphorous are bound as particulate waste (Sindilariu 2007).

Particulate wastes

Using the farms of Piscicola Entre Rios as examples, freshwater raceway trout farms have three primary collection stages for particulate wastes. These have been described by the farm owners for this assessment (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023), and are also articulated in the Environmental Impact Declaration (Declaración de Impacto Ambiental—DIA) documents of the Huite farm, which are available from the SEIA database.[23] In addition, a detailed independent analysis of the sludge management at the Huite farm is available in Silob (2007).

As shown in Figure 5, the first (and dominant) collection of particulate wastes is from two settlement locations within the raceways, both in quiescent areas ahead of overflows and the outflow. These collect uneaten feed and fecal particles.

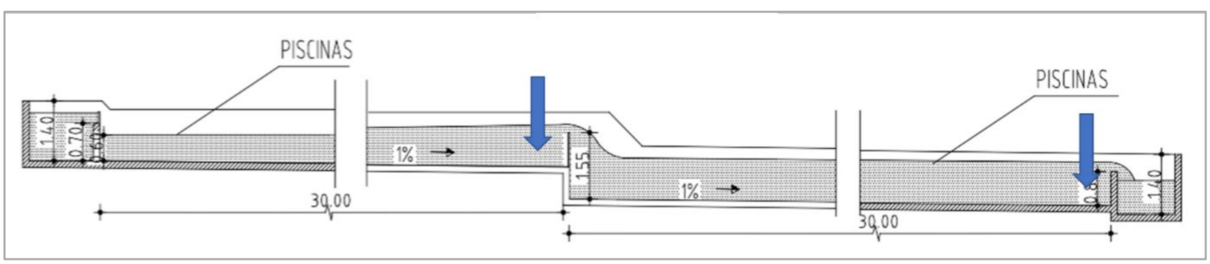

Figure 5: Longitudinal cross-section of a raceway (piscina), showing the two settlement zones (blue arrows). Image reproduced from the Declaración de Impacto Ambiental "Centro de Cultivo Huite"—SEIA.

The particulate waste removed from the raceways is pumped to two secondary settlement tanks (approximately 3 m × 2 m × 1 m deep), where the particulates settle out again. The

[22] https://snifa.sma.gob.cl/

[23] Declaración de Impacto Ambiental "Centro de Cultivo Huite". Previsualización de Declaración de impacto ambiental (DIA) (sea.gob.cl)

supernatant (the liquid above the settled material) from this secondary settlement tank enters the third stage of the settling ponds, along with the main overflow from the raceways. The settling ponds are intended to further decrease the particulate wastes below regulatory limits (80 mg/l of suspended solids; see Table 1). The settling ponds are clearly visible on satellite images of all the farms (see Figure 1 in the Introduction). The sludge in the secondary settlement tank is collected weekly, and the sludge in the settling ponds is collected once or twice a year. The sludge is air-dried in a holding area of the farm that is designed according to an independent analysis (Silob 2007), and distributed to local farms for use as a soil conditioner/fertilizer (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023). An independent study of the quality and potential uses of the sludge (Silob 2007) confirms the suitability of the dewatered sludge as a soil improver or organic fertilizer of benefit to neighboring communities. Figure 6 shows the dried sludge and bagged for delivery. Monitoring of the groundwater at farms is also required to demonstrate that there is no infiltration from the settling ponds or sludge treatment.

Figure 6: Dried sludge (left) and bagged for delivery (right). Images provided by Juan Villasante, Piscicola Entre Rios.

It was noted from documents in the SNIFA database that flaws in the operation of the sludge management system were associated with sanctions against the farms; for example, in 2016, a lack of apparent waterproofing in the settling ponds at Llallalca farm was classified as a serious infringement, but later absolved.[24] In the same sanction process, a failure to extract the sludge from the settling ponds with the required frequency was also classified as a serious infringement in 2017, and later absolved. In 2019, an accumulation of sludge at the Pichico

[24] The farm is required to monitor groundwater quality to demonstrate there is no infiltration. SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)

farm was also classified as a serious infringement[25] and addressed with a compliance program (Programa de Cumplimiento) with no penalty. As noted in the "Evidence of Impacts" section (further in Criterion 2), there is no evidence of any specific environmental impact resulting from these incidents.

Soluble wastes

Regarding the soluble wastes, the effluent is regulated as liquid industrial waste (Los Residuos Industriales Líquidos—RILs), and the farms are required to take weekly water-quality samples according to Decree 90 of 2000 (Emission Standard for the Regulation of Pollutants Associated with Discharges of Liquid Waste to Marine and Continental Surface Waters[26]). Thirty-eight parameters are required to be monitored by Piscicola Entre Rios, of which the most relevant to this assessment (physical and chemical) are shown in the left column of Table 1, along with the maximum permitted values (from Table 1, Section 4.2 of Decree 90). The water-quality monitoring results (including the independent laboratory reports) are available in the SNIFA database, although not all time periods appear to be available. An example of the laboratory results for a full suite of parameters is provided in Appendix 1 from a randomly selected report prepared by the testing laboratory (Hidrolab in Quilcura).

Accessing all the monitoring results in SNIFA is challenging because of their volume, but Piscicola Entre Rios provided all their water-quality monitoring results for all farms from 2017 to 2022 (pers. comm., Juan Villasante, Piscicola Entre Rios, February 2023), and these can be used as robust examples of the effluent from freshwater raceway rainbow trout farms in Chile.[27] The values for all parameters are all typically minor compared to the maximum permitted values from Decree 90 shown in Table 1. The maximum values for each parameter recorded at any farm in the 6-year period are also shown in the right column of Table 1 and are also much lower than the permitted maximums. Figure 7 shows the monitoring results for total nitrogen[28] for all farms[29] from 2017 to 2022, with all results well below the permitted maximum of 50 mg/l.

Table 1: Effluent parameters required to be measured at freshwater raceway trout farms discharging into rivers in Chile, according to Decree 90. The units and maximum permitted values are from Table 1 in Decree 90. Also included (right column) are the peak values recorded at any of the Piscicola Entre Rios farms between 2017 and 2022.

Parameter	Maximum Value (D90)	Units	Peak Value (2017–22)

[25] SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)
[26] Decreto 90—Norma de Emision para la Regulacion de Contaminantes Asociados a las Descargas de Residuos Liquidos a Aguas Marinas y Continentales Superficiales. https://www.bcn.cl/leychile/navegar?idNorma=182637
[27] The values provided from the farm can be verified against the result in SNIFA and the independent laboratory reports for any sample date.
[28] The nitrogen parameter was selected for display here because the results were presented as decimalized numerical values (e.g., 2.34 mg/l), whereas most of the phosphorus values were presented as "less than" results (e.g., <3 mg/l), which are not possible to analyze or plot accurately. Nitrogen is an important indicator of water quality when high protein feeds are used, but it is recognized that phosphorous is also an important water-quality indicator in freshwater environments.
[29] The Llallalca farm has two production modules, for which separate data were provided.

Oils and fats	20	mg/l	<14
pH	6.0 to 8.5	—	6.2 to 7.8
Chlorides	400	mg/l	41.5
Biological oxygen demand	35	mg O_2/l	21.8
Suspended solids	80	mg/l	49.0
Total phosphorous	10	mg/l	8.9
Total nitrogen	50	mg/l	11.0
Foam	7	mm	2.0

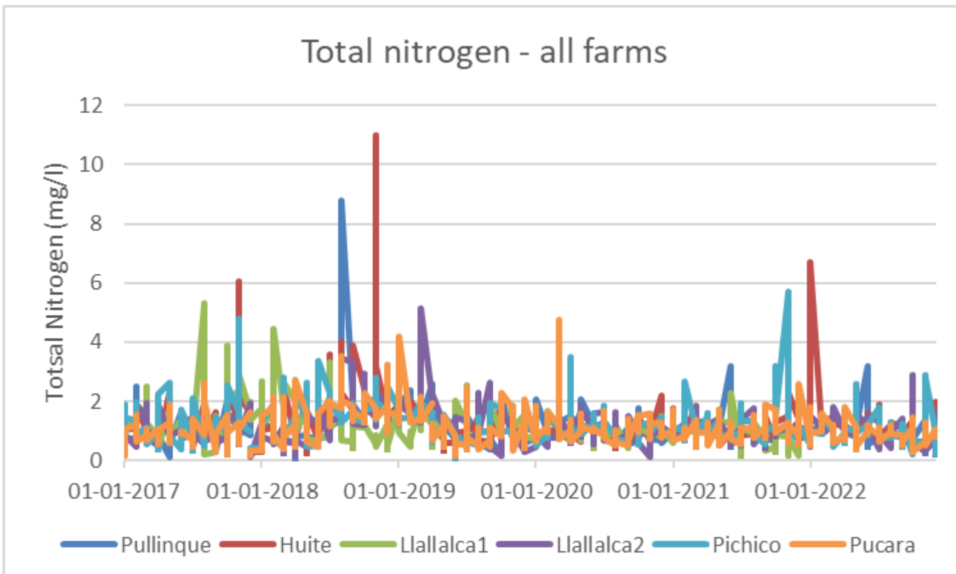

Figure 7: Total nitrogen water-quality monitoring results from five freshwater rainbow trout farms in Chile, from 2017 to 2022. The regulatory maximum permitted value is 50 mg/l. Note that the Llallalca farm has two production modules, for which separate data were provided. Data are available from SNIFA, and were provided by Piscicola Entre Rios.

Although the parameters of Table 1 are the most relevant to this assessment, it is noted that the Llallalca farm had a minor infringement of Decree D90 in February 2021, for exceeding the manganese parameter (the infringement records did not say by how much it was exceeded, and the cause is not immediately clear). According to the farm, this was due to a mistake in the data entry, and the case was closed (pers. comm., Juan Villasante, Piscicola Entre Rios, February 2023).

A further set of water-quality samples taken at the water intake upstream of the raceways (influent) can be compared to the results at the discharge point downstream of the raceways and settling ponds (effluent). These tests are conducted as part of the certification requirements for the Best Aquaculture Practices scheme. The results provided six separate occasions in 2022 from three farms when the same parameters were measured. Because of the reporting of nonspecific values (e.g., “<5 mg/l”), only the ammoniacal nitrogen and biological oxygen demand (BOD) could be compared (Figure 8).

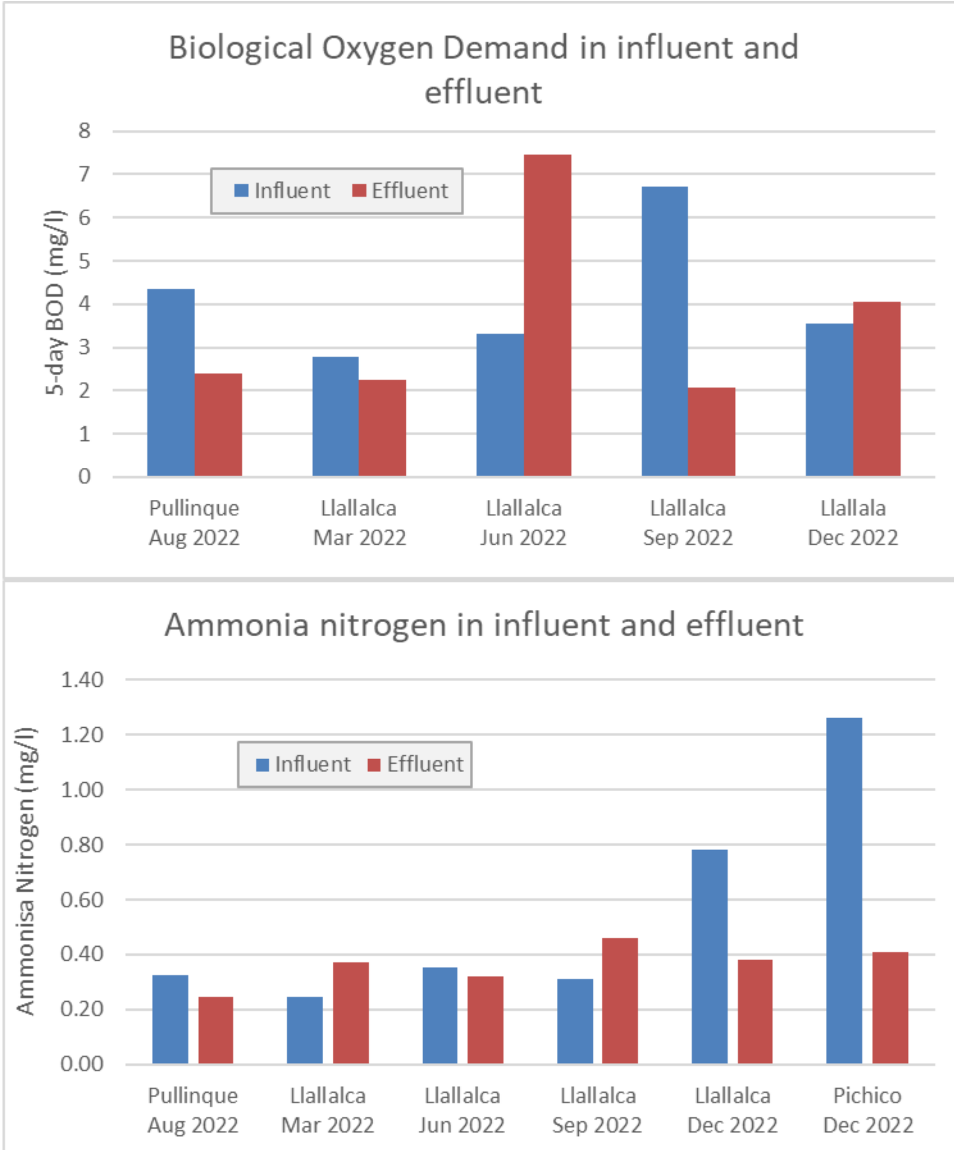

Figure 8: Comparison of water-quality indicators in the influent and effluent of three farms at six sampling occasions in 2022 (note only five samples for BOD are comparable). The maximum permitted values in the effluent according to Decree D90 are 5.0 mg/l for ammoniacal nitrogen and 35.0 mg/l for BOD. Data from Piscicola Entre Rios.

The results show the same low values compared to the regulatory limits in Decree 90, and there are no consistent indications of increased concentrations in the effluent compared to the influent. In fact, on average, the values in the effluent were slightly lower than the influent for both parameters over the six matching sampling occasions.

Regulations and enforcement

As noted above, Decree D90 is the primary measure by which the discharges of effluents from raceway rainbow trout farms in Chile are regulated. In addition to the effluent monitoring requirements described above, other monitoring requirements (such as aquatic faunal surveys) are specified in the Environmental Qualification Resolution (RCA) documents. The RCA gives permission for a project to operate (such as a raceway trout farm), but sets out various compliance requirements. The RCA process operates as part of Law No. 19,300 on General Environmental Bases[30] and Supreme Decree No. 40 of 2012 from the Ministry of the Environment, which approves the Regulation of the Environmental Impact Assessment System (SEIA Regulations[31]). Thus, the compliance requirements in each farm can differ, depending on the nature (and timeline) of the RCAs. For example (as noted above), the Llallalca and Huita farms were either constructed or expanded most recently, so they have more extensive monitoring requirements than the other three farms that were constructed or modified earlier.

It is not immediately clear how Decree D90 (or other regulations) manage the potential cumulative impacts of multiple aquaculture operations or of other potential nutrient dishcarges to rivers (e.g., agriculture). But, Campalans et al. (2017) noted that the low number of pan-sized fish farms in Chile, together with their low annual production, lead to a low incidence of their residues in the environment, so it is considered unlikely that these farms would be significantly contributing to any impacts beyond the farm or any regional impacts (see the following Evidence of Impacts section).

Regarding enforcement, the volume and detail of the public records available in the SNIFA and SEIA databases indicate that enforcement is transparent and robust. All water monitoring records are available, as is evidence of any infringements and penalties. Infringements are classified as minor, moderate, or serious. As an example of detailed enforcement, the Llallalca farm had a documented minor infringement for failing to report a single effluent parameter (coliforms—out of the total 37 weekly parameters) in December 2019. Other examples of minor infringements are temporarily exceeding the maximum discharge flow rate at various times in 2018–20. These infringements typically result in a compliance program for the farm, with increased monitoring and reporting. Examples of serious infringements (subsequently absolved) have been described above in relation to sludge handling. In 2018, the Llallalca farm received a fine of 256 UTA (Unidad Tributaria Annual or Annual Tax Unit, equivalent in total to approximately USD700) for a direct discharge of effluent to the river in 2016 that bypassed the treatment units. The same fine also related to not allowing sufficent retention time in the settling ponds on an occasion in 2017, and a failure to install drum filters in 2017 as indicated in the RCA. The installation of drum filters was initially planned and approved for the farm, but later not needed; however, because of some overlap in procedural timing, an infringement was stated for not installing them (pers. comm., Juan Villasante, Piscicola Entre Rios February 2023).

As noted in the following Evidence of Impacts section, these infringements, although classified as “serious” in the SNIFA/SEIA records, are not considered to be associated with any specific environmental impacts. Given their occasional timeframes across the five farms, they are not

[30] Ley N° 19.300 sobre Bases Generales del Medio Ambiente
[31] SEIA—Sistema de Evaluación de Impacto Ambiental (Reglamento del SEIA)

considered to reflect persistent management failures or illegal activites. Nevertheless, they are evidence of detailed enforcement of the regulations.

Evidence of Impacts

The RCA documents for two of the five farms of Piscicola Entre Rios (Llallalca and Huite) require surveys of aquatic fauna in the river upstream and downstream of the farm, to identify any potential impacts of the farm's operations. These must be conducted twice per year at Huite and once per year at Llallalca. Specifically, the Huite survey is required to monitor Ichthyfauna (fish), the southern river otter (*Lontra provocax*), and the riparian vegetation adjacent to the farm. At Llallalca, the aquatic surveys also include an analysis of the zoobenthic fauna. The surveys are carried out by a third party, which obtains a fishing permit from SERNAPESCA. Detailed reports of most surveys are available from SNIFA for each farm,[32] and the most recent survey reports (November 2022, and not yet available on SNIFA) were supplied by the farm (pers. comm., Juan Villasante, Piscicola Entre Rios February 2023).

The most recent surveys available in the SNIFA database (Llallalca: March 2022; Huite: November 2022) make conclusions based on all the previous surveys at each farm (18 at Huite and 9 at Llallalca over a 9-year period dating to 2013). Although detailed results are available in each report, the latest assessment at Huite concludes: "*[T]here are no differences in the faunal composition or in the water quality between the fluvial sections upstream and downstream of the Huite farming center.*" Similarly at the Llallalca farm, the latest assessment concludes: "*There are no evident differences between the stations positioned upstream of the intake, with respect to those positioned downstream of the discharge.*" To refer again to the fine and the "serious" infringements of the RCA compliance requirements at the Llallalca site: while these procedures indicate flaws in the management of the farms, they do not appear to be associated with any significant and/or long-term environmental impacts at the site.

