Rainbow Trout

Oncorhynchus mykiss

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Colombia

Freshwater net pen, Freshwater raceways and Ponds

Assessment ID 28255

January 8, 2024

Seafood Watch Standard used in this assessment: Aquaculture Standard v3.2

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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

Rainbow trout produced in net pens and raceways/ponds in Colombia.

Criterion	Score: Net Pens		Score: Raceways/Ponds
C1 Data	5.46		5.00
C2 Effluent	4.00		4.00
C3 Habitat	6.93		5.47
C4 Chemicals	4.00		4.00
C5 Feed	4.35		4.35
C6 Escapes	4.00		6.00
C7 Disease	4.00		4.00
C8X Source	0.00		0.00
C9X Wildlife	–5.00		–5.00
C10X Introduction of secondary species	–4.00		–4.00
Total	23.74		23.82
Final score (0–10)	**3.39**		**3.40**

OVERALL RATING

	Net Pens		Raceways/Ponds
Final Score	3.39		3.40
Initial rating	Yellow		Yellow
Red criteria	0		0
Interim rating	Yellow		Yellow
Critical Criteria?	0		0
Final rating	**Yellow**		**Yellow**

Scoring note: Scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Two or more Red criteria, or one Critical criterion, trigger an overall Red recommendation.

Summary

- The final numerical score for rainbow trout (*Oncorhynchus mykiss*) produced in net pens in Colombia is 3.39 out of 10, which is in the Yellow range. The final recommendation is Yellow or “Good Alternative.”
- The final numerical score for rainbow trout (*Oncorhynchus mykiss*) produced in raceways and ponds in Colombia is 3.40 out of 10, which is in the Yellow range. The final recommendation is Yellow or “Good Alternative.”

Executive Summary

Colombia's total finfish aquaculture production is approximately 190,000 metric tons (mt) (188,658 mt in 2021), of which 16% or approximately 30,000 mt is rainbow trout. This represents 3.2% of global rainbow trout production (952,690.8 mt in 2021). Colombia's total export of rainbow trout has varied between 900 mt and 1,800 mt over the past decade, with 1,745 mt of trout exports in 2022, of which approximately half was destined for the United States (an average of 790 mt between 2019 and 2021). There is also a strong domestic market.

In Colombia, rainbow trout is produced in two primary types of production systems. The first group is net pens located in two high-altitude freshwater lakes: Lake Tota in the central-northern department of Boyacá and Lake Cocha (also known as Lake Guamuez) in the southern department of Nariño. The second group of production systems is a variety of land-based ponds, pools, and raceways of simple cement or earthen construction, also located in the high-altitude areas of Colombia. The bulk of land-based production comes from the departments of Cauca and Antioquia, with lesser volumes from Tolima, Cundinamarca, and Risaralda. There is considerable physical variation within this land-based group, but they are referred to throughout this report as raceways and ponds.

The assessment involves criteria covering 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.[2] Two separate assessments have been conducted for net pens and raceways/ponds. It should be noted that Seafood Watch also has separate recommendations for farmed rainbow trout certified to various assurance schemes. See the Seafood Watch information on certified seafood here.[3]

Data availability in Colombia has improved with increasing amounts of information available from a variety of sources, particularly the government, as well as industry; for example, the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), the National Authority on Aquaculture and Fisheries (Autoridad Nacional de Acuicultura y Pesca—AUNAP), the Institute of Agriculture (Instituto Colombiano Agropecuario—ICA), the Information System of the Colombian Fishing Statistical Service (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC), and the industry body Fedeacua (Federación Colombiana De Acuicultores). Nevertheless, many of the criteria in this assessment suffer from limited relevant data, and the specific roles of additional organizations regarding aquaculture (for example, the Ministry of Environment and Sustainable Development; Ministerio de Ambiente y Desarrollo Sostenible—MADS), are not easy to determine. From a list of 1,342 aquaculture farms available from AUNAP, 67 were identified as trout producers (by name or location) and contacted by email. Four companies responded and provided useful information and data, but understanding typical production practices and the nature of their impacts (if any) across the large number of farms in the country remains

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

[3] https://www.seafoodwatch.org/recommendations/certified-seafood

challenging. The industry organization Fedeacua also provided some information and facilitated some specific feed data from two companies. While many academic studies provided useful information, some were specifically misleading, and many research gaps remain. Overall, the Data score for net pens is slightly higher than that of ponds (there are only two lakes in which net pen trout production is permitted), and the final scores for Criterion 1—Data are 5.5 out of 10 for net pens and 5.0 for raceways and ponds.

It is clear that the production of trout in net pens (which is based on the addition of external formulated feeds) represents a direct source of soluble and particulate nutrient wastes into freshwater lakes, and the ecological importance of maintaining high water quality in these lakes is recognized. But even though the two lakes, Tota and Cocha, have some similar characteristics and conditions, the nutrient dynamics of both lakes are complex and affected by many factors. In Lake Tota, nutrient studies show that the intensive onion farming industry (and particularly its poorly controlled fertilizer applications) is the dominant nutrient source in the lake, followed by the municipal wastes from the town of Aquitaine, which has not had an operational wastewater treatment plant for decades. There were concerns that the lake was becoming eutrophic from these nutrient inputs in the early 1980s, before the development of trout farming in the lake. Nevertheless, it is clear from both lakes that intensive trout production will have a local impact on the water column and the benthos, and some nutrient dynamics in these lakes (e.g., of phosphorous) remain unclear. Because of these concerns, since 2018, all producers in Lake Tota are required to use collector devices under the net pens to remove particulate waste from the lake, but no evidence could be found that this is also done in Lake Cocha. The soluble portion of the total waste is still released into the lakes. Overall, the available monitoring data show that the water quality in both lakes is acceptable, but there are clear concerns regarding a trend toward eutrophication with the long-term accumulation of anthropogenic nutrients in lakes with long hydraulic retention times. The relevance of several nutrient studies relating to the farms is limited by fieldwork conducted before installation of the collectors in Lake Tota. Nevertheless, given the importance of both lakes in Colombia and the desire to limit any further progress toward eutrophication, the direct contribution of nutrients from net pen trout farms to the lakes is inevitably a concern. Although the nutrient inputs from trout farms may be minor compared to other sources, and studies show that the direct impacts are limited, there is considered to be a clear potential for cumulative impacts at the waterbody scale. Thus, the score for Criterion 2—Effluent for net pens is 4 out of 10.

Influent and effluent monitoring data from a raceway farm, in addition to specific effluent studies (e.g., of three trout farms on the Siecho River), show that the effluent concentrations are low and that impacts may be minor. But without sufficient data to understand the impacts (or lack thereof) of raceway and pond farms more broadly in Colombia, the risk-based assessment was used. Considering typical feed use, it is estimated that there is a total nitrogen input of 88.6 kg N/mt of trout. After the removal of nitrogen in harvested trout, the total waste nitrogen produced is 63.4 kg N/mt. Given the typical flow-through nature of the production systems, 80% of the waste produced is considered to be discharged to the environment (50.8 kg N/mt, and a score of 4 out of 10 for Factor 2.1). Educational information produced by Fedeacua and the government describes a substantial regulatory permitting framework, but there do not appear to be specific effluent limits in place for individual farms. There continues to be a low uptake of permits because the large majority of farms operate in an “informal” manner. Considerable efforts are being made to increase permitting, but the costs of compliance are a challenge for small producers, and the goal of 50% of formalized producers by 2032 shows that progress is slow. Thus, with limitations in the regulations and low effective enforcement, the effluent management score (Factor 2.2) is 2.4 out of 10. The scores for Factors 2.1 and 2.2 combine to give a final score for Criterion 2—Effluent for raceways and ponds of 4 out of 10.

Although examples of companies with chemical-free rainbow trout production are available in Colombia, there is no central source of data with which to understand chemical use across all the farms in the country. Personal communications with representatives of two grow-out farms (one using net pens and one using raceways) and one fingerling producer helped describe common chemical-use characteristics, but it is noted that their practices cannot robustly be extrapolated to other trout farms. Antimicrobial use is the primary concern, and there is no evidence of pesticide use or any other chemicals of concern. Antimicrobial use appears to be largely restricted to the moderately frequent treatment of small fish in the hatchery (up to 3 g), or a common treatment immediately after transfer to the net pens or raceways (between 10 and 30 g). These treatments are mostly associated with the *Flavobacteirum* pathogen, which causes rainbow trout fry/fingerling syndrome. Thus, it is possible that some fish may be treated more than once per production cycle, but because of the small amounts of active chemicals used for such small fish (for example, compared to rainbow trout grown to a large harvest size in marine net pens), the overall concern for potential environmental impacts or contributions to the development of resistance is generally lower. Regarding the scoring, it cannot be confirmed that the frequency of antimicrobial treatments is less than 1 per cycle (which would score 8 out of 10), but considering the treatment of only small fish, it could be argued that there is a demonstrably low need for chemical use (which would score 6 out of 10). Nevertheless, the somewhat routine use of antimicrobials could also be argued to indicate a dependency on chemical intervention (which would score 2 out of 10), and the regular use of only two different types of antimicrobials, even in small quantities (in addition to an isolated case reporting antimicrobial resistance in *Weissella* bacteria), could represent some concern for the development of resistance (score 4 out of 10). Overall, with the typical use apparently focused on small quantities of antimicrobials to treat small fish, the intermediate score of 4 is considered to be the most appropriate, indicating a moderate concern. It could be argued that the larger companies (on whose personal communication this assessment was based) have more robust management and better control of chemical use, so the score of 4 out of 10 may not be representative of the many smaller companies in Colombia. On the other hand, it could be argued that the big companies are more likely to have disease problems and may be more willing to use expensive antimicrobial treatments than small farms. Therefore, although the generalization is noted here, the final score for Criterion 4—Chemical Use of 4 out of 10 is applied to all farmed trout in Colombia.