Conclusions and Final Score

Raceway trout farms produce substantial quantities of soluble and particulate effluent wastes. Detailed water-quality compliance requirements and monitoring data are publicly available for all farms in the SNIFA database. Extensive supporting information is also available in the farm RCA compliance documents, and in the associated regulations (particularly Decree 90—Emission Standard for the Regulation of Pollutants Associated with Discharges of Liquid Waste to Marine and Continental Surface Waters). Raceway trout farms collect particulate wastes via various sedimentation processes and (at least for the farms of Piscicola Entre Rios) utilize the dried sludge as an agricultural soil conditioner. Soluble wastes in the effluent water are monitored weekly, and of the parameters of most interest to this assessment, the results show that the concentrations are consistently quite low compared to the maximum permitted values in the D90 regulation. Publicly available enforcement records show some flaws in the management of the farms, with occasional minor and serious infringements of the compliance requirements, and one fine (in 2018). Nevertheless, twice-yearly independent aquatic fauna

[32] Llallalca - https://snifa.sma.gob.cl/UnidadFiscalizable/Ficha/8248;
Huite - https://snifa.sma.gob.cl/UnidadFiscalizable/Ficha/4435

surveys at the farms show that their operations (including any infringements) do not cause any detectable impacts in their associated rivers in the vicinity of the farms. Because of their sparse distribution and relatively small scale of production, there is not considered to be a significant risk of regional or cumulative impacts. Therefore, the final score for Criterion 2—Effluent is 8 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

C3 Habitat parameters	Value	Score
F3.1 Habitat conversion and function (0–10)		8
F3.2a Content of habitat regulations (0–5)	5	
F3.2b Enforcement of habitat regulations (0–5)	5	
F3.2 Regulatory or management effectiveness score (0–10)		10.0
C3 Habitat Final Score (0–10)		**8.67**
Critical?	No	Green

Brief Summary

Freshwater raceway trout farms in Chile have a small total footprint and operate primarily in a mixed landscape of agriculture and forestry. Nevertheless, somewhat by necessity, the farms are also located in riparian locations near their water supply, and some impacts to these habitats are inevitable with farm construction. Using the examples of the five farms of Piscicola Entre Rios, the score for Factor 3.1—Habitat Conversion and Function is 8 out of 10. The earlier farm constructions may have had less regulatory oversight, but for the past 20 years, there has been a substantial regulatory system in place, with transparent regulations. There is also a highly transparent enforcement process through the Superintendence of the Environment (SMA), the Environmental Impact Assessment System (SEIA), and the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA). If the raceway trout industry were to expand, it would likely utilize existing land-based freshwater facilities that are no longer used for the freshwater stage of the larger marine salmonid grow-out industry, with minimal further habitat impacts. With a comprehensive and transparent system in place, the score for Factor 3.2—Farm Siting Regulation and Management is 10 out of 10. Overall, although there are considered to have been some impacts to riparian habitats, the farms have primarily been converted from agricultural land, and because of their small size and effective regulatory system, Factors 3.1 and 3.2 combine to give a final score for Criterion 3—Habitat of 8.67 out of 10.

Justification of Rating

Factor 3.1: Habitat Conversion and Function
Raceway trout farms have a relatively small footprint; for example, the Llallalca and Huite farms have a total area of 3 hectares (ha) and 4.4 ha, respectively. For comparison, the average size of a single shrimp pond in Ecuador is 6.6 ha, and the average farm size is 175.6 ha (Boyd et al. 2021). Nevertheless, the nature of the flow-through raceway system largely necessitates the use of riparian locations, and though the total area of the farms is small, the potential habitat impacts are assessed here.

The locations of all aquaculture facilities in Chile are available in SNIFA, including a satellite image and map layer (Figure 9). From these images, the general habitat types in the area surrounding a farm can be seen. In addition, a large amount of documentary information is available in the SEIA database that is related to the initial construction or expansions of the facilities and to the various monitoring requirements. As noted in Criterion 1, the amount of documentary information varies considerably by farm: primarily according to its time of construction and/or its most recent application for modifications.[33]

Regarding freshwater raceway trout farms in Chile, the SNIFA database shows that the five example farms operated by Piscicola Entre Rios were constructed between 1991 and 2007–08. The Huite farm was the last to be constructed in 2007–08, and two farms, Llallalca and Huite, had applications to increase production in 2013 and 2015, respectively. These farms therefore have greater information available.

[33] This is particularly the case where farms have requested to increase production, and it can be seen that this triggers more intensive monitoring requirements.

Figure 9: Screenshot from the SNIFA database for the Huite farm, showing the link to a map layer of the farm location. The general habitat type of the area can be visually observed. Tabs to other monitoring and regulatory processes can be seen.

A visual examination of the five sites from satellite images shows that the farms are indeed located in riparian agricultural landscapes that primarily comprise grazing lands and forests. Campalans et al. (2017) confirms that the primary activities in the regions where pan-sized trout are produced are agriculture and forestry. Regarding the specific former habitats before construction of the farms, the farm owners describe them as cattle- and sheep-grazing land (pers. comm., Juan Villasante, Piscicola Entre Rios January 25, 2023). The Huite farm, which was built most recently in 2007–08, and the Llallalca farm (built in 1999) appear (at least visually from satellite images) to have had the greatest forest cover (Figure 10). The original independent Declaration of Environmental Impact (Declaración de Impacto Ambiental—DIA) for the Huite farm (Silob, 2007b; available from SNIFA[34]) describes the vegetation of the former habitat as "*a formation of low-density trees with undergrowth of grasses and sedges surrounded by arborescent scrub of Myrtle (Myrceugenia apiculata)".* A 2007 independent "agroecological" survey[35] (see Factor 3.2a) conducted before construction at the site of the proposed Huite farm described the vegetation as *"low-density native trees and an understory of scrub, currently used for extensive grazing of cattle*."

Nevertheless (as discussed in Factor 3.2b), when presented with evidence of native trees in the farm's independent survey (which was part of the application for permission to construct the farm), the Environmental Assessment Service (El Servicio de Evaluación Ambiental—SEA)

[34] The DIA document is available in the Annexes of the farm application - Annexes (e-seia.cl). Project Profile: Huite Cultivation Center (sea.gob.cl)

[35] Informe Agrologico Proyecto Piscicultura Rio Huite, prepared by Silo Chile (https://silobchile.cl/), and available from SNIFA - SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)

requested further information[36] and the consideration of the need for a Sectoral Environmental Permit No. 102 (Permiso Ambiental Sectorial), which relates to the cutting or reforestation of native forest or plantations for the execution of civil works. After a subsequent census of the trees showed considerable sparsity (6% land cover) in addition to the farm's intent to maintain as many of the trees as possible (visible in recent satellite images), the Permit 102 was not required. It is also of interest to note from the tree census that the sparse tree cover and scrub on the former site had no habitat continuity with adjacent areas, which were planted with nonnative eucalyptus trees.

Figure 10: The Huite farm in Los Rios Region, constructed in 2007–08. The riparian nature of the habitat in which the farm is located is clear, yet it is also surrounded by agriculture and (nonnative) commercial forestry.

Considering freshwater raceway trout farms in general, the five example farms from Piscicola Entre Rios appear to show that the typical habitat type used for freshwater raceway trout farms in Chile is former riparian agricultural land. A land-use change from agriculture to aquaculture is not considered to result in the loss of any critical ecosystem services; however, it is likely that, because of their necessary association with rivers and varying circumstances at each location, there is some change and/or disturbance of riparian habitats. In this case, the score for Factor 3.1—Habitat Conversion and Function would be 9 out of 10, with an estimation of minimal

[36] Specifically, the SMA required the farm to: "irrefutably prove the type of vegetation that exists, whether it is isolated trees, or whether it constitutes forest as defined by Decree 701 of 1974."

impacts. In the case of two of the farms (discussed previously) that appear to have converted primarily riparian scrub land with sparse tree cover used for extensive grazing, and given the small and discrete nature of the land conversion, there are considered to be moderate impacts to ecosystem functionality but no loss of critical ecosystem services (score of 7 out of 10 for Factor 3.1). To generate an overall score for freshwater raceway trout farms in Chile, the five example farms yield a simple average score for Factor 3.1 of 8.2 out of 10.[37] If the freshwater raceway trout industry were to expand, it is considered most likely that it would utilize existing freshwater aquaculture facilities that are no longer used by the salmon farming industry (pers. comm., Juan Villasante, Piscicola Entre Rios, January 25, 2023)—thereby causing no further loss of critical ecosystem services.

Factor 3.2: Farm Siting Regulation and Management

Factor 3.2a: Content of habitat management measures

A practical demonstration of the regulations relating to the construction or modification of a freshwater raceway trout farm can be seen in the documentary repository in the SEIA database—specifically, the steps necessary to get an approval (an Environmental Qualification Resolution; Resolución de Calificación Ambiental—RCA) for the construction or modification of a farm. Although it is clear from the lower documentary volume associated with farms that were constructed longest ago (for example, SEIA was established in 1997), this assessment considers the present system of habitat management for these farms in Chile.

The foundation for the environmental regulations is Law 19.300 of 1994, "General Bases of the Environment" (Ley Sobre Bases Generales del Medio Ambiente), in addition to Law 18.892 of 1989, "General Law of Fisheries and Aquaculture" (Ley General de Pesca y Acuicultura, which was consolidated by Decree 430 in 1992). An older law 458 of 1976, "General Law on Urban Planning and Construction," may also apply.

More recently, Supreme Decree No. 95/2001, "Regulation of the Environmental Impact Assessment System," is important to the permitting process, in addition to Supreme Decree No. 320/2001, "Environmental Regulation for Aquaculture" (Reglamento Ambiental para la Acuicultura), and its accompanying resolution No. 404 of 2003. In practice, the output of these processes is Sectoral Environmental Permits (Permiso Ambiental Sectorial—PAS).

Currently, SEA is the dominant authority; it is described as: "an environmental management instrument for the evaluation and prediction of environmental impacts that may be generated by projects and activities carried out in the country and that, according to the law, are required to be evaluated."[38] There are two methods of evaluating environmental impacts: an Environmental Impact Study (Estudio de Impacto Ambiental—EIA) and an Environmental Impact Statement (Declaración de Impacto Ambiental—DIA). The more comprehensive EIA is

[37] This needs to be an integer in the Seafood Watch Aquaculture Standard, and is therefore rounded to 8 out of 10.
[38] https://www.chileatiende.gob.cl/fichas/2638-estudio-de-impacto-ambiental-eia-y-declaracion-de-impacto-ambiental-dia

required if any of the conditions specified in Law 19.300 of1994, “General Bases of the Environment,” are triggered. These include concerns relating to the Risk to health of population (Article 5), Adverse effect on renewable natural resources (Article 6), Resettlement of human communities, or significant alteration of the systems of life and customs of human groups (Article 7), Location and environmental value of the territory (Article 8), Landscape or tourist value (Article 9), or Alteration of cultural heritage (Article 10). If a project does not trigger these concerns, then a DIA is required instead.

As can be seen in the documentary evidence for the raceway trout farms in SEIA, the DIA involves one or more independent assessments of different aspects of the project (in addition to the DIA itself); for example, an “agrological report” (Informe Agrologico; covering site geology, geomorphology, soil types, climate, drainage, vegetation), a water test report (Informe de Ensayo de Agua), hydrological surveys (Estudio Hidrológico e Hidráulico), a habitat/tree-density study, and various contingency plans for different aspects of production (Plan de Contingencias Ante Emergencias). Other specific activities also may require permits, such as moving rock for flood defenses (Sectorial Environmental Permit 106), or altering native trees (Sectorial Environmental Permit 102).

What is not immediately clear from these farm-level processes is the consideration of potential cumulative impacts from multiple aquaculture facilities, and/or cumulative impacts with other industries such as agriculture. But, it is clear from the search and mapping function in the SNIFA database that the 54 aquaculture facilities in Los Rios region—in particular, the 5 farms that are under the scope of this assessment (Figure 11; blue arrows)—are dispersed and have limited to no potential to interact with each other from a habitat connectivity or fragmentation perspective.

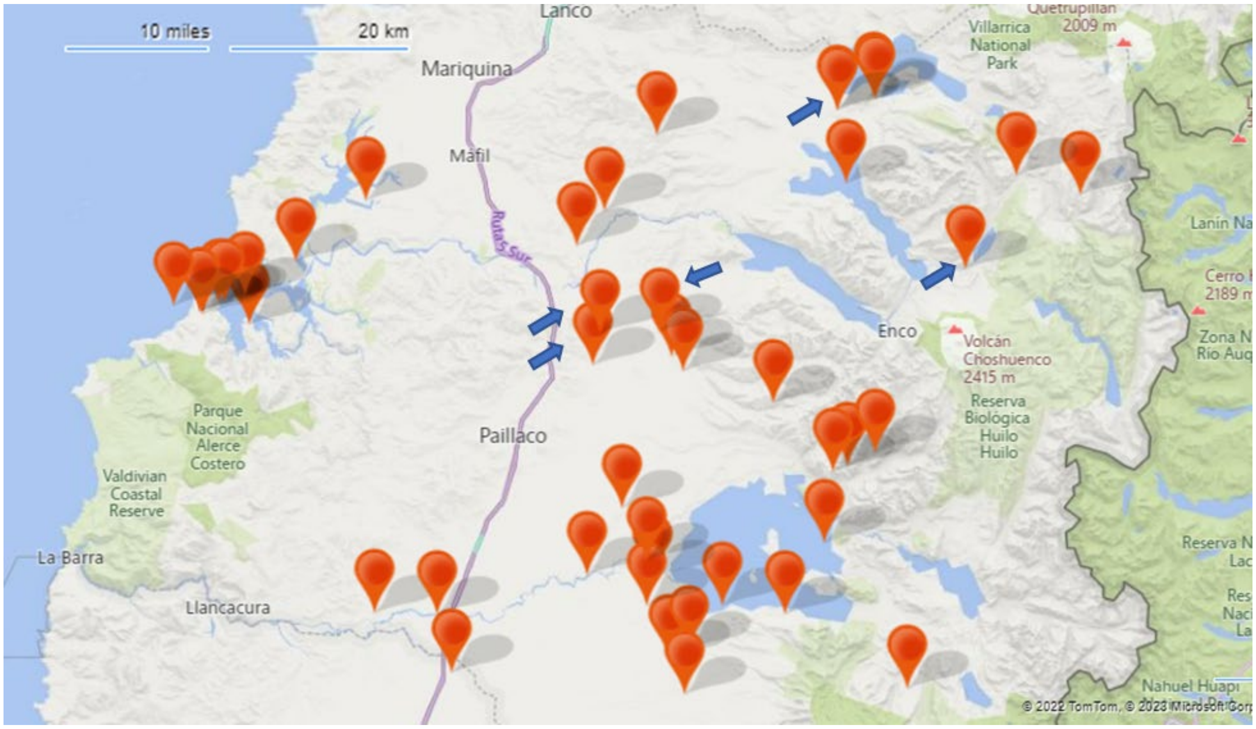

Figure 11: Map of all aquaculture facilities in Los Rios Region of Chile (for all species, and all types of production system). The five freshwater raceway farms of Piscicola Entre Rios are shown with blue arrows. Note that the large size of the markers imply a closer proximity between farms than in reality; see the scale in the top left corner. Map reproduced from SNIFA.

As noted in Factor 3.1, the farms are primarily located in agricultural and forestry landscapes, so the potential for cumulative habitat impacts with these industries is somewhat inherent in the planning and permitting process of potential new or altered aquaculture activities. If the raceway trout industry were to expand, it would likely utilize existing land-based freshwater facilities that are no longer used for the freshwater stage of the larger marine grow-out industry, with no further habitat impacts. Overall, the regulatory oversight of farms built earlier was limited, but the present system (for the past 20 years) has a robust set of regulations for the assessment of the risk of habitat impacts from new or modified raceway trout farms. It appears to be inherently integrated with the primary agricultural and forestry industries in the region. Thus, the score for Factor 3.2a is 5 out of 5.

Factor 3.2b: Enforcement of habitat management measures

The primary enforcement body for the regulations described in Factor 3.1a is the Superintendencia del Medio Ambiente (Superintendence of the Environment—SMA).[39] According to their website, the SMA is exclusively responsible for executing, organizing, and coordinating the monitoring and supervision of the Environmental Qualification Resolutions (note that this resolution, or RCA, is the final permission required to begin any new construction or modification to farms or other facilities). As noted previously, the SEIA

[39] https://portal.sma.gob.cl/

database, operated by SMA and SEA, provides a public record of the SMA's activities regarding the review of applications and eventual granting of an RCA.

Although it has been noted that farms built before the establishment of the SEIA (in 1997) have much less documentary evidence and monitoring requirements, farms built or modified since then have considerable documentation. It is clear from the level of detail and scrutiny in these documents (e.g., repeated requests for further information or additional assessments) that the enforcement system is effective. In addition to SEIA, the SNIFA database provides all the information relating to any monitoring requirements stipulated in the RCA. For example, for the more recently constructed or expanded raceway trout farms, these include various water-quality parameters (as discussed in Criterion 2—Effluent), in addition to annual surveys of aquatic habitats and fauna. The SNIFA also includes all documentary evidence relating to any infringements, sanctions, penalties, or compliance programs.

Overall, the abundant publicly available documentary evidence indicates that the enforcement process is effective and highly transparent. The score for Factor 3.2b is 5 out of 5. When combined with the Factor 3.2a score of 5 out of 5, the final Factor 3.2 score is 10 out of 10, demonstrating a highly effective habitat management system for freshwater raceway trout farms in Chile.

Conclusions and Final Score

Freshwater raceway trout farms in Chile have a small total footprint and operate primarily in a mixed landscape of agriculture and forestry. Nevertheless, somewhat by necessity, the farms are also located in riparian locations near their water supply, and some impacts to these habitats are inevitable with farm construction. Using the examples of the five farms of Piscicola Entre Rios, the score for Factor 3.1—Habitat Conversion and Function is 8 out of 10. The earlier farm constructions may have had less regulatory oversight, but for the past 20 years, there has been a substantial regulatory system in place with transparent regulations. There is also a highly transparent enforcement process through the Superintendence of the Environment (SMA), the Environmental Impact Assessment System (SEIA), and the National Information System for Environmental Control (Sistema Nacional de Información de Fiscalización Ambiental—SNIFA). If the raceway trout industry were to expand, it would likely utilize existing land-based freshwater facilities that are no longer used for the freshwater stage of the larger marine salmonid grow-out industry, with minimal further habitat impacts. With a comprehensive and transparent system in place, the score for Factor 3.2—Farm Siting Regulation and Management is 10 out of 10. Overall, although there are considered to have been some impacts to riparian habitats, the farms have primarily been converted from agricultural land, and because of their small size and effective regulatory system, Factors 3.1 and 3.2 combine to give a final score for Criterion 3—Habitat of 8.67 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary

C4 Chemical Use parameters		Score
C4 Chemical Use Score (0–10)		**10.0**
Critical?	No	Green

Brief Summary

Of the 463.4 mt of antimicrobials used in salmonid aquaculture in Chile in 2021, 1.26% or 5.84 mt were used in freshwater facilities (for any species). Data provided by Piscicola Entre Rios showed that no antimicrobials were used in their five farms during 2021–22, with a last application in September 2020. The data provided showed that antimicrobials were used at up to 33.3 g/mt of production (compared to 138 g/mt for rainbow trout in marine net pens in the neighboring Region X), but after a change of management practices to stock larger fingerlings in the on-growing raceways, the antimicrobial use declined to zero. Occasional salt baths are the only other treatment used. The aquatic faunal surveys at locations both upstream and downstream of the farms show that the rivers are not significantly affected in abundance or diversity by the discharges of salts or nutrients, or by other activities of the farms. The final numerical score for Criterion 4—Chemical Use is 10 out of 10.

Justification of Rating

Antimicrobials

SERNAPESCA produces semiannual and annual reports on the use of antimicrobials in aquaculture in Chile. At the time of writing this report (March 2023), antimicrobial reports are available for 2021 and the first half of 2022 (SERNAPESCA, 2022a,b). These reports show that nearly all antimicrobial use in salmonid aquaculture in Chile occurs in seawater aquaculture sites. Of the 463.4 mt of antimicrobials used in 2021, 1.26% or 5.84 mt were used in freshwater. In the first half of 2022, the 4.6 mt used in freshwater represented a considerable increase on the 2.76 mt during the same period in 2021. In 2021, two-thirds of the antimicrobials used (by weight) in freshwater were oxytetracycline, and almost one-third were florfenicol.

Of the antimicrobial use in freshwater, 12.81% (0.75 mt) were used for rainbow trout in 2021, and 7.61% (0.35 mt) in the first half of 2022.[40] But, it is not possible to further differentiate these values between the freshwater hatchery production of rainbow trout for grow-out in marine farms versus the freshwater raceway production of pan-sized fish for harvest. With the concentration of the five farms of Piscicola Entre Rios in Los Rios Region, it is of interest to note that, of the total antimicrobials used in Chile in 2021, 14.89% were used in Los Rios Region (47% were used in Los Lagos region). According to SNIFA, there are 54 "auditable units" (Unidades Fiscalizables) for all farmed species in Los Rios Region, of which 5 belong to Piscicola Entre Rios.

These data from SERNAPESCA in no way specify the level of antimicrobial use in freshwater raceway rainbow trout farms, but as a starting point, they indicate that the use is likely to be relatively low. Detailed antimicrobial records from the five farms of Piscicola Entre Rios were provided for 2018 to 2022, and were available for 2016 to 2022 from one farm (pers. comm., Juan Villasante, Piscicola Entre Rios February, 2023). At the time of writing this report (March 2023), the last use of antimicrobials at any of the farms was September 2020. The records included the number of prescriptions, prescription reference numbers, active ingredients, and the relative use in g/mt. Any use of antimicrobials must be prescribed by a veterinarian (Prescripción Médico Veterinaria—PMV), and an example of a prescription was provided (see Appendix 1); the prescriptions are provided to the feed mill to allow the purchase of a medicated feed. During the 2016 to 2022 period, there was a single treatment with oxytetracycline, and all other prescriptions were for florfenicol.

Figure 12 shows a decline in antimicrobial use from a peak of 33.3 g/mt in 2018 to zero in 2021. The decline is due to a company decision to transition to antimicrobial-free production, and this has mostly been achieved by stocking larger fingerlings in the grow-out raceways (15 g, as opposed to approximately 5 g previously), which are substantially more resistant to the Flavobacterium pathogen (see Criterion 7—Disease). It is also noted here that the additional freshwater rainbow trout producer in Chile (operated by Food for Future), which was identified in an internet search, states that it operates without antimicrobials.[41]

[40] In 2021, 67.74% of the antibiotics used in freshwater aquaculture were administered to Atlantic salmon, and 19.29% to coho salmon. The remaining 0.16% was used for Chinook salmon.
[41] https://truchacircular.cl

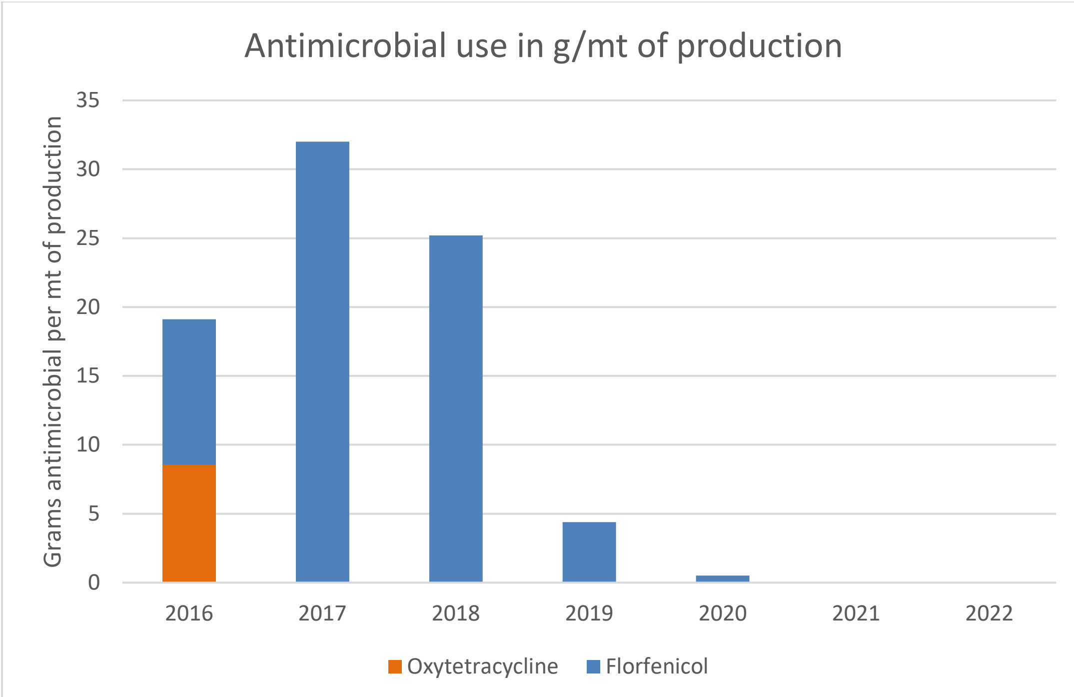

Figure 12: Average relative antimicrobial use in g/mt from five freshwater raceway trout farms in Chile. None of the farms have used antimicrobials since September 2020. Data and prescription numbers provided by Piscicola Entre Rios.

Referring to the SERNAPESCA data, the peak relative use in the Piscicola Entre Rios data of 33.3 g/mt is substantially lower than the average 138 g/mt used for rainbow trout in marine net pen farms in the neighboring region of Los Lagos (Region X) in 2021 (the most recent data available from SERNAPESCA). The typical length of the complete rainbow trout production cycle from egg to a harvest size of 500 g takes approximately 6 to 8 months (depending on temperature) (FAO 2020), so it can be seen that the Chilean freshwater raceway trout farms have not used antimicrobials for multiple production cycles (i.e., since the last treatment in September 2020).

<u>Pesticides</u>

According to Piscicola Entre Rios, salt is the only other chemical used in freshwater raceway trout farms as a simple treatment for external parasites and fungi [salt helps to reduce the risk of bacterial and fungi infections after handling, and is an effective and safe product to control some external parasites (Kubitza 2016a,b)(pers. comm., Juan Villasante, Piscicola Entre Rios February 2023)]. Typically, a bath of 20–30 ppt of salt for 10–30 minutes can be used to treat some gill and skin parasites, bacterial diseases such as Flavobacterium, or fungi (see Criterion 7—Disease) (Kubitza, 2016a). Fish are typically treated in a reduced volume of water by crowding in part of the raceway; nevertheless, Kubitza (2016a,b) notes that, despite the reduced volume, the discharge of salted water is an issue that farmers need to consider when using salt in freshwater aquaculture. Incar (2020), referencing Kamjunke et al. (2017) and Figueroa et al. (2017), noted that the use of high volumes of sodium chloride in sea salt format for the prevention and control of bacterial infections such as flavobacteriosis can result in an impact on the abundance of micro- and macro-organisms present in the bottoms and water of the river.

Chloride is 1 of the 37 parameters measured weekly in the effluent at the farms; however, it is noted that these sampling events may not coincide with any saltwater discharges. But, annual and biannual aquatic fauna surveys available (from SNIFA) for two freshwater raceway trout farms in Chile show that the aquatic fauna community sampled at locations both upstream and downstream of the farm are not significantly affected in abundance or diversity by the discharges of salts or nutrients, or by other activities of the farms.

Conclusions and Final Score

Of the 463.4 mt of antimicrobials used in salmonid aquaculture in Chile in 2021, 1.26% or 5.84 mt were used in freshwater facilities (for any species). Data provided by Piscicola Entre Rios showed that no antimicrobials were used in their five farms during 2021–22, with a last application in September 2020. The data provided showed that antimicrobials were used at up to 33.3 g/mt of production (compared to 138 g/mt for rainbow trout in marine net pens in the neighboring Region X), but after a change of management practices to stock larger fingerlings in the on-growing raceways, the antimicrobial use declined to zero. Occasional salt baths are the only other treatment used. The aquatic faunal surveys at locations both upstream and downstream of the farms show that the rivers are not significantly affected in abundance or diversity by the discharges of salts or nutrients, or by other activities of the farms. The final numerical score for Criterion 4—Chemical Use is 10 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

C5 Feed parameters	Value	Score
F5.1a Forage Fish Efficiency Ratio	1.34	
F5.1b Source fishery sustainability score (0–10)		3
F5.1: Wild fish use score (0–10)		2.35
F5.2a Protein INPUT (kg/100 kg fish harvested)	43.07	
F5.2b Protein OUT (kg/100 kg fish harvested)	15.70	
F5.2: Net Protein Gain or Loss (%)	–63.54	3.00
F5.3: Species-specific kg CO_2-eq kg^{-1} farmed seafood protein	14.23	6.00
C5 Feed Final Score (0–10)		**3.43**
Critical?	No	Yellow

Brief Summary

A substantial amount of feed data was made available by two feed companies in Chile, and was used anonymously on request. In addition, detailed feeding records were provided for the five farms of Piscicola Entre Rios. Nevertheless, some estimation of the nonmarine ingredient inclusion levels was needed, based on an academic review of rainbow trout nutrition. The feeding records showed that the economic feed conversion ratio in 2022 was 0.99, and with moderate levels of fishmeal and fish oil, the Forage Fish Efficiency Ratio was 1.34. This means that, from first principles, 1.34 mt of wild fish would need to be caught to provide the oil in the feed used to grow 1 mt of farmed rainbow trout. Most of the fishery sources for marine ingredients used by one feed company were certified to the Marin Trust, but there was some uncertainty about the second feed company (score of 2.35 out of 10 for Factor 5.1). With an average feed protein content of 43.5%, and a whole-body protein content of harvested rainbow trout of 15.7%, there is a net protein loss of 63.5% (score of 3 out of 10 for Factor 5.2). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 14.23 kg CO_2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for Criterion 5—Feed of 3.43 out of 10 (see the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations).

Justification of Rating

The specific ingredients used in aquaculture feeds, and particularly their inclusion levels in each feed, are seldom readily available because feed producers consider this information proprietary (Boyd et al. 2021). Two feed companies that produce grow-out feeds for freshwater rainbow trout provided data through Piscicola Entre Rios. For reasons of anonymity, these data have been aggregated and used as necessary in the following calculations; i.e., without attribution to any one feed company. The data included a list of feed ingredients used, and the inclusion levels and sources of the marine ingredients (fishmeal and fish oil).

For the nonmarine ingredients, the generalized feed formulation for rainbow trout in Kamalan et al. (2020)[42] closely matches the ingredient lists provided by the two feed companies. Therefore, in the absence of specific inclusion levels for nonmarine ingredients from the two feed companies, the levels in Kamalan et al. (2020) have been used to approximate a best-fit feed total formulation (Table 2).

The dominant producer, Piscicola Entre Rios, also provided a detailed breakdown of the type, size, and quantity of feeds used for the most recent full data year of 2022.[43] In that year, feeds from the two companies were used in a ratio of 61.7% to 38.3%. In addition, different sizes of feed are used in different quantities during the production cycle; i.e., small amounts of starter feeds are used while the bulk of growth is accounted for in the larger feed sizes. As discussed in the following relevant factors, some parameters such as the protein content vary by feed size. Therefore, with a total of 28 discrete feed types or sizes used, weighted averages were used wherever possible (weighted by the amount of each feed type and size in 2022), to most accurately account for the different types and sizes of feed from the two feed companies (see Appendix 3 of the Seafood Watch Standard for Aquaculture for more details).

It is noted here that a characteristic of the Food For Future freshwater rainbow trout producer in Chile is the use of insect meal-based ingredients in their feeds. Specific details were not readily available, and the production volume is currently small, so this assessment is based on the feeds of the dominant producer.

Table 2: Best-fit feed formulation based on marine ingredient inclusion levels from two feed companies in Chile, lists of nonmarine ingredients, and the general rainbow trout formulation from Kamalan et al., (2020).

Ingredient	Aggregated or estimated inclusion level (%)

[42] Kamalan et al. (2020) provided a review of the "Nutrition and Feeding of Rainbow Trout (*Oncorhynchus mykiss*)."
[43] The company Piscicola Entre Rios plans to use feed from only one company in 2023, but the analysis here has been conducted using the last full data year of 2022.

Fishmeal (from whole fish)	7.0
Fishmeal (from by-products)	2.3
Fish oil (from whole fish)	6.8
Fish oil (from by-products)	0.2
Soy protein concentrate	12.0
Soy meal	5.0
Soy lecithin	1.0
Wheat flour	17.0
Wheat gluten	10.0
Sunflower oil	12.0
Poultry meal	6.0
Feather meal	7.0
Pork meal	5.0
Blood meal	4.0
Vitamins and minerals/other	4.7
Total	**100.0**

Economic feed conversion ratio (eFCR)

The eFCR (calculated by dividing the total feed use by the total harvest) is an important parameter in this assessment. Using the 2022 total feed data and the total harvest from the five farms of Piscicola Entre Rios (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023), an economic feed conversion ratio of 0.99 was calculated. This is at the lower end of the typical range of eFCRs of 1.0 to 2.0 for rainbow trout (in different production systems) in Fry et al. (2018).

Factor 5.1: Wild Fish Use

Factor 5.1 combines an estimate of the quantity of wild fish used to produce farmed rainbow trout with a measure of the sustainability of the source fisheries.

Factor 5.1a: Feed Fish Efficiency Ratio (FFER)

The inclusion levels of fishmeal and fish oil from whole fish and from by-products were provided by two feed companies. Table 3 shows the weighted average values (weighted by the quantity of feed used from each company in 2022; see Appendix 3 of the Seafood Watch Standard for Aquaculture for more details). By using the standard yield values for fishmeal and fish oil from wild fish [22.5% and 5%, respectively, from Tacon and Metian (2008)], in addition to the eFCR of 0.99, the FFER values of 0.31 for fishmeal and 1.34 for fish oil can be calculated. This means that, from first principles, 1.34 mt of wild fish would need to be caught to provide the oil in the feed used to grow 1 mt of farmed rainbow trout.

Table 3: Fishmeal and fish oil inclusion levels from whole fish and by-product sources (weighted averages across the two feed companies for 2022), eFCR values, and calculated FFER values for rainbow trout in raceways.

Parameter	Data

Fishmeal inclusion level (total)	9.3%
Fishmeal inclusion level from whole fish	7.0%
Fishmeal inclusion level from by-product[44]	2.3%
Fishmeal yield	22.5%
Fish oil inclusion level (total)	7.0%
Fish oil inclusion level from whole fish	6.8%
Fish oil inclusion level from by-product[45]	0.2%
Fish oil yield	5.0%
Economic Feed Conversion Ratio	**0.99**
FFER fish meal	0.31
FFER fish oil	1.34
Assessed FFER	**1.34**

Factor 5.1b: Sustainability of the Source of Wild Fish

Both feed companies provided information on the sourcing of marine ingredients, including some countries of origin, but it was not sufficient to define specific species and fisheries. One company provided information on the certifications of the source fisheries, which can be used to inform the scoring for this factor. It is considered here that articulating the participation (or lack thereof) of the feed companies in the Ocean Disclosure Project would breach the conditions of anonymity. In addition, the data available in the ODP are global in nature, and with the dominance within the companies of salmon feed production in the Northern Hemisphere, the fishery sources reported at the global scale are likely to have limited relevance to freshwater trout feeds in Chile. Thus, ODP data have not been used here.

The certification data showed that the majority of fish meal and fish oil (95.1% and 72.3%, respectively) were certified by the Marin Trust[46] in 2021–22 (score 4 out of 10 for Factor 5.1b). Small amounts were certified to the Marine Stewardship Council[47] (score 6 out of 10 for Factor 5.1b) or in a Marin Trust improvement project (score 4 out of 10 for Factor 5.1b). The remainder (4.4% of fish meal and 20.2% of fish oil) were uncertified, and no source fishery information was available for this fraction (score 0 out of 10 for unknown source fishery). Overall, these sources generate a weighted average score of 3.8 out of 10 for fishmeal, and 3.3 out of 10 for fish oil (see Appendix 3 of the Seafood Watch Standard for Aquaculture for further details). Given the uncertainty in the sources of the other feed company, these are rounded down to a score of 3 out of 10 for Factor 5.1b, which is considered to reflect the limited transparency in the sourcing of marine ingredients from both companies in a precautionary manner.

[44] Note that 5% of the by-product fishmeal inclusion (i.e., inclusion level x 0.05) is included in the FFER calculations.
[45] Note that 5% of the by-product fish oil inclusion (i.e., inclusion level x 0.05) is included in the FFER calculations.
[46] https://www.marin-trust.com/
[47] https://www.msc.org

Therefore, the score for Factor 5.1b—Sustainability of the Source of Wild Fish is 3 out of 10. When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1—Wild Fish Use score of 2.35 out of 10.

Factor 5.2: Net Protein Gain or Loss

Data on the total feed protein content provided by two feed companies show a range of protein contents across different types and sizes of feed, from 40% to 54%. Starter feeds (used in low quantities for small fish) have the highest protein levels compared to the larger grow-out feeds that represent the bulk of the total feed to harvest. These feed company data, combined with the detailed farm-level feeding records, allow the calculation of a weighted-average feed protein content for 2022 (across both feed companies and all feed sizes) of 43.5% (see Appendix 3 of the Seafood Watch Standard for Aquaculture for further details). This value is based on 98% of the feeds used in 2022 (the protein contents of 10 minor feeds from the total of 28 feed types or sizes were not provided). The calculated value of 43.5% protein content is well within the 40% to 50% range specified in the review of rainbow trout nutrition by Kamalan et al. (2020).

In a study of the body composition of rainbow trout, Dumas et al. (2007) reported a whole-body protein content of fish weighing <1,580 g of 15.7%. This is similar to the value of 15.6% reported by Boyd et al. (2007). The value 15.7% is used here. Table 4 shows that 1 mt of feed contains 435 kg of protein, and 0.99 mt of feed are used to produce 1.00 mt of farmed rainbow trout; therefore, the net protein input per mt of farmed rainbow trout production is 430.7 kg. With only 157 kg of protein in 1 mt of harvested whole rainbow trout, there is a net loss of 63.5% protein. This results in a score of 3 out of 10 for Factor 5.2.

Table 4: Values used to calculate net protein gain or loss.

Parameter	Data
Protein content of feed (%)	43.5
Protein content of whole harvested rainbow trout (%)	15.7
Economic Feed Conversion Ratio	0.99
Total protein INPUT per mt of farmed rainbow trout (kg)	430.7
Total protein OUTPUT per mt of farmed rainbow trout (kg)	157.0
Net protein gain or loss (%)	**–63.5% loss**
Seafood Watch Score (0–10)	3

Factor 5.3: Feed Footprint

This factor is an approximation of the embedded global warming potential (kg CO_2-eq, including land-use change [LUC]) of the feed ingredients required to grow 1 kilogram of farmed seafood protein. This calculation is performed by mapping the ingredient composition of a typical feed used against the Global Feed Lifecycle Institute (GFLI) database[48] to estimate the global

[48] http://globalfeedlca.org/gfli-database/gfli-database-tool/

warming potential (GWP) of 1 metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. To get a single value representative of all three feed types, a weighted average based on the percentage of feed use is then calculated. The detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Standard for Aquaculture.

Table 5 shows the ingredient categories selected from the GFLI database, according to the above methodology for ingredients of unknown origins. Because of the licensing agreement, the specific values for each ingredient from the GFLI database are not reproduced here, but the calculated value per mt of feed for each ingredient is shown.

Table 5: Estimated embedded global warming potential of 1 mt of tilapia feed used in Colombia. GFLI refers to the Global Feed Lifecycle Institute.

Ingredient	Ingredient listing in the GFLI Database	Inclusion %	kg CO_2-eq/ mt feed
Fishmeal	Fishmeal, from fishmeal and fish oil production, at plant/CL Economic S	9.2	119.88
Fish oil	Fish oil, from fishmeal and fish oil production, at plant/GLO Economic S Fish oil, from fishmeal and oil production, at plant/PE Economic S	7.0	55.26
Soy protein concentrate	Soybean protein concentrate, from crushing (solvent, for protein concentrate), at plant/GLO Economic S Soybean protein concentrate, from crushing (solvent, for protein concentrate), at plant/AR Economic S	12.0	770.02
Soybean meal	Soybean expeller, from crushing (pressing), at plant/GLO Economic S Soybean expeller, from crushing (pressing), at plant/AR Economic S	6.0	234.89
Poultry meal*	Animal meal, poultry, from dry rendering, at plant/RER Economic S	6.0	74.00
Blood meal	No data in GFLI database	4.0	0.0
Feather meal	Maize gluten meal, from wet milling (gluten drying), at plant/GLO Economic S	7.0	82.64
Wheat	Wheat flour, from dry milling, at plant/GLO Economic S Wheat flour, from dry milling, at plant/ES Economic S	17.0	132.82
Wheat gluten	Wheat gluten feed, from wet milling, at plant/GLO Economic S Wheat gluten feed, from wet milling, at plant/ES Economic S	10.0	82.64
Pork meal*	Animal meal, pig, from dry rendering, at plant/RER Economic S	5.0	32.84
Vegetable oil	Crude vegetable oil blend, from crushing, at plant/GLO Economic Crude vegetable oil blend, from crushing, at plant/RER Economic	12.0	605.12

Vitamins, minerals*	Total minerals, additives, vitamins, at plant/RER Economic S	4.7	55.82
Total		**100.0**	**2,245.80**

* These ingredients are a single line item in the GFLI database and therefore not averaged.