Specific data on the composition of rainbow trout feeds in Colombia are limited (and typically considered proprietary information), but some important details on marine and other aquatic ingredients were provided by two feed companies through third-party communications with Fedeacua. Additional data on feed ingredients, and particularly on protein contents, were available from the websites of four companies representing six brands of feeds. An academic reference feed from a review of rainbow trout nutrition was also used to create a best-fit feed formulation for this assessment. An average feed conversion ratio value of 1.35 was approximated from a variety of sources. Although this value may vary between production systems (i.e., slightly higher in net pens and slightly lower in raceways), there was not sufficient granularity of data to generate separate scores here. With a high proportion of the fishmeal coming from by-product fishmeal sources, and all the fish oil (from tuna processing wastes from Ecuador and domestic farmed tilapia by-products), the Feed Fish Efficiency ratio was low. From first principles, 0.23 mt of wild fish would need to be caught to supply the fishmeal to produce 1 mt of rainbow trout in Colombia. The sources and sustainability of the fishmeal from whole fish was not provided, and this reduced the Wild Fish Use score (Factor 5.1) to 4.20 out of 10. With the bulk of production taking place on feeds with 40% protein, the weighted average feed protein content for the whole production cycle was 41.0%. With a lower protein output in farmed trout, there is a substantial net loss of protein of 71.8%, and a score of 2 out of 10 for Factor 5.2. Using economic allocations, the use of by-product aquatic ingredients helped to give a relatively low feed footprint (calculated as the embedded climate change impact in kg CO_2-eq of the feed ingredients) of 11.77 kg CO_2-eq kg^{-1} and a score of 7 out of 10 for Factor 5.3. Factors 5.1, 5.2, and 5.3 combine to give a final Criterion 5—Feed score of 4.35 out of 10.

No data or records are available on escape events from trout farms in Colombia. Resolution 2879 lists the escape minimization requirements for ponds and net pens, but it is not known how thoroughly these are implemented across the formalized and nonformalized farms in Colombia. It can be seen that the typical net pen structures and typical fish handling practices inevitably have some vulnerability to large-scale or trickle losses. As flow-through systems with high densities of fish, raceways and ponds also have a risk of escape, but the likely use of multiple screens and the potential for direct on-farm recapture substantially reduce the risk. Flooding is inevitably a concern in riparian locations, but the areas suitable for trout farming in Colombia are outside the country's major flooding regions. Although no specific data are available, in the event of an escape in the lakes, an active angling presence in addition to arrangements with local fishers indicate that significant recapture is likely, but no data on recaptures are available for either net pens or raceways/ponds. The escape risk remains high, and the escape risk score (Factor 6.1) is 2 out of 10 for net pens. The potential for recaptures in the rivers is less clear, but the escape risk score is 6 out of 10 for the more contained raceways and ponds. Rainbow trout is considered to have been widely established in the wild in Colombia because of its introduction and active stocking before the development of aquaculture in net pens and raceways/ponds. Nevertheless, as a highly invasive species that has successfully established across large areas of South America with documented impacts to native species, rainbow trout escapes from farms inevitably continue to be a concern. The apparent decline of rainbow trout populations in the wild after the cessation of active stocking, combined with the sterile all-female nature of the farm stocks, reduces this concern but does not negate it entirely. Therefore, any escapes must be considered to have a risk of competition, predation, disturbance, or other impacts to wild species, habitats, or ecosystems. The score for Factor

6.2—Competitive and Genetic Interactions is 6 out of 10. Factors 6.1 and 6.2 combine to give final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 6 out of 10 for raceways and ponds.