The total estimated embedded GWP of 1 mt of raceway rainbow trout feed is 2,245.8 kg CO_2-eq. Considering a whole harvested farmed rainbow trout protein content of 15.7% (from Factor 5.2) and an eFCR of 0.99, it is estimated that the feed-related GWP of 1 kg farmed salmon protein is 14.23 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

A substantial amount of feed data was made available by two feed companies in Chile, and was used anonymously on request. In addition, detailed feeding records were provided for the five farms of Piscicola Entre Rios. Nevertheless, some estimation of the nonmarine ingredient inclusion levels was needed, based on an academic review of rainbow trout nutrition. The feeding records showed that the economic feed conversion ratio in 2022 was 0.99, and with moderate levels of fishmeal and fish oil, the Forage Fish Efficiency Ratio was 1.34. This means that, from first principles, 1.34 mt of wild fish would need to be caught to provide the oil in the feed used to grow 1 mt of farmed rainbow trout. Most of the fishery sources for marine ingredients used by one feed company were certified to the Marin Trust, but there was some uncertainty about the second feed company (score of 2.35 out of 10 for Factor 5.1). With an average feed protein content of 43.5%, and a whole-body protein content of harvested rainbow trout of 15.7%, there is a net protein loss of 63.5% (score of 3 out of 10 for Factor 5.2). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 14.23 kg CO_2-eq kg^{-1} farmed seafood protein (score of 6 out of 10). The three scores combine to give a final score for Criterion 5—Feed of 3.43 out of 10 (see the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations).

Criterion 6: Escapes

Impact, unit of sustainability and principle

- Impact: competition, genetic loss, predation, habitat damage , spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations
- Sustainability unit: affected ecosystems and/or associated wild populations.
- Principle: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

C6 Escape parameters		Value	Score
F6.1 System escape risk (0–10)		7	
F6.1 Recapture adjustment (0–10)		0	
F6.1 Final escape risk score (0–10)			7
F6.2 Invasiveness score (0–10)			4
C6 Escape Final Score (0–10)			**5**
	Critical?	No	Yellow

Brief Summary

Raceway farms have a high-flow throughput of water, so they have an inherent risk of escape. Nevertheless, the constrained physical structure also provides opportunities for multiple escape prevention measures. No escapes have been reported from freshwater raceway trout farms, and government data show that there have been no reported escapes of rainbow trout in Los Rios or Araucanía Regions since at least 2011. Annual aquatic surveys at two freshwater raceway rainbow trout farms from 2013 to 2022 show only a single detection of a rainbow trout in 2015. Nevertheless, the Fisheries Development Institute (IFOP) shows that rainbow trout represent 29.1% of the fish caught in annual sampling of wild, feral, and escaped fish in rivers and lakes in Los Rio Region (and 24.0% in Araucanía). A genetic analysis (by IFOP) shows that the majority of rainbow trout captured in the Araucanía region are farm escapees, as opposed to wild-spawned feral fish. Nevertheless, because of the presence of large numbers of freshwater rainbow trout facilities in Araucanía growing fingerlings and smolts for on-growing in marine net pens, in addition to the widespread establishment of the species from historical stocking, none of the fish detected in the wild can be attributed to escapes from freshwater raceway grow-out farms in Los Rios Region (or elsewhere) covered by this assessment. With multiple escape barriers, and no apparent escapes for >10 years, the escape risk score (Factor 6.1) is 7 out of 10.

Although rainbow trout became ecologically established in Chile before aquaculture began, it is considered that escapes from farms have aided the high establishment success and rapid expansion of the species' range. There is contradicting evidence on the potential impacts of escaped rainbow trout on native ecosystems and their biodiversity, and some difficulty in attributing impacts to any one of the several nonnative salmonid species present in Chile. Nonetheless, if there were to be an escape from a freshwater raceway trout farm, then competition, predation, and impacts to wild species, habitats, or ecosystems may occur, although this would be unlikely to affect the population status of wild species. Thus, the score for Factor 6.2—Invasiveness is 4 out of 10. Factors 6.1 and 6.2 combine to give a final score of 5 out of 10 for Criterion 6—Escapes.

Justification of Rating

Factor 6.1: Escape Risk

Raceway farms have a high-flow throughput of water (e.g., the Llallalca farm has a maximum permitted flow rate of 1,700 l/s)[49] and a high density of fish (the same farm specifies a maximum fish density of 60 kg/m^3). Therefore, they have an inherent risk of escape; nevertheless, the constrained physical structures of the farms also provide multiple opportunities to place escape prevention measures. For example, the farms operated by Piscicola Entre Rios have nets at the end of each raceway (mesh size varies from 3 mm to 20 mm depending on the size of the fish), plus a grid barrier before and after the settling ponds (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023). There is also a mesh barrier at the upstream water intake. In addition to this description by the farm owners, these aspects are laid out in contingency plans for escapes[50] in the documentary evidence supporting applications for the construction or expansion of farms in the SEIA database and can be seen in annotated technical drawings of the sites (Figure 13). It must be noted that the correct sizing and maintenance of these devices is critical to their effectiveness. Detailed data on fish stocking, mortality, and harvest numbers are also available from the farms.

[49] Reported in the 2015 Resolucion de Calificación Ambiental (RCA) document for Piscicola Llallalca, available from SNIFA - SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)
[50] Microsoft Word - Plan de Contingencia _listo_.doc (e-seia.cl)

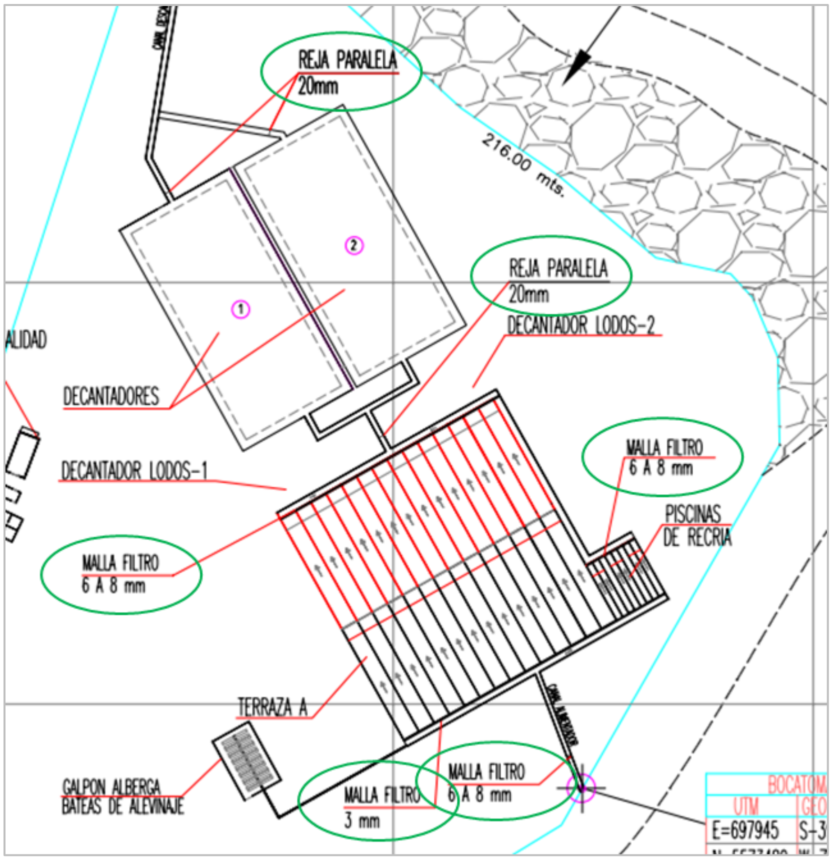

Figure 13: Example of escape prevention measures (circled in green) at a freshwater raceway trout farm (Huite farm) in Chile. These include mesh filters (malla filtro) and parallel grid barriers (reja paralela). Image reproduced from SEIA database.[51]

Because of the riparian locations of the farms, there is considered to be an inherent risk of flooding, and therefore an associated risk of escape. Flooding is common due to heavy rains in southern-central Chile during the austral winter.[52] This has been a factor in the design and construction of the farms; for example, documents associated with the DIA (Declaración de Impacto Ambiental) for the Huite farm show that the SEA requested a detailed hydrological study to account for the areas affected by flooding for a range of extreme flow rates in the Pichico River. All the hydrological survey documents and extensive calculations can be found in the SEIA database,[53] and the constructed barrier can be seen (in green) in Figure 14. It is also visible in satellite images (e.g., Google Earth). The remaining farms of Piscicola Entre Rios have some type of constructed barrier to protect the vulnerable parts of the farms, except for Llallalca, which is naturally protected (pers. comm., Juan Villasante, Piscicola Entre Rios February 2023). Despite the regional floods, none of the farms have experienced any flooding

[51] https://seia.sea.gob.cl/archivos/20071123.155249.pdf
[52] https://floodlist.com/tag/chile
[53] Estudio Hydrologico – available from https://seia.sea.gob.cl/documentos/documento.php?idDocumento=2522897

since they began operations between approximately 15 and 30 years ago (pers. comm., Juan Villasante, Piscicola Entre Rios January 25, 2023).

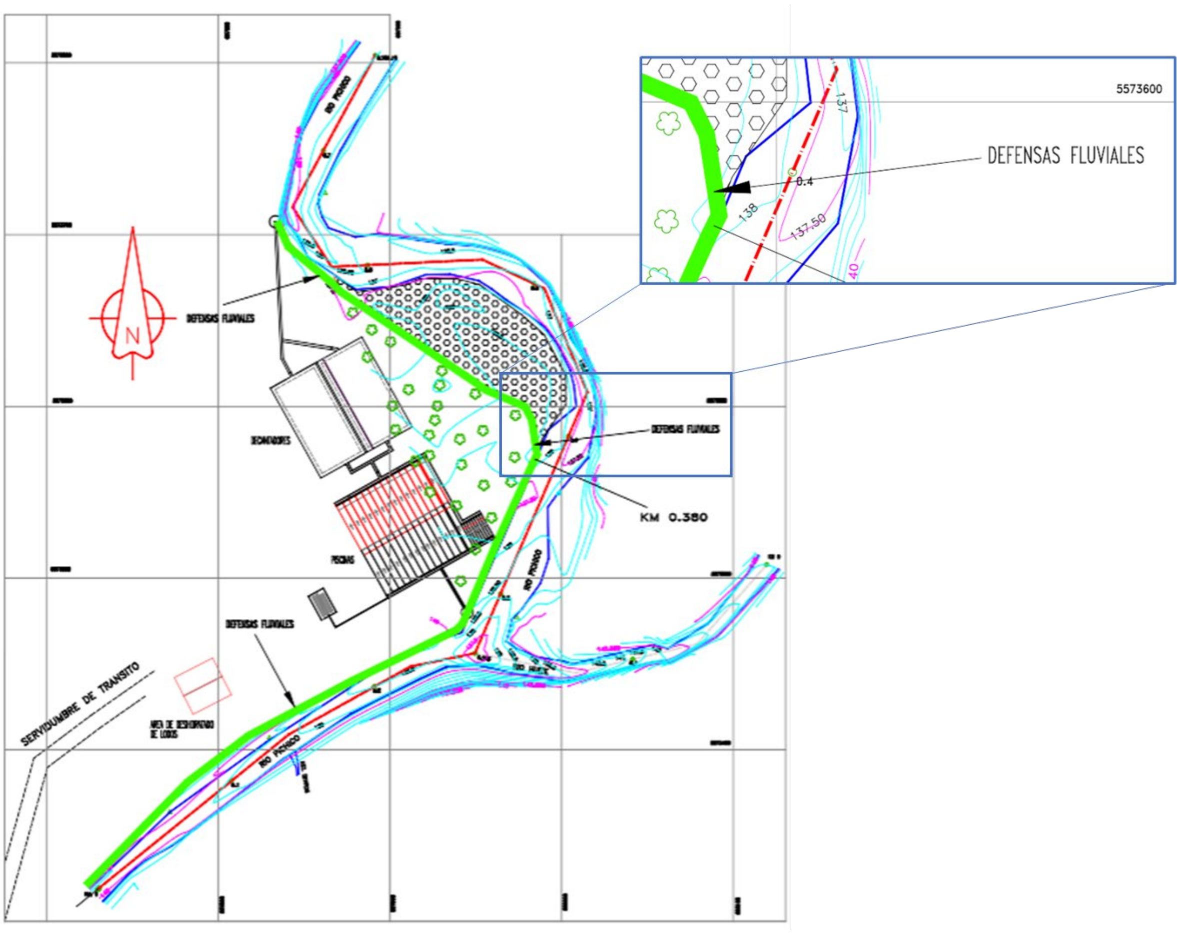

Figure 14: Farm plans of a freshwater raceway trout farm in Chile (Huite Farm), showing flood defense barriers (defensas fluviales) in green.

SERNAPESCA publishes escape data aggregated across salmonid species for the total reported escaped fish and the number of reported escape events.[54] These data, for the period 2010 to 2020 (accessed January 2023) show two escape events in Los Rios Region in 2010 (total of 110,317 fish) and two in 2014 (total of 22,446 fish). In an analysis of these escape statistics from 2013 to 2022, BCN (2022) notes that the 2014 escapes in Los Rios were of coho salmon (from a freshwater hatchery). The species escaping in Los Rios in 2010 is not specified. No escapes were reported from Los Rios Region from 2014 to January 2022 (the latest data available), nor were there any reports of escapes in the Araucanía Region from 2010 to 2022 (SERNAPESCA data and BCN 2022). It must be noted that, in addition to the reported escapes (typically large and easily detected events), undetected or unreported trickle losses may occur and 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; referring to net pen salmon farms).

[54] Escape de Peces de la Salmonicultura | Servicio Nacional de Pesca y Acuicultura (sernapesca.cl)

Demonstrating the escapes of fish from farms by detecting them in the wild is complicated by the fact that rainbow trout became established in southern Chile many decades before trout aquaculture began (discussed further in Factor 6.2). But, as suggested by Arismendi et al. (2014), the abundance of rainbow trout in the wild could be the product of the presence of specimens from past generations, in addition to any recent escapes from fish farms. Two freshwater trout farms (Llallalca and Huite) are required to conduct independent aquatic fauna surveys at locations upstream and downstream of the farms twice each year.[55] The survey results (documents are available from SNIFA, with the latest supplied by the farms) show that, although native galaxids and to a lesser extent brown trout (*Salmo trutta*) have been detected throughout the annual samplings, there has been only one detection of a single rainbow trout at Llallalca (in 2015, and not in any of the years 2016 to 2022), and none at the Huite farm (surveyed from 2013 to 2022).

The Fisheries Development Institute (Instituto de Fomento Pesquero—IFOP[56]) has conducted an annual "Evaluation and monitoring of the health situation of wild fish in freshwater and sea"[57] since 2010. This has involved the collection of 44,573 fish from a variety of freshwater and marine locations throughout southern Chile (IFOP 2023). Of interest here are the sampling locations closest to the freshwater trout farming operations in Los Rios Region. There are sampling locations in the following freshwater lakes: Lago Villarrica and Lago Colico in the Araucanía Region, and Lago Riñihue, Lago Panguipulli, and Lago Ranco in Los Ríos. Rainbow trout have commonly been the dominant species caught by IFOP in freshwater in Los Rios. In the 2021–22 sampling period, rainbow trout were 29.1% of all fish caught in Los Rios Region (in freshwater; see Figure 15), but this figure was 46.0% in the 2020–21 period. In Araucanía, 24.0% of the fish caught were rainbow trout during the 2021–22 sampling period. Note that, for clarity, Figure 15 does not include three specimens of perch trout (*Percichthys trucha*).

[55] These two farms requested to make modifications and increase production in 2015 and 2013, respectively. The approval (Resolución de Calificación Ambiental—Environmental Qualification Resolution) triggered the requirements for the twice-yearly aquatic surveys in these farms. The RCA documents and the aquatic survey reports are available from SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)
[56] https://www.ifop.cl/
[57] Evaluación y seguimiento de la situación sanitaria de peces silvestres en agua dulce y mar

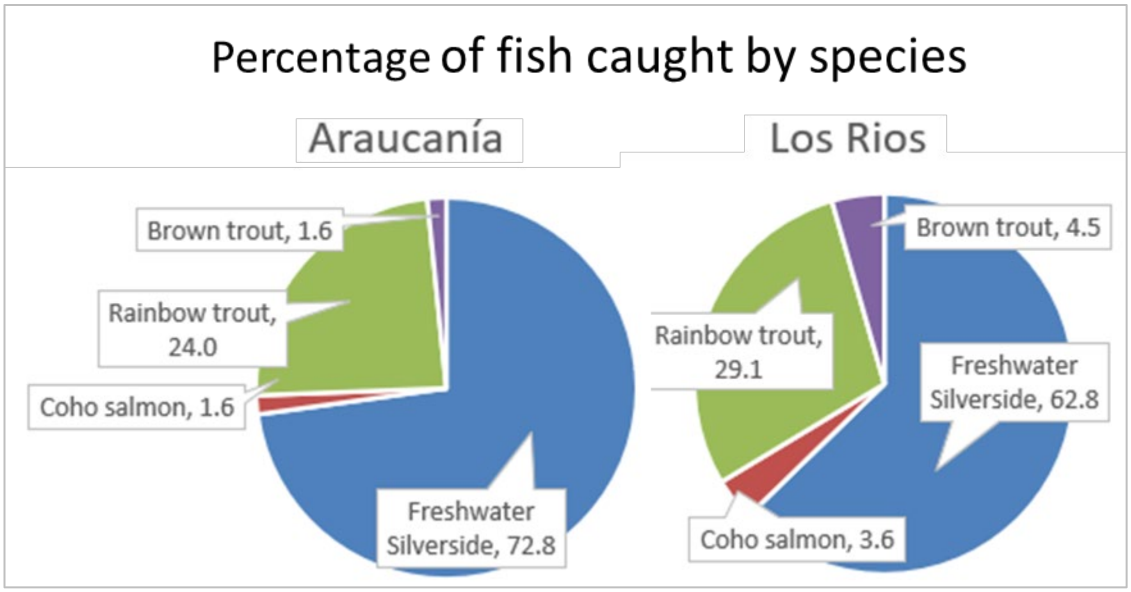

Figure 15: Percentage of species caught in IFOP sampling in freshwater in Araucanía and Los Rios Regions of Chile in 2021–22; brown trout—*Salmo trutta*; coho salmon—*Oncorhynchus kisutch*; freshwater silverside—*Basilichthys australis*. These graphs do not show the minor catch of three perch trout in Los Rios. The total number of fish represented in Araucanía = 125, and in Los Rios = 247. Data from IFOP (2021).

By visual inspections of skin color, visceral fat, maturity, stomach contents, damage, and parasites, all captured fish were classified as escaped, feral, or wild. For all rainbow trout captured throughout Chile (i.e., including regions other than Los Rios and Araucanía where salmon are farmed in marine net pens), 67.6% of the rainbow trout were classified as escaped, with the remaining 32.4% as feral (i.e., spawned in the wild).