It is clear that pathogens and parasites have become increasingly problematic in trout aquaculture in Colombia as it has intensified and increased in scale, and there is evidence of large mortality events associated with disease. But there is no readily available routine monitoring information or data on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and raceway/pond farms are considered to be "open" to the environment, in terms of the potential for amplification of pathogens within them and the subsequent release of those pathogens into waters shared with wild fish. Although some biosecurity measures and best practices have been established (by the government's Institute of Agriculture), their level of implementation among farms is uncertain. The limited amount of data means that the risk-based assessment has been used (the Data Criterion score for the disease section is <7.5 out of 10), and with open systems but no evidence of infections or mortalities in wild fish as a result of pathogen discharges from trout farms, the final score for Criterion 7—Disease for both net pens and raceways/ponds is 4 out of 10.

Rainbow trout has been selectively bred for beneficial traits such as growth rate and disease resistance for decades throughout the world. Two international companies supply all the eggs currently used in Colombia (Troutlodge from the United States and Troutex from Denmark). These suppliers specialize in the domestication and selective breeding of trout from captive breeding stocks. The production of rainbow trout in Colombia 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.

Because of the visually attractive nature of farmed fish to avian or other predators, some wildlife interactions with trout farms in Colombia are to be expected. A now-dated study from 2003 indicated that lethal control (shooting) was used, but expert opinion now considers this to have ceased. One company provided details on predator exclusion and deterrence methods, but there is no robust information available on current activities or mortality data across the broader industry. The presence of occasional reports and anecdotal evidence in the media of injuries to some animals, including vulnerable species, suggests that if there were a substantial mortality concern, then it would be similarly reported. As noted in Criterion 3—Habitat, trout farms in Colombia have developed in landscapes that had already been substantially affected by humans, and similar predatory species have been (and may continue to be) exploited for human consumption by rural communities. Thus, the extent of current interactions with wildlife in trout farms are challenging to determine, but given Colombia's biodiversity and large numbers of vulnerable species, there is inevitably some concern and a need for precaution. There are regulations in place and examples of farm management plans regarding the use of predator netting, and it is likely that farmers would use nets or other exclusions whenever there is a significant risk of loss to the stock. A small risk of entanglement remains. Overall, expert opinion indicates that lethal control is no longer used, and there is some evidence of regulations or management measures in place for nonharmful exclusion; however, their enforcement or enactment across the industry are uncertain, and mortality numbers are unknown. The potential for accidental mortalities such as entanglements remains. With considerable uncertainty, the risk-based assessment must be used, and the final score for Criterion 9X is a precautionary deduction of –5 out of –10.

Throughout its development, the Colombian rainbow trout industry has relied on imported trout eggs, and according to the Colombian Institute of Agriculture, the majority of production still relies on imported sources. Troutlodge in the United States and Troutex in Denmark are considered to be the dominant suppliers of eggs, but the ICA has also defined import arrangements for trout eggs with Chile and Spain (there are also reports of trout eggs being smuggled into Colombia from Ecuador, but information on the scale or frequency is not readily available). There are substantial movements of trout within Colombia from fingerling producers to grow-out farms, and these are likely to occur between waterbodies. It is estimated that 75% of trout production in Colombia is dependent on live animal movements between waterbodies (i.e., there is a risk that an organism not already present in the receiving waterbody could be introduced from the source). The importation of eggs from the authorized sources has significant biosecurity requirements, particularly the certification of pathogen- and/or disease-free status for 13 pathogens/diseases, and requirements to disinfect eggs within 48 hours of shipment. Although robust biosecurity measures for live fish movements are known to be in place in some fingerling producers (e.g., those certified as biosecure facilities by the ICA), the extent of this program is currently unclear. Overall, the movement of fingerlings within Colombia originating from tank/raceway nurseries is considered to represent a risk of unintentionally introducing organisms to new waterbodies. The final score for Criterion 10X—Introduction of Secondary Species is –4 out of –10.

- The final numerical score for rainbow trout (*Oncorhynchus mykiss*) produced in net pens in Colombia is 3.39 out of 10, which is in the Yellow range. The final recommendation is Yellow or “Good Alternative.”
- The final numerical score for rainbow trout (*Oncorhynchus mykiss*) produced in raceways and ponds in Colombia is 3.40 out of 10, which is in the Yellow range. The final recommendation is Yellow or “Good Alternative.”