In their 2018–19 sampling period, IFOP (2019) conducted a genetic analysis of the rainbow trout caught in the wild in four lakes in the Araucanía Region. Captured fish were assigned to either farm escapes (asignación a centros de cultivo) or wild-spawned and designated as the naturalized Araucanía population (asignación a poblaciónes Araucanía). The results show that the majority of rainbow trout captured were assigned to the farm escape group, and this was highest in the sampling locations in Lake Villarica, which also had the greatest density of nearby aquaculture locations (blue dots; Figure 16). Although these results indicate the importance of aquaculture escapes to the presence of rainbow trout in the wild in Chile, it is important to note that none of the raceway trout farms covered by this assessment are present in the sampling area covered by IFOP (the Huililco hatchery is in this area, but the grow-out farms are farther south in Los Rios Region). It is also of relevance to note again that, according to escape data from SERNAPESCA, there were no reported aquaculture escapes between 2010 and 2020 in the Araucanía Region.

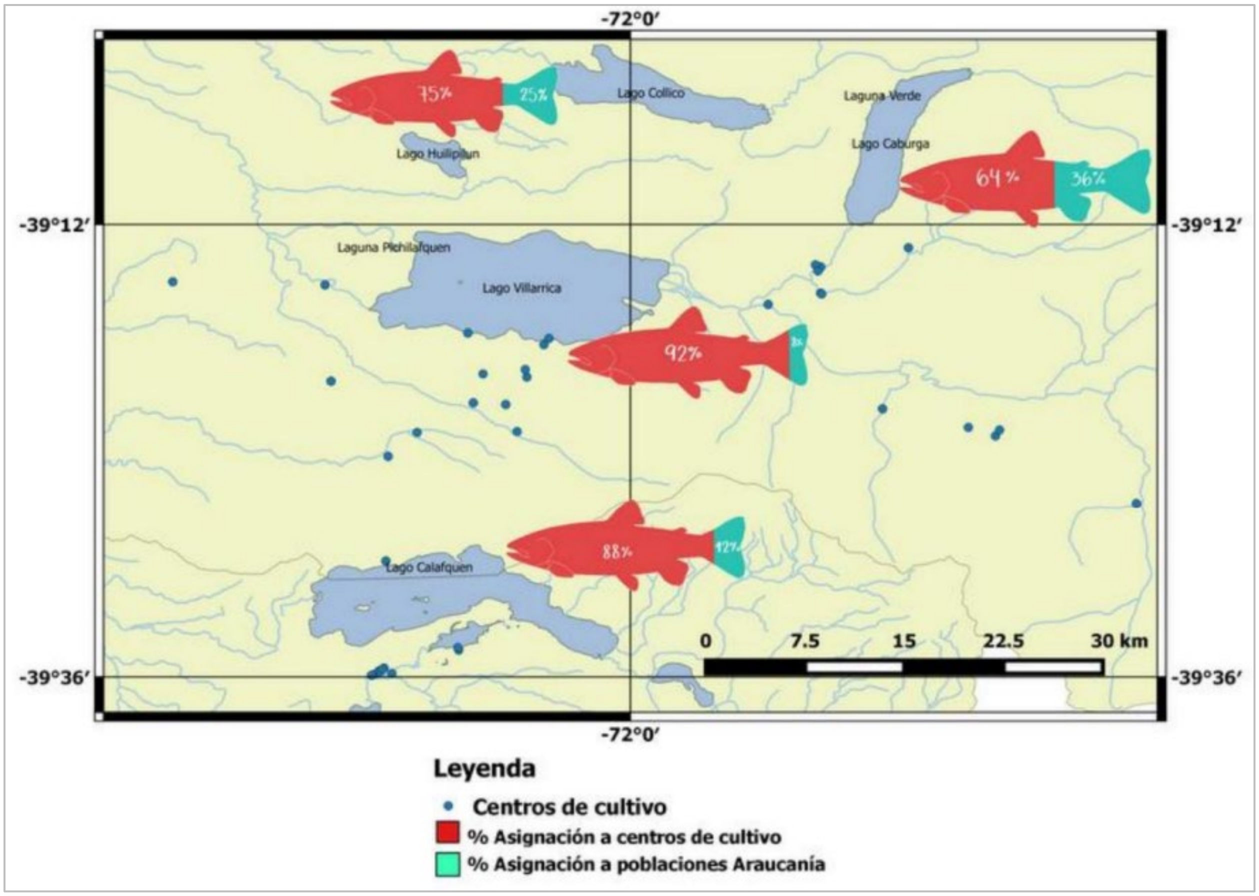

Figure 16: Genetic identification using branchial tissue of rainbow trout from four lakes in Araucanía (Region IX). Blue dots represent the geographic location of rainbow trout facilities (note: none of these facilities are covered by this assessment). Analyzed individuals were assigned to two reference groups: "centros de cultivo (Red)" = farm escape group, and "poblaciones Araucanía (green)" = feral from Araucanía. Map copied from IFOP (2019).

Regarding the detection of rainbow trout in the wild as a possible indicator of escapes from the raceway trout farms covered in this assessment, this example from IFOP in the Araucanía Region highlights the importance of escapes from the numerous freshwater facilities that produce rainbow trout for marine grow-out. Because of the widespread production of rainbow trout fingerlings and smolts in Los Rios and Araucanía Regions (for grow-out in marine net pens), in addition to the historical widespread stocking and establishment of the species, it is not possible to attribute any of the rainbow trout captured by IFOP to the freshwater raceway trout farms in Los Rios Region covered in this assessment. Therefore, the presence of rainbow trout in the wild in Chile (as demonstrated by IFOP) cannot be used to indicate that any escapes have (or have not) occurred from the raceway trout farms, nor to imply any ongoing risk of future escapes from them.

<u>Recaptures</u>

With multiple escape prevention barriers in place in the farm, there are multiple recapture options in theory; that is, if fish were to escape from a raceway, they could be recaptured by the barrier before the settling pond, and if they entered the settling pond, they could be recaptured by the barrier at the exit. The escapes contingency plan (footnote 50) also shows that the first action following the detection of an escape would be to isolate the farm by closing the water entry and exit from the farm as a whole, followed by immediate notification of SERNAPESCA. The intent of the recapture adjustment relates to those fish that have already entered the environment beyond the farms, and the contingency plan shows that this would involve immediate efforts to recapture fish up to 400 m downstream (method not specified), followed by an ongoing recapture plan for a number of days and distances to be specified by SERNAPESCA. With no evidence with which to estimate the potential for success of such activities, no recapture adjustment is applied.

In conclusion, the raceway farms, though not immune to escapes, allow the placement of multiple escape barriers. There have been no reported fish escapes by the farm owners, based on fish counting at entry, mortality, and harvest. The annual aquatic fauna surveys from two freshwater trout farms show minimal detections of rainbow trout in the vicinity of the farms. SERNAPESCA data also show that reported escapes are quite infrequent, yet the IFOP sampling and genetic analysis show that escaped rainbow trout are frequently detected in the wild. It is not possible to attribute any of these escaped rainbow trout to the raceway grow-out farms, as opposed to the more numerous facilities growing rainbow trout for grow-out in marine net pens. Overall, the flow-through raceways with multiple escape barriers are considered to have a low to moderate escape risk, in addition to an apparently low risk of flooding (score 6 out of 10); however, the lack of apparent escapes for approximately 15 to 30 years across the five sites indicates a low escape risk (score 8 out of 10). The score for Factor 6.1 is an intermediate 7 out of 10.

Factor 6.2. Competitive and Genetic Interactions

Freshwater fish are one of the most threatened faunal groups globally, and the introduction of exotic species is one of the most important factors in explaining this situation (Habit et al. 2015). Since the beginning of the 20th century, 10 salmonid species, including rainbow trout, have been intentionally introduced throughout Chile and Argentinian Patagonia as a consequence of governmental and private efforts. Habit et al. (2015) note that 27 species have been introduced to Chilean waters. Three species of trout (brown, rainbow, and brook[58]) established rapidly and are now present throughout Patagonia, which happened well before aquaculture in the region began (Di Prinzio et al. 2009)(Pascual et al. 2007). Rainbow trout is known to be one of the most successful salmonid invaders in Chile; it and brown trout are the only two introduced species that can be considered to be distributed throughout the country (Habit et al. 2015). A possible factor for its success is its facultative anadromous lifestyle, which allows it to disperse into streams via the sea (Di Prinzio et al. 2009)(Young et al. 2010). Hence, escaped rainbow trout poses a significant threat to native Chilean ecosystems because it has the greatest potential to establish naturalized populations as a result of its high plasticity (Monzón-Argüello et al. 2014). Although Chalde et al. (2019) note that established nonnative trout species have interacted with native species for a long time and have likely reached a balance that allows them to cohabitate stably, it is also important to consider the genetic differences between trout raised for the stocking of wild waterbodies versus those raised to be

[58] Brook trout - Salvelinus fontinalis

grown in net pens. Though genetic diversification would be a priority in the former to maintain a healthy feral population that could more likely cohabit with native species, the latter would be selected for faster growth and resiliency (e.g., disease resistance). Therefore, trout escapes would present a higher environmental risk than those purposefully introduced into wild habitats (Soto et al., 2022).

Soto et al. (2022) further explain that rainbow trout presents a higher risk of affecting biodiversity and ecosystem services than the other salmonids (i.e., Atlantic and coho salmon), and it receives the highest risk scores for the three assessed criteria: species hazard, habitat sensitivity, and habitat exposure. Rainbow trout's risk scores were mainly driven by its survival, trophic impacts, reproductive capacity, availability of suitable food, stream reproductive potential, and the presence of native or endangered species that trout compete with. Regarding reproductive capacity, it is noted here that the eggs produced by the Huililco facility and used by all five farms of Piscicola Entre Rios are single-sex all-female.[59]

In Chile and elsewhere in the Southern Hemisphere, the primary concern is the impact of nonnative salmonids on native Galaxiid fish. According to De Leaniz et al. (2010), "Across the Southern Hemisphere, exotic salmonids directly impact native galaxiids by reducing their foraging efficiency, limiting their growth, restricting their range, forcing them to seek cover or to use suboptimal habitats, and also by preying upon them." Escaped rainbow trout has been found to significantly decrease the 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, yet the authors speculate if local extirpations may occur with time. Although major declines in abundance have been observed, Galaxiid genetic diversity has not been shown to be affected by aquaculture escapees, but more research is required to truly explain the impact of escaped rainbow trout on native fish populations (Vanhaecke et al. 2012).

Overall, although rainbow trout became fully ecologically established in Chile before aquaculture began (Carcamo et al. 2015), it is considered that escapes from farms have aided the high establishment success and rapid expansion of the species' range, through increased propagation pressure and the maintenance/enhancement of genetic diversity in feral populations. There is contradicting evidence on the potential impacts of escaped rainbow trout on native ecosystems and their biodiversity, and some difficulty in attributing impacts to any one of the several nonnative salmonid species present in Chile. Nonetheless, if there were to be an escape from a freshwater raceway trout farm, then competition, predation, and impacts to wild species, habitats, or ecosystems may occur, although they would be unlikely to affect the population status of wild species. Therefore, the score for Factor 6.2—Invasiveness is 4 out of 10.

[59] https://www.ovasdetrucha.cl/produccion/

Conclusions and Final Score

Raceway farms have a high-flow throughput of water, so they have an inherent risk of escape. Nevertheless, the constrained physical structure also provides opportunities for multiple escape prevention measures. No escapes have been reported from freshwater raceway trout farms, and government data show that there have been no reported escapes of rainbow trout in Los Rios or Araucanía Regions since at least 2011. Annual aquatic surveys at two freshwater raceway rainbow trout farms from 2013 to 2022 show only a single detection of a rainbow trout in 2015. Nevertheless, the Fisheries Development Institute (IFOP) shows that rainbow trout represent 29.1% of the fish caught in annual sampling of wild, feral, and escaped fish in rivers and lakes in Los Rio Region (and 24.0% in Araucanía). A genetic analysis (by IFOP) shows that the majority of rainbow trout captured in Araucanía are farm escapees, as opposed to wild-spawned feral fish. Nevertheless, because of the presence of large numbers of freshwater rainbow trout facilities in Araucanía that grow fingerlings and smolts for on-growing in marine net pens, in addition to the widespread establishment of the species from historical stocking, none of the fish detected in the wild can be attributed to escapes from freshwater raceway grow-out farms in Los Rios Region (or elsewhere) covered by this assessment. With multiple escape barriers, and no apparent escapes for more than 10 years, the escape risk score (Factor 6.1) is 7 out of 10.

Although rainbow trout became ecologically established in Chile before aquaculture began, it is considered that escapes from farms have aided the high establishment success and rapid expansion of the species' range. There is contradicting evidence on the potential impacts of escaped rainbow trout on native ecosystems and their biodiversity, and some difficulty in attributing impacts to any one of the several nonnative salmonid species present in Chile. Nonetheless, if there were to be an escape from a freshwater raceway trout farm, then competition, predation, and impacts to wild species, habitats, or ecosystems may occur, although this would be unlikely to affect the population status of wild species. Thus, the score for Factor 6.2—Invasiveness is 4 out of 10. Factors 6.1 and 6.2 combine to give a final score of 5 out of 10 for Criterion 6—Escapes.

Criterion 7: Disease; Pathogen and Parasite Interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

C7 Disease parameters		Score
Evidence or risk-based assessment	Evidence	
C7 Disease Final Score (0–10)		**8**
Critical	No	Green

Brief Summary

Detailed data from the freshwater raceway trout farms in Chile show that two pathogens, *Flavobacterium psychrophilum* and the infectious pancreatic necrosis virus (IPNv), are associated with an average annual mortality from disease of 5.5%. No high-risk pathogens (as defined by SERNAPESCA) have been detected. These farm-specific data closely reflect the annual fish health monitoring data from SERNAPESCA for all freshwater facilities in Chile, where the same two pathogens are dominant. A 2017 risk assessment of pan-sized trout farms in Chile carried out by the University of Valparaíso showed that, because of the high flow rates through the raceways, there is a high risk that wild fish will be exposed to pathogens from farms. But, they also noted that Flavobacterium and, to a lesser extent, IPN virus are ubiquitous in the environment in Chile, and concluded that the risk to wild fish was low to moderate. Annual monitoring of the health status of wild fish in Chile by the Fisheries Development Institute (IFOP) shows low detections of fish testing positive for 13 pathogens. Between 2010 and 2022, 0.58% and 0.40% of fish tested positive for *F. psychrophilum* and IPNv, respectively. Detections of parasites in wild fish were also at background levels. Overall, it is considered (as indicated by the mortality disease data, the high flow rates in the raceways, and the risk assessment) that disease transmission may occur, but (as indicated by the risk assessment and the IFOP data), pathogens or parasites in wild fish are not considered to be amplified above background levels, nor to cause morbidity. Thus, the score for Criterion 7—Disease is 8 out of 10.

Justification of Rating

The detailed mortality data from five freshwater raceway trout farms, in addition to the risk assessment of Campalans et al. (2017) and the IFOP monitoring data of the health status of wild fish, are considered to give a reliable representation of the assessed farms and their potential disease impacts. The data score for disease in Criterion 1—Data is 7.5 out of 10, so the evidence-based assessment is used.

The presence of pathogens on farms

SERNAPESCA publishes an annual "sanitary report" (also a semiannual interim report) for freshwater and marine aquaculture sites in Chile (Informe Sanitario con Información Sanitaria de Agua Dulce y Mar; SERNAPESCA 2022c,d). In 2021, the average monthly mortality rate of rainbow trout in all freshwater facilities was 4.5% (54% annually), which increased slightly to 5.0% in the first half of 2022. It is considered that the high annual mortality rate is due to the dominance of hatcheries and nurseries within the freshwater facilities, and therefore the higher mortalities to be expected in early stages of egg, alevin[60] and fingerling production. Of these total mortalities (with many causes[61]), SERNAPESCA attributed 14.6% to secondary infections; i.e., disease. Using the 2021 annual total mortality rate of 54%, this equates to 7.9% mortality from disease. Of these disease-related mortalities, 71.3% were attributed to flavobacteriosis (caused by the bacterial pathogens of *Flavobacterium* spp.), 23.0 % to infectious pancreatic necrosis (IPN, caused by the IPN virus), and 5.6% to fungal infections.

Regarding the five raceway trout farms operated by Piscicola Entre Rios, the company provided detailed mortality data for the last 3 years (2020 to 2022) for two sizes of fish, which were categorized as "alevins" of less than 15–20 g and fattening fish (engorda) larger than 15–20 g. In the 3-year period, the average annual mortality due to disease was 5.5% (range 3.7% to 6.6%).[62] The farms have monthly visits by a fish veterinarian and the same two diseases, flavobacteriosis and IPN, were attributed as the causes, with flavobacteriosis attributed to an average of 97.3% of disease-related mortality. These mortalities were predominantly in the alevin stages (average 88.4% of all flavobacteriosis mortalities). All IPN mortalities occurred in the alevin stages (i.e., <15–20 g).

Campalans et al. (2019) obtained 2012 to 2015 data for the same farms of Piscicola Entre Rios from the government's monitoring program for high-risk diseases (PSEV).[63] Those data also showed that the primary pathogens were *Flavobacterium* spp. and IPNv. Campalans et al. (2019) pointed out that the farms dedicated to the production of pan-sized rainbow trout are free of dangerous diseases according to the World Organization for Animal Health (WOAH, formerly the OIE) and free of high-risk diseases in Chile (as defined by SERNAPESCA). The more recent 2020–22 data from the farms support this conclusion. Regarding parasites, the farm owners report minimal occurrence in the farm, but note that parasites may be seen in wild fish caught in the region (pers. comm., Juan Villasante, Piscicola Entre Rios January 2023).

The potential transmission of pathogens from farms to wild fish

[60] Alevin: a newly hatched salmon or trout still carrying the yolk.

[61] For example, poor performers, deformities, mechanical damage, poor adaptation, and environmental and embryonic mortality.

[62] Comparing this to the 2021 value from SERNAPESCA, the mortality due to disease in the five farms was 3.7%, compared to the 7.9% for all freshwater facilities in the same year from SERNAPESCA data.

[63] Programa Sanitario Específico de Vigilancia de Enfermedades de Alto Riesgo en Peces

According to Campalans et al. (2017), the greatest concern that aquaculture currently generates in the country's continental ecosystems is the possibility of dispersion of pathogens and parasites from the farmed species to native species and eventually to salmonid cultures in seawater. Although Campalans et al. (2017) noted that the high flow rate of water through the raceway farms reduced the exposure time of the fish to any microorganisms, it also has the disadvantage of making effluent disinfection impractical, because of the large volume of water. The same authors also noted that the *Flavobacterium* spp. and IPN virus are difficult to eliminate, and typical potential treatment methods would be ineffective during periods of higher turbidity. Therefore, it is inevitable that the freshwater raceway trout farms amplify pathogens to some degree and represent a source of the same pathogens in the receiving waters.

Regarding this potential transmission and the subsequent potential for impacts to wild fish (or other organisms), Campalans et al. (2017) conducted a risk assessment for these pathogens from raceway rainbow trout farms in Chile. The full risk assessment is available from Subpesca (in Spanish),[64] but in summary, the methodology included the typical four components of such assessments; i.e., (i) pathogen release or escape assessment, (ii) exposure assessment, (iii) consequence assessment, and (iv) risk estimation (integrating the results of parts i–iii). As might be expected from the previous data, the risk assessment model showed a high probability of dissemination and exposure of *Flavobacterium psychrophilum* and the IPN virus. The assessment also noted that there is little knowledge in terms of the sensitivity of native fish populations to these pathogens. But, the authors noted that Flavobacteria are found in very diverse habitats, soils, freshwater and marine environments, sediments, glaciers, etc., and considered them to be part of the normal bacterial flora of the environment. Similarly, IPN is widely distributed and has been detected in marine, estuarine, and freshwater fish and is "practically endemic" in the country (Campalans et al. 2017, 2019). Therefore, the risk assessment of Campalans et al. (2017) concluded that the high level of theoretical risk observed for IPN and Flavobacterium was adjusted to a low to moderate level of risk, particularly when simple farm-level controls such as egg disinfection are implemented. The low number and modest size of freshwater raceway trout farms producing pan-sized fish was also noted as a factor reducing the risk of impact to wild fish (Campalans et al. 2017, 2019).

A practical demonstration of the outcomes of this risk assessment is available in the annual monitoring of the health situation of wild fish in fresh and marine waters of Chile[65] conducted by the Fisheries Development Institute (Instituto de Fomento Pesquero) (IFOP, 2023). Between 2010 and 2022, the surveys have analyzed 44,573 wild, feral, and recently escaped fish, of which (across all species in freshwater and marine locations), 2,641 (5.9%) tested positive for the detection of genetic material from 1 or more of the 13 pathogens of concern. Of those 2,641 positive fish, 9.73% (0.58% of the total sample) tested positive for *Flavobacterium*

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[64] https://www.subpesca.cl/fipa/613/w3-article-92056.html#:~:text=Peces%20%3E%20Trucha%20arcoiris-,Evaluaci%C3%B3n%20de%20riesgo%20de%20los%20sistemas%20de%20producci%C3%B3n%20de%20trucha,a%20trav%C3%A9s%20de%20sus%20efluentes.

[65] Evaluación y seguimiento de la situación sanitaria de peces silvestres en agua dulce y mar.

psychrophilum, and 6.78% for the IPN virus (0.40% of the total sample). The largest proportion of fish, 79.14%, tested positive for the bacterium *Piscirikketsia salmonis*, which causes salmon Rickketsial syndrome in marine aquaculture facilities.

Of the 257 fish that tested positive for *F. psychrophilum* between 2010 and 2022*,* 140 (0.31% of the total sample) were rainbow trout, and 64 (0.14% of the total sample) were freshwater silverside (*Basilichthys australis*). For IPNv, of the 179 fish that tested positive, 43 (0.1% of the total sample) were rainbow trout, 32 (0.07% of the total sample) were freshwater silverside, 32 (0.07% of the total sample) were marine bass/robalo (*Eleginops maclovinus*), and 28 (0.06% of the total sample) were marine silversides (*Odontesthes regia*). In the most recent sampling data from 2021–22, only 1 of the 409 freshwater silversides that were caught tested positive for *F. psychrophilum*, and none for IPNv; regarding the primary location of the freshwater raceway trout farms in Chile, none of the fish sampled in Los Rios Region tested positive for *F. psychrophilum* or the IPN virus (IFOP 2023). In addition, it is important to note that, during the 2010 to 2021 sampling period, only one fish (a coho salmon) had clinical signs consistent with the presence of clinical disease (bacterial kidney disease) caused by any of the pathogens tested (IFOP 2023). Nevertheless, it is also important to note that detecting or studying disease in wild populations is complex, and sampling efforts solely capture live fish; therefore, it has been suggested that weak and dying fish may be predated before a disease progresses to mortality, and fish showing clinical signs of disease may not be detected in sampling efforts such as those by IFOP (Miller et al. 2014, 2017)(Mordecai et al. 2019).

Regarding the detection of parasites in wild fish, IFOP (2023) reported that, of 2,625 fish caught in the wild in the 2021–22 survey period, 87.4% were free of parasites. Of those infected, 76.0% had internal (endo) parasites, and 24.0% had external (ecto) parasites. The most parasitized species were the marine species robalo (*Eleginops maclovinus*) (55.3% of infected fish) and rainbow trout (28.5% of infected fish). The most parasitized nonsalmonid freshwater fish was the freshwater silverside, for which 10 of the 331 fish caught were infected with internal tapeworms (*Diphyllobothrium* spp.) and roundworms (*Hysterothylacium* spp.). These detections are considered to represent background levels of parasitism in wild fish.

Conclusions and Final Score

Detailed data from the freshwater raceway trout farms in Chile show that two pathogens, *Flavobacterium psychrophilum* and the infectious pancreatic necrosis virus (IPNv), are associated with an average annual mortality from disease of 5.5%. No high-risk pathogens (as defined by SERNAPESCA) have been detected. These farm-specific data closely reflect the annual fish health monitoring data from SERNAPESCA for all freshwater facilities in Chile, where the same two pathogens are dominant. A 2017 risk assessment of pan-sized trout farms in Chile carried out by the University of Valparaíso showed that, because of the high flow rates through the raceways, there is a high risk that wild fish will be exposed to pathogens from farms. But, they also noted that Flavobacterium and, to a lesser extent, IPN virus are ubiquitous in the environment in Chile, and concluded that the risk to wild fish was low to moderate. Annual monitoring of the health status of wild fish in Chile by the Fisheries Development Institute (IFOP) shows low detections of fish testing positive for 13 pathogens. Between 2010 and 2022, 0.58% and 0.40% of fish tested positive for *F. psychrophilum* and IPNv, respectively. Detections of parasites in wild fish were also at background levels. Overall, it is considered (as indicated by the mortality disease data, the high flow rates in the raceways, and the risk assessment) that disease transmission may occur, but (as indicated by the risk assessment and the IFOP data), pathogens or parasites in wild fish are not considered to be amplified above background levels, nor to cause morbidity. Thus, the score for Criterion 7—Disease is 8 out of 10.

Criterion 8X: Source of Stock—Independence from Wild Fisheries

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

C8X Source of Stock—Independence from wild fish stocks	Value	Score
Percent of production dependent on wild sources (%)	0.0	0
Use of ETP or SFW "Red" fishery sources	No	
C8X Source of Stock Final Score (0 to –10)		**0**
Critical?	No	Green

Justification of Rating

Rainbow trout has 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)(Reis Neto et al. 2019). In Chile, the fingerlings used by Piscicola Entre Rios are raised from eggs produced at the Piscicola Huililco[66] breeding center in the Araucanía Region of Chile (Region IX). The company uses a domesticated strain of rainbow trout called Blueback, which it has developed in a selective breeding program since 2005. The facility operates as a closed-cycle breeding center, with no entry of external eggs, fingerlings, juveniles, or adults. As a result, the production of rainbow trout in freshwater (and seawater) in Chile is considered fully independent of wild stocks for broodstock, eggs, or fingerlings, and the score for Criterion 8X—Source of Stock is a deduction of 0 out of –10.

[66] https://www.ovasdetrucha.cl/

Criterion 9X: Wildlife Mortalities

Impact, unit of sustainability and principle

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

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

Criterion 9X Summary

C9X Wildlife Mortality parameters		Score
Single species wildlife mortality score		–1
System score if multiple species assessed together		n/a
C9X Wildlife Mortality Final Score		**–1**
Critical?	No	Green

Brief Summary

It is to be expected that the fish in raceway farms attract predators, but the evidence from the farms in Chile, and from similar systems elsewhere, shows that nonlethal exclusionary techniques such as fences and predator netting are the primary methods used to manage interactions. Overall, effective management practices are in place for the nonharmful exclusion of wildlife, and deliberate lethal wildlife control is not used or permitted. It is possible that accidental mortalities may occur, but are likely to be limited to exceptional cases and highly unlikely to affect the health of the population. Therefore, the final score for Criterion 9X—Wildlife Mortalities is a small deduction of –1 out of –10.

Justification of Rating

Although specific studies in Chile are not readily available, it can be robustly assumed that the fish in raceway trout farms attract various predators, as they do in similar systems elsewhere (e.g., Fornshell and Hinshaw 2008). The five farms operated by Piscicola Entre Rios use fences and netting around and over the raceways to protect the fish from birds or other predators, particularly when the fish are small (pers. comm., Juan Villasante, Piscicola Entre Rios January 25, 2023). This is considered to be standard practice in these and similar farms, and the company also notes that it is illegal to harm wildlife in this regard (for example,[67] Law 19.473 of 1996 from the Department of Agriculture updated Chile's original 1923 controls on hunting, capture, breeding, conservation, and sustainable use of wild animals, in addition to specific aquaculture requirements regarding birds in the General Law of Fisheries and Aquaculture—Law 19.624 of 1999). Examples of predator nets can be seen in Figure 17. Occasionally, the farms have been required by the government to place traps for the invasive American mink, for which traps are supplied by the government and collected with live animals (pers. comm., Juan Villasante, Piscicola Entre Rios, January 2023).

A search of the International Union for the Conservation of Nature (IUCN) Red List[68] database shows many examples of globally vulnerable, endangered, or critically endangered bird and mammal species in Chile, but only the endangered southern sea otter (*Lontra provocax*) is a potentially relevant species within the regions where the freshwater raceway rainbow trout farms are located (according to the IUCN,[69] the farms are at the northern limit of the otter's range). The semiannual independent aquatic fauna surveys conducted at two of the farms have not detected any evidence of the otter in the vicinity of the farms.

Figure 17: Predator netting can be seen over the raceways to the left and right of this image of Llallalca farm. The central area without netting is a settling pond and does not contain fish. Image provided by Juan Villasante, Piscicola Entre Rios.

[67] There are many relevant regulations for birds and other wildlife; for example, ENCA (2022) provides a detailed list of regulations for birds in Chile.
[68] https://www.iucnredlist.org/
[69] https://www.iucnredlist.org/species/12305/95970485

With the use of predator nets, there is an inevitable risk of occasional entanglement by species such as birds; although there have been no entanglements reported by the farm management, there are no specific data, and it is considered that such events could occur in exceptional circumstances.

Although the information available from the dominant farms in Chile (in addition to similar farms elsewhere) is considered to give a reliable representation of typical practices and the risk of interactions (i.e., the Criterion 1—Data score for wildlife mortalities is 7.5 out of 10), there are no specific mortality data or readily available population data for relevant species in Chile. Therefore, the risk assessment is used here.

Conclusions and Final Score

It is to be expected that the fish in raceway farms attract predators, but the evidence from the farms in Chile, and from similar systems elsewhere, shows that nonlethal exclusionary techniques such as fences and predator netting are the primary methods used to manage interactions. Overall, effective management practices are in place for the nonharmful exclusion of wildlife, and deliberate lethal wildlife control is not used or permitted. It is possible that accidental mortalities may occur, but they are likely to be limited to exceptional cases and highly unlikely to affect the health of the population. Therefore, the final score for Criterion 9X—Wildlife Mortalities is a small deduction of –1 out of –10.

Criterion 10X: Introduction of Secondary Species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on trans-waterbody movements (%)	100.0	0
Biosecurity score of the source of animal movements (0–10)		7
Biosecurity score of the farm destination of animal movements (0–10)		4
C10X Introduction of Secondary Species Final Score		**–3.0**
Critical?	No	Green

Brief Summary

The five raceway grow-out farms used as an example in this assessment rely on the movement of live eggs, alevins, or fingerlings to and from three separate facilities in the Araucanía and Los Rios Regions of Chile. Although these source and destination locations are broadly similar ecologically, they are on different rivers and watersheds, so the farmed trout production is considered to be fully reliant on trans-waterbody movements of live fish. The final destinations of the movements (i.e., the raceway grow-out farms) have biosecurity limitations because of their flow-through nature; however, the egg and fingerling producers in indoor tank-based facilities have greater biosecurity potential. For example, the egg provider operates as a closed-cycle breeding center with no entry of foreign eggs, fingerlings, juveniles, or adults, and along with the fingerling producers, it has the ability to treat and disinfect the water, eggs, and facilities. There are also several documentary and testing requirements from SERNAPESCA regarding permissions to move fish, veterinary health certificates, and testing for specific high-risk pathogens. The emergence of a novel pathogen is always a possibility, but overall, during live fish movements, there is a relatively low risk of introducing species that are not native to or present in the destination rivers (e.g., a pathogen). The final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3 out of –10.

Justification of Rating

Factor 10Xa International or Trans-Waterbody Live Animal Shipments

As noted in Criterion 8X—Source of Stock, the fingerlings used by Piscicola Entre Rios are raised from eggs produced at the Piscicola Huililco hatchery in the Araucanía Region of Chile. Most of the eggs or alevins[70] are transported to three other facilities (one in Araucanía and two in the adjoining Region XIV, Los Rios) that hatch the eggs and/or raise the alevins into fingerlings before their final transport to the grow-out farms (also in Region XIV). The Huililco hatchery also produces some fingerlings (approximately 7.2% of the fingerlings used by Piscicola Entre Rios between 2020 and 2022), and these are transported directly to the grow-out farms. One of the three fingerling facilities—and the dominant supplier of fingerlings for Piscicola Entre Rios farms overall (producing 43.7% of the fingerlings used between 2020 and 2022)—is located at the Llallalca grow-out farm site. The two other facilities together supplied 49% of the fingerlings to the grow-out farms in 2020–22. In the Piscicola Entre Rios example, the fingerlings from these three facilities are transported to the remaining four grow-out farms.

Although relatively close geographically (yet in different administrative regions of Chile), the egg production, fingerling producers, and the grow out farms utilize different rivers and watersheds. Figure 18 shows a map of rivers and watershed basins (cuencas) in Los Rios Region of Chile. The locations of the various facilities associated with the rainbow trout production of Piscicola Entre Rios show that the egg supplier is in a different watershed (River Toltén) to that of the remaining seven facilities (fingerling and grow-out sites) in the Valdivia River basin. Of the seven facilities in the Valdivia River basin, Figure 18 shows that they are in different sub-basins (subcuencas) and sub-sub-basins (subsubcuencas).

[70] Alevin: a newly hatched salmon or trout still carrying the yolk.

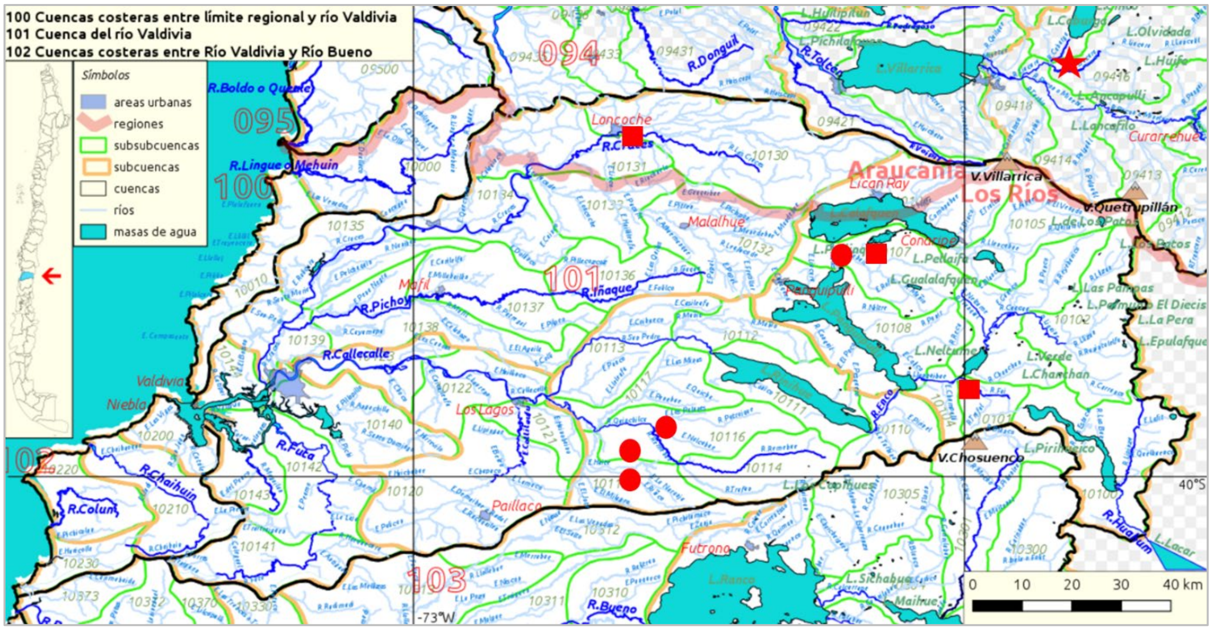

Figure 18: Map of watershed basins (cuencas) in Region XIV in Chile. Outlined in black, 101 is the Cuenca del Rio Valdivia, and 094 is the Cuenca Rio Toltén. Orange lines show sub-basins (subcuencas) and green shows sub-sub-basins (subsubbcuencas). The Huililco hatchery is shown by a red star. The fingerling producers are red squares, and the remaining grow-out farms are red circles. Map reproduced from Wikimedia Commons.[71]

In Criterion 7—Disease, it was noted that the primary pathogens currently affecting freshwater rainbow trout producers in Chile are ubiquitous in the environment; however, the potential for emerging pathogens remains a constant risk in aquaculture production. Therefore, although the locations of the various facilities may be ecologically similar, the live fish movements are considered to represent a risk of introducing species that are not native to or present in the destination rivers (e.g., a pathogen). Therefore, 100% of production is considered to be reliant on trans-waterbody movements of live fish, and the score for Factor 10Xa is 0 out of 10.

Factor 10Xb: Biosecurity of Source/Destination

As the source of eggs and some fingerlings, the Huililco hatchery operates as a closed-cycle breeding center, with no entry of foreign biological material (eggs, fingerlings, juveniles, or adults).[72] According to its website, rainbow trout eggs are disinfected with iodophor on multiple occasions, and fingerlings are given low-salinity baths to prevent the development of fungal pathogens. The tank-based hatchery has a source of clean groundwater, and uses sanitary entry barriers such as disinfection of vehicles and people entering the premises, mandatory use of visitor clothing, foot baths, and hand baths. There is also periodic disinfection of the infrastructure, utensils, and culture units.

The Huililco facility also notes (on its website) that it is officially supervised by the government aquaculture authority (SERNAPESCA[73]) for compliance with the different surveillance plans

[71] https://commons.wikimedia.org/wiki/Category:Maps_of_rivers_of_Chile_(drainage_basins_BCN)
[72] https://www.ovasdetrucha.cl/manejo-sanitario/
[73] http://www.sernapesca.cl/area-trabajo/acuicultura

determined by the fish health regulations in Chile. These include the Specific Health Program for Active Surveillance for High-Risk Diseases (PSVC-EAR[74]), the Specific Sanitary Program for Surveillance and Control of Infectious Salmon Anemia (PSEVC-ISA[75]), and the General Sanitary Program for Sanitary Management of Fish Reproduction (PSGR[76]). The three other hatcheries used by Piscicopla Entre Rios have less readily available information but are indoor facilities (clearly visible in satellite images in the SNIFA database[77]) and use nearby rivers as their water source. They are expected to have similar biosecurity procedures as Huililco, particularly regarding disinfections and fish treatments, and similar supervision by SERNAPESCA.

In order to move live fish or eggs, there are a number of procedures and documentary requirements in place in Chile:

- The authorized movement certificate (Autorización de movimiento de especies salmónidas—CAM[78]) from SERNAPESCA; see the example in Appendix 3.
- A sanitary certificate for movements (Certificado Sanitario de Movimiento—CSM[79]); see the example in Appendix 4.
- A certificate of health from a veterinary professional (Certificado de Salud para Transporte de Peces Vivos[80]); see the example in Appendix 5.
- Testing for infectious salmon anemia virus (ISAv); see the example in Appendix 6.

Additional practical requirements include a certificate for disinfection of the transportation tanks (an example was provided by Piscicola Entre Rios). Given the characteristics and the fish movement requirements, the egg and fingerling producers (as the source of live animal movements) are considered to have relatively high biosecurity, although they do not operate as fully contained recirculation systems. Therefore, the biosecurity score for the source of transported animals is an intermediate 7 out of 10.

The destinations of live fish movements are the raceway grow-out farms, which have high throughputs of water, so they have inherent biosecurity limitations. The score for the destination of the transported animals is 4 out of 10. Therefore, the score for Factor 10Xb is 7 out of 10 (based on the more biosecure location, and therefore the higher of the two scores).

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[74] Programa Sanitario Específico de Vigilancia de Enfermedades de Alto Riesgo en Peces - http://www.sernapesca.cl/programas/programa-sanitario-especifico-de-vigilancia-de-enfermedades-de-alto-riesgo-en-peces

[75] Programa Sanitario Específico de Vigilancia y Control Anemia Infecciosa del Salmón - http://www.sernapesca.cl/programas/programa-sanitario-especifico-de-vigilancia-y-control-anemia-infecciosa-del-salmon

[76] Programa para la Gestión Sanitaria en la Acuicultura - http://www.sernapesca.cl/programas/programa-para-la-gestion-sanitaria-en-la-acuicultura

[77] SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)
SNIFA - Sistema Nacional de Información de Fiscalización Ambiental (sma.gob.cl)

[78] http://www.sernapesca.cl/informacion-utilidad/autorizacion-de-movimiento-de-especies-salmonidas

[79] http://www.sernapesca.cl/informacion-utilidad/solicitar-certificado-sanitario-de-movimiento-de-especies-salmonidas-csm

[80] http://www.sernapesca.cl/sites/default/files/certificado_de_salud_para_transporte_de_peces_vivos.pdf

Conclusions and Final Score

The five raceway grow-out farms used as an example in this assessment rely on the movement of live eggs, alevins, or fingerlings to and from three separate facilities in the Araucanía and Los Rios Regions of Chile. Although these source and destination locations are broadly similar ecologically, they are on different rivers and watersheds, so the farmed trout production is considered to be fully reliant on trans-waterbody movements of live fish. The final destinations of the movements (i.e., the raceway grow-out farms) have biosecurity limitations because of their flow-through nature; however, the egg and fingerling producers in indoor tank-based facilities have greater biosecurity potential. For example, the egg provider operates as a closed-cycle breeding center, with no entry of foreign eggs, fingerlings, juveniles, or adults, and along with the fingerling producers, it has the ability to treat and disinfect the water, eggs, and facilities. There are also several documentary and testing requirements from SERNAPESCA regarding permissions to move fish, veterinary health certificates, and testing for specific high-risk pathogens. The emergence of a novel pathogen is always a possibility, but overall, during live fish movements, there is a relatively low risk of introducing species that are not native to or present in the destination rivers (e.g., a pathogen). The final score for Criterion 10X—Introduction of Secondary Species is a deduction of –3 out of –10.

Acknowledgements

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

Seafood Watch would like to thank the consulting researcher and author of this report, Peter Bridson of Seagreen Research. Seafood Watch would also like to thank Juan Villasante of Piscicola Entre Rios for the willingness to answer all questions and to satisfy all requests for available data.

References

Arismendi, I., B. Penaluna, J. B. Dunham, C. Garcia de Leaniz, D. Soto, I. A. Fleming, D. Gomez-Uchida, G. Gajardo, P. V. Vargas and J. Leon-Munoz (2014). "Differential invasion success of salmonids in southern Chile: patterns and hypotheses." Reviews in Fish Biology and Fisheries 24(3): 919-941..

Aubin, J., Tocqueville, A., & Kaushik, S. J. (2011). Characterisation of waste output from flowthrough trout farms in France: comparison of nutrient mass-balance modelling and hydrological methods. Aquatic Living Resources, 24(1), 63–70. doi:10.1051/alr/2011008

BCN. 2022. Salmónidos escapados al medio ambiente. Estadísticas en Chile 2013-2022 (enero). Biblioteca del Congreso Nacional de Chile | Asesoría Técnica Parlamentaria. Octubre 2022.

Billard, P. R. (1989). "Taxonomic change in rainbow trout scientific name. Salmo gairdneri (Richardson, 1836) becomes Oncorhyncus mykiss (Walbaum, 1792)." Aquatic Living Resources 2(4): 189-189.

Boyd, CE, C Tucker, A McNevin, K Bostick, J Clay (2007) Indicators of Resource Use Efficiency and Environmental Performance in Fish and Crustacean Aquaculture. Reviews in Fisheries Science 15: 327-360.

Boyd, C.E., Davis, R.P., Wilson, A.G., Marcillo, F., Brian, S. and McNevin, A.A., 2021. Resource use in whiteleg shrimp Litopenaeus vannamei farming in Ecuador. Journal of the World Aquaculture Society, 52(4), pp.772-788.

Campalans, M., Cortes, M., Campalans, J., Fritis, J., Brito, E., Navarrete, R. 2017. Evaluación de riesgo de los sistemas de producción de trucha pan size. Consejo de Investigación Pesquera. Pontificia Universidad Católica de Valparaíso Facultad de Ciencias del Mar y Geografía. Escuela de Ciencias del Mar. Proyecto FIP Nº 2014-89. Abril, 2017.

Campalans, M., Toledo, M., Sobenes, C., Campalans, J et al. 2019. Adecuación de la normativa ambiental y Sanitaria a proyectos de acuicultura de pequeña escala (APE). Pontificia Universidad Católica de Valparaíso Facultad de Ciencias del Mar y Geografía. Escuela de Ciencias del Mar. Proyecta (FIPA 2017-16). Diciembre, 2019.

Cárcamo, C. B., N. F. Diaz, and F. M. Winkler. (2015). Genetic diversity in Chilean populations of rainbow trout, Oncorhynchus mykiss. Latin American Journal of Aquatic Research 43:59-70.

Carrera, N. Ítalo. (2020). Breve historia de la acuicultura y salmonicultura en el sur de Chile (1856-2000) . Territorios Y Regionalismos, 3(3), 36-49. Recuperado a partir de https://revistas.udec.cl/index.php/rtr/article/view/2663

Chalde, T., Nardi, C.F. and Fernández, D.A., 2019. Early warning: detection of exotic coho salmon (Oncorhynchus kisutch) by environmental DNA and evidence of establishment at the extreme south of Patagonia. Canadian Journal of Fisheries and Aquatic Sciences, 76(12), pp.2343-2349.

Cussac, V., Becker, L., Aigo, J., Conte-Grand, C., Blasetti, G., Cordero, P., … Nabaes, D. (2014). Abundance of native fishes, wild-introduced salmonids and escaped farmed rainbow trout in a Patagonian reservoir. Lakes & Reservoirs: Research & Management, 19(2), 74–85.doi:10.1111/lre.12063

De Leaniz, C. G., G. Gajardo, and S. Consuegra. 2010. From Best to Pest: changing perspectives on the impact of exotic salmonids in the southern hemisphere. Systematics and Biodiversity 8:447-459.

Di Prinzio, C. Y., M. L. Miserendino and R. Casaux (2013). "Feeding strategy of the non-native rainbow trout, Oncorhynchus mykiss, in low-order Patagonian streams." Fisheries Management and Ecology 20(5): 414-425.

Dumas, A., de Lange, C. F. M., France, J., & Bureau, D. P. (2007). Quantitative description of body composition and rates of nutrient deposition in rainbow trout (Oncorhynchus mykiss). Aquaculture, 273(1), 165–181. doi:10.1016/j.aquaculture.2007.09.026

Estay. F.. 2017. Una mirada a la industria de la trucha arcoíris cultivada en agua dulce en Chile y el mundo. Salmon Expert, No 49. 2017. www.salmonexpert.cl
FAO (2005). "Cultured Aquatic Species Information Programme. Oncorhynchus mykiss." Cultured Aquatic Species Information Programme

FAO. 2020. Small-scale rainbow trout farming. The Food and Agriculture Organization of the United Nations FAO TECA. Regional Office for Europe and Central Asia Fisheries and Aquaculture. ID 7492. Rome. https://www.fao.org/teca/en/technologies/7492

Fornshell, G., & Hinshaw, J. M. (2008). Better Management Practices for Flow-Through Aquaculture Systems. In C. S. Tucker & J. A. Hargreaves (Eds.), Environmental Best Practices for Aquaculture (pp. 331–388). Ames, Iowa: Blackwell Publishing.

Fornshell, G., Hinshaw, J. M., & Tidwell, J. H. (2012). Flow-through Raceways. In J. H. Tidwell (Ed.), Aquaculture Production Systems (pp. 173-190). John Wiley & Sons, Inc.

Fry, J.P., Mailloux, N.A., Love, D.C., Milli, M.C. and Cao, L., 2018. Feed conversion efficiency in aquaculture: do we measure it correctly?. Environmental Research Letters, 13(2), p.024017.

Figueroa D, Aguayo C, Valdivia P, Encina-Montoya F, Nimptsch J & Esse C (2017) Evaluación y análisis de los posibles parámetros ambientales a ser incorporados en las normas de emisión y/o de calidad de aguas fluviales y lacustres, destinados a centros de cultivo ubicados en tierra.

Informe Final. Subsecretaría de Pesca y Acuicultura FIP N°2015-05.

Glover KA, Solberg MF, McGinnity P, et al. 2017. Half a century of genetic interaction between farmed and wild Atlantic salmon: Status of knowledge and unanswered questions. Fish Fish. 2017;00:1–38.

Habit, E., González, J., Ortiz-Sendoval, J., Elgueta, A., Sobenes, C. 2015. Effects of salmonid invasion in rivers and lakes of Chile. Ecosistemas 24(1): 43-51. Doi.: 10.7818/ECOS.2015.24-1.08

Henríquez, L. 2013. Cinco décadas de transformaciones en La Araucanía Rural. Polis vol.12 no.34
Santiago abr. 2013

IFOP. 2019. Quntanilla-Correa, J. C., Gonzalez-Gomez, M. (2019). "Evaluacion y seguimiento de la situacion sanitaria de especies silvestres en agua dulce y mar." Instituto de Fomento Pesquero. Subsecretaria de Economia y Empresas de Menor Tamaño.

IFOP, 2021. Evaluación y seguimiento de la situación sanitaria de peces silvestres en agua dulce y mar, 2020. Instituto de Fomento Pesquero. Subsecretaría de Economía y Emt / Diciembre 2021.

IFOP, 2023. Evaluación y seguimiento de la situación sanitaria de peces silvestres en agua dulce y mar, 2021-2022. Instituto de Fomento Pesquero. Subsecretaría de Economía y Emt / Enero 2023.

INCAR (2020). Pisciculturas de agua dulce: El gran pendiente de la industria salmonera chilena.Recomendaciones para políticas públicas. Contribución de la investigación de Centro INCAR a las políticas públicas (Nº8) www.incar.cl

Janssen, K. P. E., Berentsen, P. B. M., & Komen, J. (2015). Current status of selective breeding in European aquaculture. Poster session presented at Aquaculture Conference 2015, Montpellier, France.

Kamalam, B.S., Rajesh, M. and Kaushik, S., 2020. Nutrition and Feeding of Rainbow Trout (Oncorhynchusmykiss). In Fish nutrition and its relevance to human health (pp. 299-332). CRC Press.

Kamjunke N, Nimptsch J, Harir M, Herzsprung P, Schmitt-Kopplin P, Neu TR, Graeber D, Osorio S, Valenzuela J, Reyes JC, Woelfi S & Hertkorn N (2017) Land-based salmon aquacultures change the quality and bacterial degradation of riverine dissolved organic matter. Scientific Reports 7 (43739):1– 15.

Kubitza, F. 2016a. Common salt a useful tool in aquaculture, part 1. Responsible Seafood Advocate, Global Seafood Alliance. 23 May, 2016.

https://www.globalseafood.org/advocate/common-salt-a-useful-tool-in-aquaculture-part-1/

Kubitza, F. 2016b. Common salt a useful tool in aquaculture, part 2. Responsible Seafood Advocate, Global Seafood Alliance. 26 May, 2016. https://www.globalseafood.org/advocate/common-salt-a-useful-tool-in-aquaculture-part-2/

Luna, S. and A. Torres. (2011). "Oncorhynchus mykiss." from http://www.fishbase.org/summary/239.

Miller, K. M., Teffer, A., Tucker, S., Li, S., Schulze, A. D., Trudel, M., Juanes, F., Tabata, A., Kaukinen, K. H., Ginther, N. G., Ming, T. J., Cooke, S. J., Hipfner, J. M., Patterson, D. A. and Hinch, S. G. (2014), Infectious disease, shifting climates, and opportunistic predators: cumulative factors potentially impacting wild salmon declines. Evol Appl, 7: 812–855. doi:10.1111/eva.12164

MMA. 2022. Estrategia Nacional de 2021-2030 Conservación de Aves, Chile. . Ministerio del Medio Ambiente. Primera edición 2022. https://mma.gob.cl/wp-content/uploads/2022/06/Estrategia-Nacional-de-Conservacio%CC%81n-de-Aves-2021-2030.pdf

Monzón-Argüello, C., C. Garcia de Leaniz, G. Gajardo and S. Consuegra (2013). "Less can be more: loss of MHC functional diversity can reflect adaptation to novel conditions during fish invasions." Ecology and Evolution 3(10): 3359-3368.

Mordecai, G.J., Miller, K.M., Di Cicco, E., Schulze, A.D., Kaukinen, K.H., Ming, T.J., Li, S., Tabata, A., Teffer, A., Patterson, D.A. and Ferguson, H.W., 2019. Endangered wild salmon infected by newly discovered viruses. Elife, 8, p.e47615.

Pascual, M.A., Cussac, V., Dyer, B., Soto, D., Vigliano, P., Ortubay, S. and Macchi, P., 2007. Freshwater fishes of Patagonia in the 21st Century after a hundred years of human settlement, species introductions, and environmental change. Aquatic Ecosystem Health & Management, 10(2), pp.212-227.

Reis Neto, R.V., Yoshida, G.M., Lhorente, J.P. et al. Genome-wide association analysis for body weight identifies candidate genes related to development and metabolism in rainbow trout (Oncorhynchus mykiss). Mol Genet Genomics 294, 563–571 (2019). https://doi.org/10.1007/s00438-018-1518-2

Rosenfeld, C. & L. Manley. 2011. Diagnóstico de Bioseguridad en Centros Acuícolas. Universidad Austral de Chile-Servicio Nacional de Pesca. Informe Final.

Sepulveda, M., I. Arismendi, D. Soto, F. Jara and F. Farias (2013). "Escaped farmed salmon and trout in Chile: incidence, impacts, and the need for an ecosystem view." Aquaculture Environment Interactions 4(3): 273-283.

Sernapesca. 2022a. Informe Sobre Uso de Antimicrobianos en la Salmonicultura Nacional Primer Semestre - Año 2022. Subdirección de Acuicultura, Departamento de Salud Animal Valparaíso, Septiembre 2022.

Sernapesca. 2022b. Informe Sobre Uso de Antimicrobianos en la Salmonicultura Nacional Año 2021. Subdirección de Acuicultura, Departamento de Salud Animal Valparaíso, Mayo 2022.

Sernapesca. 2022c. Informe Sanitario con Información Sanitaria de Agua Dulce y Mar Año 2021. Departamento de Salud Animal Subdirección de Acuicultura. Servicio Nacional De Pesca Y Acuicultura, .

Sernapesca. 2022d. Informe Sanitario con Información Sanitaria de Agua Dulce y Mar, 1° Semestre Año 2022. Departamento de Salud Animal Subdirección de Acuicultura. Servicio Nacional De Pesca Y Acuicultura. Septiembre, 2022.

SILOB. 2007a. Proyecto de Revalorización de Residuos Sólidos Centros de Cultivo de Salmonídeos Piscícola Entre Ríos. Departamento Ambiental, Silob Chile, N° Documento Per 06/2007June, 2007. Ficha del Proyecto: Centro de Cultivo Huite (sea.gob.cl)

SILOB. 2007b. Declaración De Impacto Ambiental Proyecto De Cultivo De Salmonídeos - Centro Huite. Document # PERIOS 05/2007. 04/07/07. Ficha del Proyecto: Centro de Cultivo Huite (sea.gob.cl)

Sindilariu, P.D. (2007). Reduction in effluent nutrient loads from flow-through facilities for trout production: a review. Aquaculture Research, 38(10), 1005–1036. doi:10.1111/j.1365-2109.2007.01751.x

Soto, D., Arismendi, I., Olivos, J. A., Canales-Aguirre, C. B., Leon-Muñoz, J., Niklitschek, E. J., Sepúlveda, M., Paredes, F., Gomez-Uchida, D., & Soria-Galvarro, Y. (2022). Environmental risk assessment of non-native salmonid escapes from net pens in the Chilean Patagonia. Reviews in Aquaculture. https://doi.org/10.1111/raq.12711

Tacon, A. G. J., & Metian, M. (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture, 285(1-4), 146–158. doi:10.1016/j.aquaculture.2008.08.015

Vanhaecke, D., Garcia de Leaniz, C., Gajardo, G., Young, K., Sanzana, J., Orellana, G., Fowler, D., Howes, P., Monzon-Arguello, C., & Consuegra, S. (2012). DNA barcoding and microsatellites help species delimitation and hybrid identification in endangered galaxiid fishes. PLoS One, 7(3), e32939. https://doi.org/10.1371/journal.pone.0032939

Young, K. A., J. B. Dunham, J. F. Stephenson, A. Terreau, A. F. Thailly, G. Gajardo and C. Garcia de Leaniz (2010). "A trial of two trouts: comparing the impacts of rainbow and brown trout on a native galaxiid." Animal Conservation 13(4): 399-410.

Appendix 1: Example of Laboratory Report on Water Quality

Hidrolab

Informe de Análisis 66292/2021.1

Este informe de análisis cancela y sustituye el informe 66292/2021.0

Cotización: C2235/2021.2

(AC-041)

Fecha Emisión Informe: 24-01-2022 15:25

Identificación del Cliente		
Cliente: PISCICOLA ENTRE RIOS LIMITADA	**RUT:**	96.594.200-9
Dirección: Hijuela II, Fundo el Carmen de Sorrento, Talagante, RM - Chile		

N° Muestra: 66292-1/2021.1 - Id: 152362 - Piscicola Entre Rios Ltda / Efluente - Piscicultura Huite / (Tabla N°1 DS90)			
Matriz:	Agua residual		
Término de muestreo:	01-12-2021 09:50	**Fecha de Recepción:**	02-12-2021 09:00
Comuna:	Los Lagos	**Región:**	Región de Los Ríos
Lugar de muestreo:	Piscicultura Huite	**Punto de muestreo:**	Efluente
Dirección de muestreo:	Parcela N°19, Lote B, Colonia Lipingue, Sector el Salto	**Instrumento ambiental:**	RES: 4151/2011
Proyecto:	Piscicultura Huite	**Muestreado por:**	Carlos Almonacid LLanquin
Tipo de muestreo:	Compuesto 8 h		

Resultados Analíticos

Parámetro	Resultado	LD	Referencia	Fecha y Hora Análisis
Aceites y grasas	< 5,00 mg/L	< 5,00 mg/L	NCh 2313/6:2015	02-12-2021 16:41
Aluminio	0,113 mg Al/L	< 0,01 mg Al/L	NCh 2313/25.Of97	08-12-2021 00:00
Arsénico	< 0,001 mg As/L	< 0,001 mg As/L	NCh 2313/9.Of96	10-12-2021 10:32
Boro	0,073 mg B/L	< 0,02 mg B/L	SM 3030 F, 3120 B	08-12-2021 00:00
Cadmio	< 0,001 mg Cd/L	< 0,001 mg Cd/L	NCh 2313/25.Of97	08-12-2021 00:00
Cianuro	< 0,02 mg CN/L	< 0,02 mg CN/L	NCh 2313/14.Of97	03-12-2021 15:34
Cinc	0,052 mg Zn/L	< 0,002 mg Zn/L	SM 3030 E, 3125 B	08-12-2021 00:00
Cloruro	4,84 mg Cl/L	< 3,00 mg Cl/L	NCh 2313/32.Of1999	07-12-2021 09:07
Cobre	0,113 mg Cu/L	< 0,005 mg Cu/L	NCh 2313/25.Of97	08-12-2021 00:00
Conductividad	78,9 us/cm	< 1,0 us/cm	SM 2510 B	02-12-2021 14:19
Cromo hexavalente	< 0,010 mg/L	< 0,010 mg/L	NCh 2313/11.Of96	02-12-2021 09:30
Demanda Bioquímica de Oxígeno	5,48 mg/L	< 2,00 mg/L	NCh 2313/5.Of2005	02-12-2021 10:00
Fluoruro	< 0,10 mg F/L	< 0,10 mg F/L	NCh 2313/33.Of1999	13-12-2021 18:22
Fósforo	< 0,200 mg P/L	< 0,200 mg P/L	NCh 2313/15:2009	09-12-2021 18:02
Hidrocarburos fijos	< 5,000 mg/L	< 5,000 mg/L	NCh 2313/7.Of97	02-12-2021 16:41
Hierro disuelto	< 0,020 mg/L	< 0,020 mg/L	SM 3030 B, 3120 B	10-12-2021 00:00
Índice de fenol	< 0,100 mg/L	< 0,100 mg/L	SM 5530 C	03-12-2021 16:09
m,p xileno	< 5 ug/L	< 5 ug/L	NCh 2313/31.Of1999	03-12-2021 10:30
Manganeso	0,007 mg Mn/L	< 0,001 mg Mn/L	NCh 2313/25.Of97	08-12-2021 00:00
Mercurio	< 0,001 mg Hg/L	< 0,001 mg Hg/L	NCh 2313/12.Of96	10-12-2021 09:29
Molibdeno	< 0,005 mg Mo/L	< 0,005 mg Mo/L	NCh 2313/25.Of97	08-12-2021 00:00
Níquel	< 0,005 mg Ni/L	< 0,005 mg Ni/L	NCh 2313/25.Of97	08-12-2021 00:00
Nitrógeno total Kjeldahl	2,3 mg/L	< 0,1 mg/L	NCh 2313/28-2009	06-12-2021 10:57
o-Xileno	< 5 ug/L	< 5 ug/L	NCh 2313/31	03-12-2021 10:30
Pentaclorofenol	< 0,0010 mg/L	< 0,0010 mg/L	NCh 2313/29.Of99	03-12-2021 13:04

Avenida Central No 681 - Quilicura - Teléfono: 22 756 6350 - www.hidrolab.com
Rut 78.370.360-2

Pag. 1/2

Hidrolab

Informe de Análisis 66292/2021.1

Este informe de análisis cancela y sustituye el informe 66292/2021.0

Cotización: C2235/2021.2

Resultados Analíticos				
Parámetro	**Resultado**	**LD**	**Referencia**	**Fecha y Hora Análisis**
pH	6,97 unidad de pH	--- unidad de pH	NCh 2313/1.Of95	02-12-2021 14:23
Plomo	< 0,02 mg Pb/L	< 0,02 mg Pb/L	NCh 2313/25.Of97	08-12-2021 00:00
Poder espumógeno	< 2 mm	< 2 mm	NCh2313/21-2010	02-12-2021 12:22
Selenio	< 0,005 mg Se/L	< 0,005 mg Se/L	NCh 2313/30.Of1999	10-12-2021 10:29
Sólidos suspendidos totales	< 5,00 mg/L	< 5,00 mg/L	NCh 2313/3.Of95	02-12-2021 17:29
Sulfatos	< 5,0 mg SO4/L	< 5,0 mg SO4/L	SM 4500 SO4 C	05-12-2021 11:16
Sulfuros	< 0,1 mg/L	< 0,1 mg/L	NCh 2313/17.Of97	03-12-2021 14:33
Temperatura pH	19,3 °C	--- °C	SM 2550 C	02-12-2021 14:23
Tetracloroeteno	< 0,0050 mg/L	< 0,0050 mg/L	NCh 2313/20.Of98	03-12-2021 11:00
Tolueno	< 0,005 mg/L	< 0,005 mg/L	NCh 2313/31.Of1999	03-12-2021 10:30
Triclorometano	< 0,0050 mg/L	< 0,0050 mg/L	NCh 2313/20.Of98	03-12-2021 11:00
Xilenos	< 0,0050 mg/L	< 0,0050 mg/L	ISO 11423-1:1997	06-12-2021 13:14

Notas

ND: No determinado.
LD: Límite de Detección. LD para todos los ensayos excepto ensayos de cromatografía gaseosa, en el cual se considera Límite de Cuantificación.
SM: *Standard Methods* for the Examination of Water and Wastewater, 23rd. Edition 2017.

Resultados válidos únicamente para la muestra analizada.
Prohibida toda reproducción parcial o total de este informe sin autorización del laboratorio.
Hidrolab se encuentra bajo las Acreditaciones INN LE 214 - LE 215 - LE 1273 - LE 1431 - LE 1432; de acuerdo a NCh-ISO 17025:2017

Ximena Cuadros Moya
I.A.: 8.701.037-6

Ximena Cuadros Moya
Responsable Técnico/Rep. Legal

Código de Validación: 1e46a0c764bb46c8b53f84fa4fa7f730

La validación de este documento puede ser realizada en: portal.mylimsweb.com.

Appendix 2: Example of Veterinary Prescription

Veterinary prescription (Prescripción Médico Veterinaria) from July 10, 2020, for florfenicol at the Llallalca site. Fish were small (4.15 g), diagnosed with Flavobacteriosis. It is interesting to note that the unit (grams) for the total active ingredient (Cantidad droga pura) is incorrect, and should be kg. The correct values (i.e., 0.22 kg active ingredient) were noted in the treatment records provided by the farm.

Aquagestión Salud

PRESCRIPCIÓN MÉDICO VETERINARIA

N° AQAA-LLA-20-2

FECHA	10-07-2020
EMPRESA	Piscicola Entre Rios Ltda
CENTRO Y CÓDIGO	Llallalca /102261
ESPECIE	*O. mykiss*
JAULAS/ESTANQUES	Bateas 23 A 32
LOTE	HLL300320
Nº DE PECES AL TRATAMIENTO	141.299
PESO PROMEDIO (gr)	4,15
DIAGNÓSTICO	Flavobacteriois
BIOMASA AL TRATAMIENTO (Kg)	586
METODO DE APLICACIÓN	medicado oral

RP: INFORME LABORATORIO Nº 4767

Droga	Florfenicol
Producto Comercial	Veterin 50%
Concentracion	50%
Laboratorio	Centrovet
Dosis (mg/Kg)	20
Tiempo de Tratamiento (días)	14
Cantidad droga pura (gr)	0,22
Cantidad droga comercial (gr)	0,43
Kgs Prod. Comercial / Ton. Alimento	1,53
Cantidad de alimento (Kg)	284
Fecha Inicio Tratamiento:	11-07-2020
Fecha Termino de Tratamiento:	24-07-2020
Temperatura del agua	9,6
UTA Recomendadas:	300
Observaciones:	% PC rebajado a 2,62%

MÉDICO VETERINARIO Alejandra Aedo Pinto
RUT 13.730.925-4

Firma

Appendix 3: Example of a Certificate for Authorized Fish Movements

Folio de Certificado de Autorización de Movimiento: 502022119212
Fecha Emisión: 10-11-2022 11:02 AM
Folio CSM Asociado: 00046654

AUTORIZACIÓN DE MOVIMIENTO DE ACUICULTURA

De conformidad con lo dispuesto en la resolución Ex. Nº 1971 del Servicio Nacional de Pesca se autoriza a:

Información Autorización

Tipo de Origen | Origen	Centros de Acuicultura | 90059
Titular	78665600-1 PISCICOLA HUILILCO LTDA.
Región | Comuna | Sector Origen	IX REGION | Pucón | CARILEUFU
Tipo Procedencia	Propia
Tipo Movimiento	Movimiento Destino Directo
Tipo Carga a Trasladar	Alevines o Smolts
Especie a trasladar | Cantidad a Trasladar	TRUCHA ARCOIRIS | 100.000
Biomasa [KG]	10
Tipo Destino | Destino	Centros de Acuicultura | 102261 LLALLALCA (Centros de Acuicultura)
Region Destino | Comuna Destino | Sector Destino	XIV REGION | Panguipulli | NELTUME CAMINO A
Fecha Inicio de Movimiento | Fecha Fin de Vigencia	10-11-2022 - 13-11-2022

Documento Tributario

Tipo Documento	Fecha Documento	Número Documento	Rut
Guía de Despacho	10-11-2022	295	78665600-1

Transporte Terrestre

Rut Empresa /Rut Persona Natural	Nombre Empresa/Nombre Persona Natural	Tipo de Vehículo	Patente Vehículo	Patente Carro Arrastre	Salmoducto
78665600-1	HUILILCO LTDA.	Camioneta	PKRL39		No

Observaciones Sin Observaciones

"Este Certificado, junto al Documento Tributario, deberá acompañar la carga durante todo el trayecto debiendo quedar una copia en el origen y el destino. En el caso de destinarse peces a planta de proceso para consumo humano, los peces que se encuentran evidentemente enfermos de la cosecha, deberán ser apartados y destinados a mortalidad."

502022905913

Appendix 4: Example of Sanitary Movement Certificate

SERNAPESCA

CERTIFICADO SANITARIO DE MOVIMIENTO

Folio CSM: 00046654

Tipo de Origen | Código del Centro de Origen	Centros de Acuicultura | 90059
Nombre del Titular	78665600-1 PISCICOLA HUILILCO LTDA.
Sector | Comuna | Región	CARILEUFU | Pucón | IX REGION
Condición Sanitaria	Negativo (PSEVC- ISA)
Actividad Desarrollada	INCUBACIÓN
Especie a trasladar | Etapa de Desarrollo	TRUCHA ARCOIRIS | ALEVINES
Tipo Carga a Trasladar	Recursos Vivos
Tipo Procedencia | Procedencia	Propia | Propia

Movimiento de Alevines o Smolts

Identificador grupo alevines o smolts muestreados	Número de Alevines o Smolts	Peso Promedio [Gr]	Biomasa [Kg]	Origen
PBB22	100.000	0,1	10	Nacional null

Destino Final

Tipo de Destino Final	Nombre	Región	Comuna	AC	Descanso Sanitario
Centros de Acuicultura	LLALLALCA 102261	XIV REGION	Panguipulli		

Observaciones Evaluador

Fecha Inicio Vigencia | Fecha Término Vigencia 10-11-2022 | 30-11-2022

Este certificado deberá acompañar cada movimiento, debiendo quedar una copia en el origen y el destino. En el caso de destinarse peces a planta de proceso para consumo humano, los peces que se encuentran evidentemente enfermos de la cosecha, deberán ser apartados y destinados a mortalidad. Las embarcaciones utilizadas en las solicitudes de movimiento, debe ser registrada en el correo navesacuicultura@sernapesca.cl, tal como establece el D.S.139, artículo 14.

ROLANDO MAURICIO ARIAS SILVA

SERVICIO NACIONAL DE PESCA Y ACUICULTURA — MINISTERIO DE ECONOMÍA FOMENTO Y TURISMO

46754

Appendix 5: Example of a Health Certificate for Live Fish Movements

CERTIFICADO DE SALUD PARA TRANSPORTE DE PECES VIVOS

(El presente certificado tiene una validez de 15 días a contar de su fecha de emisión)

N°: 658

Fecha de emisión: 10-11-2022

DATOS DE CENTRO DE CULTIVO DE ORIGEN

NOMBRE EMPRESA TITULAR	Piscícola Huililco Ltda.
NOMBRE Y CÓDIGO DE CENTRO	Ojos del Caburgua - 90059
UBICACIÓN GEOGRÁFICA	IX Región - Pucón

DATOS DE DESTINO

NOMBRE EMPRESA TITULAR	Piscícola Entre Rios Ltda.
NOMBRE Y CÓDIGO CENTRO/PLANTA	Centro Llallalca - 102261
UBICACIÓN GEOGRÁFICA	Panguipulli – XIV Región

IDENTIFICACIÓN DE LOS PECES

ESPECIE	Trucha Arco iris
IDENTIFICACIÓN DEL(LOS) LOTE(S)	PBB22
NÚMERO DE PECES	100.000
ESTADIO DE DESARROLLO	Alevines 0,141grs.

MOTIVO DEL TRANSPORTE

COSECHA		ENGORDA		ESMOLTIFICACIÓN		REPRODUCCIÓN	

OTRO (especificar): Venta

El que suscribe certifica que:

1. En el centro de cultivo de origen no se han detectado los agentes causales de las Enfermedades de Alto Riesgo (EAR) Lista 1 de Peces, de acuerdo al informe INF/PSEV N° 1934CL22 del Programa Sanitario Específico de Vigilancia de Enfermedades de Alto Riesgo.

2. El centro de cultivo de origen de los peces a transportar, correspondientes al(los) lote(s) PBB22 de acuerdo a los Programas Sanitarios Específicos de Vigilancia y Control (PSEVC) para las Enfermedades de Alto Riesgo (EAR) Lista 2 de Peces, se encuentra categorizado según las siguientes condiciones sanitarias:

	CATEGORÍA PSEVC
ANEMIA INFECCIOSA DEL SALMÓN (ISA):	
PISCIRICKETTSIOSIS (SRS):	
CALIGIDOSIS:	

3. Los reproductores que dieron origen a las ovas a transportar fueron sometidos a screening, de acuerdo a lo consignado en el informe INF/PSGR N° ______ del Programa Sanitario General de Manejo de la

4. Observaciones (indicar si los peces presentan alguna otra Enfermedad de Alto Riesgo (EAR), u otra observación):

PISCICULTURA HUILILCO LTDA. CHILE IX REGION PUCON

Francisco Javier Estay Caballero

Nombre y firma del Médico Veterinario responsable

Appendix 6: Example of Laboratory Testing Results for ISA Virus

ARMAQ Analytiq

INFORME ENSAYOS DE LABORATORIO

1935CL22

PA-FOR-LA23 V.08

Cód. Lab. Sernapesca 16

Información del cliente

Empresa / RUT	Piscicola Huilico Limitada / 78665600-1	Dirección	Carleufu Km17 C/Lago Caburg.Hj44-Pucón
Centro	Ojos de Caburga	Tipo de Centro	Piscicultura
Código de Centro	90059	Programa Sanitario	PSEVC ISA
Cuerpo de Agua	Agua Dulce	T° Agua	No Indicado
Solicitud Muestreo	059240622ISA (Cód. interno)	Atención a	Sr(a). FRANCISCO ESTAY

Identificación de la muestra

T° Recepción	6,30 °C Termógrafo 1000856374	Tipo de Muestra	Peces Muertos / No aplica
Especie	Trucha Arcoiris *Oncorhynchus mykiss*	Estado desarrollo/Sexo Peso Promedio	Adultos - Alevines - Smolt / No Aplica 246,300 g.
Tipo Muestreo	Sin Informacion	Fecha/hora muestreo	24 Junio 2022/15:00 hrs.
Resp. Recepción	Yenifer Argel	Fecha/hora recepción	28 Junio 2022/10:00 hrs.
Resp. Muestreo	Cristian Jego	Informe Sanitario	CJ-929-2022
N° de muestras	15	Fecha Informe	30 Junio 2022

Comentarios

Informe no adjunta SMU visada, de acuerdo a resolución DN-519/2022 de Sernapesca.

Biología Molecular

RT-PCR Virus de la Anemia Infecciosa del Salmón (ISAV) Riñón - Corazón - Branquias

C.I.Lab.	Grupo	Estanque	N° de muestra	Ct	Resultado
BM-31602	PBB20	C8	1 - 2 - 3	No Ct	Negativo
BM-31603	PBB21	C12	1 - 2 - 3	No Ct	Negativo
BM-31604	PBB21	C12	4 - 5 - 6	No Ct	Negativo
BM-31605	PBB22	BATEA29	1 - 2 - 3	No Ct	Negativo
BM-31606	PBB22	BATEA29	4 - 5 - 6	No Ct	Negativo

Periodo Analisis: 28 Junio 2022/10:40 hrs. al 28 Junio 2022/17:10 hrs.

PA-INS-BM-01 Instructivo de Diagnóstico de Patógenos Mediante RT-PCR Tiempo Real basado en programa sanitario general laboratorios de diagnóstico de enfermedades de animales acuáticos (LABD-NT2 Pruebas diagnósticas para enfermedades de animales acuáticos). Snow et al., 2006

El Ct de corte validado por Laboratorio Pharmaq Analytiq es 37.

Rodolfo Delpino
Responsable de análisis y resultados
ENCARGADO DE BIOLOGÍA MOLECULAR

Jaime Norambuena
Responsable de autorización de informe
JEFE DE OPERACIONES Y SISTEMAS

bf

Appendix 7: Data Points and all Scoring Calculations

Criterion 1: Data	
Data Category	**Data Quality**
Production	10.0
Management	10.0
Effluent	10.0
Habitat	7.5
Chemical Use	10.0
Feed	7.5
Escapes	7.5
Disease	7.5
Source of Stock	10.0
Wildlife Mortalities	7.5
Escape of Secondary Species	10.0
C1 Data Final Score (0–10)	**8.864**
	Green

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0–10)	**8**
Critical?	NO

Criterion 3: Habitat	
F3.1: Habitat Conversion and Function	**Data and Scores**
F3.1 Score (0–10)	8
F3.2: Management of Farm-Level and Cumulative Habitat Impacts	
3.2a: Content of habitat management measure	5
3.2b: Enforcement of habitat management measures	5
3.2: Habitat management effectiveness	10.000
C3 Habitat Final Score (0–10)	**8.667**
Critical?	No

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**
Chemical use initial score (0–10)	10
Trend adjustment	0
C4 Chemical Use Final Score (0–10)	**10**

Critical?	No

Criterion 5: Feed	
5.1: Wild Fish Use	
5.1a: Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	6.970
Fishmeal from by-products, weighted inclusion %	2.340
Byproduct fishmeal inclusion (@ 5%)	0.117
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	6.760
Fish oil from by-products, weighted inclusion %	0.180
By-product fish oil inclusion (@ 5%)	0.009
Fish oil yield value, weighted %	5.000
eFCR	0.990
FFER Fishmeal value	**0.312**
FFER Fish oil value	**1.340**
Critical (FFER >4)?	No

5.1b: Sustainability of Source Fisheries	**Data and Scores**
Source fishery sustainability score	3.000
Critical source fisheries?	No
SFW "Red" source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER ≥1)?	No
Final Factor 5.1 Score	**2.350**

5.2: Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	43.500
Protein INPUT kg/100 kg harvest	43.065
Whole body harvested fish protein content	15.700
Net protein gain or loss	–63.543
Species-specific Factor 5.2 score	**3**
Critical (Score = 0)?	No
Critical (FFER >3 and 5.2 score <2)?	No

5.3: Feed Footprint	**Data and Scores**
GWP (kg CO_2-eq kg^{-1} farmed seafood protein)	**14.226**
Contribution (%) from fishmeal from whole fish	4.017
Contribution (%) from fish oil from whole fish	2.461
Contribution (%) from fishmeal from by-products	1.349
Contribution (%) from fish oil from by-products	0.066

Contribution (%) from crop ingredients	81.285
Contribution (%) from land animal ingredients	8.571
Contribution (%) from other ingredients	2.252
Factor 5.3 score	**6**
C5 Final Feed Criterion Score	**3.4**
Critical?	**No**

Criterion 6: Escapes	**Data and Scores**
F6.1 System escape risk	7
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	7.000
F6.2 Invasiveness score	4
C6 Escape Final Score (0–10)	**5.0**
Critical?	No

Criterion 7: Disease	**Data and Scores**
Evidence-based or Risk-based assessment	Evidence
Final C7 Disease Criterion score (0–10)	**8**
Critical?	No

Criterion 8X: Source of Stock	**Data and Scores**
Percent of production dependent on wild sources (%)	0.0
Initial source of stock score (0-10)	0.0
Use of ETP or SFW “Red” fishery sources	No
Lowest score if multiple species farmed (0–10)	n/a
C8X Source of Stock Final Score (0–10)	**0**
Critical?	No

Criterion 9X: Wildlife Mortality Parameters	**Data and Scores**
Single species wildlife mortality score	–1
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**–1**
Critical?	No

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on trans-waterbody movements (%)	100
Factor 10Xa score	0
Biosecurity of the source of movements (0–10)	7

Biosecurity of the farm destination of movements (0–10)	4
Species-specific score 10X score	–3.000
Multispecies assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**–3.000**
Critical?	n/a