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
Colombia

Production Method(s)
Net pens
Raceways and ponds

Species Overview

Brief overview of the species
Oncorhynchus mykiss is a member of the family Salmonidae, which includes Pacific salmon, trout of the genus *Oncorhynchu*s, Atlantic salmon, brown trout, char, whitefishes, and grayling (ITIS 2016). Rainbow trout is native to the western seaboard of North America from Alaska to Baja California, Mexico, as well as the upper Mackenzie River drainage (Arctic basin), Alberta, and British Columbia in Canada. 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.

Salmonids are not native to Colombia. The rainbow trout, known locally as *trucha arcoiris,* was first introduced to the country's Andean streams, rivers, and lakes in 1939, primarily to populate the region's watersheds with a species of higher economic value than native species (Esquivel et al. 2014)(Cruz-Casallas 2011)(CONPES 2014). These intentional introductions and regular stocking for sportfishing resulted in established trout populations throughout nearly all the country's high-elevation lakes, rivers, and tributaries (Alvis 2006)(Cruz-Casallas 2011)(Mora et al. 1992)(Pascual et al. 2007). The stocking programs in Colombia were terminated after 2008 (Merino et al. 2013).

Production systems
In Colombia, rainbow trout is produced in two primary types of production systems, although as discussed below, there is some variation within each group. The first group is net pens located in high-altitude freshwater lakes, primarily in Lake Tota in the central-northern

department of Boyaca and Lake Guamuez (also known as Lake Cocha[4]) in the southern department of Narino (Roca-Lanao et al. 2018). The net pen systems are typically of simple construction with a round or square floating collar from which netting enclosures are suspended (Figures 1–2).

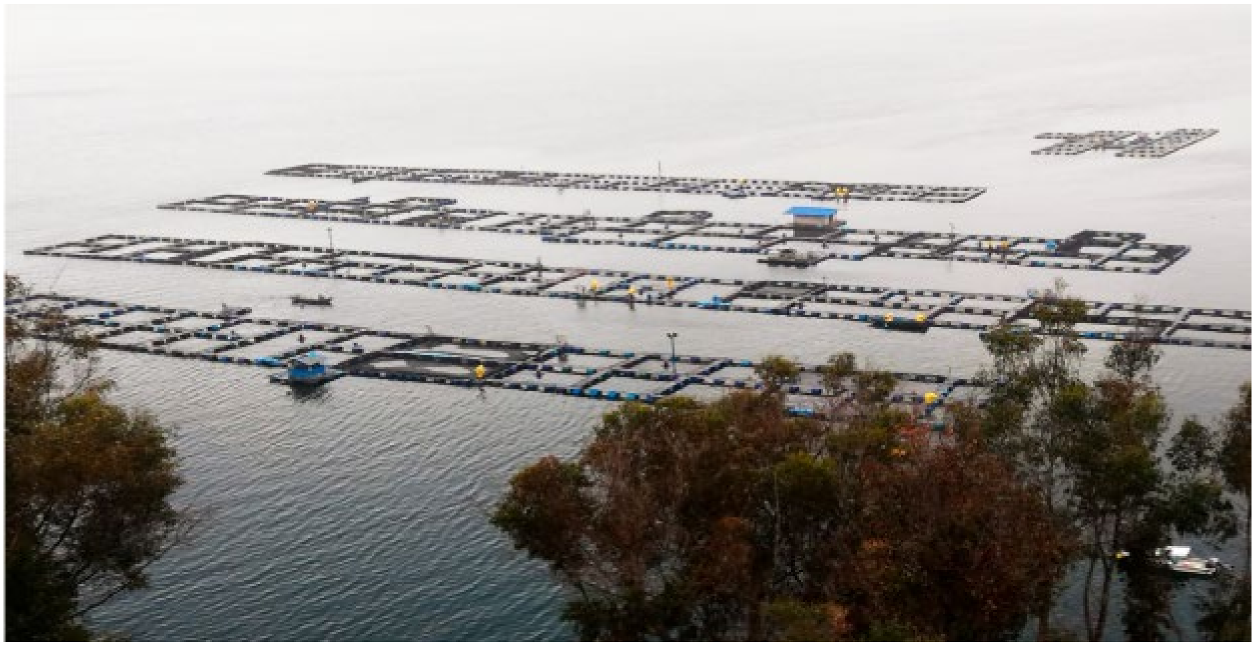

Figure 1: Example of a large net pen rainbow trout farm in Lake Tota.

Figure 2: Example of a small net pen trout farm on Lake Guamuez (Cocha) in southern Colombia (Narino department). Image reproduced from Marcias and Benevidas (2013).

[4] These waterbodies are referred to by several different names in Spanish, including Lago or Laguna, and in the case of Lake Guamuez, as Lago or Laguna Cocha or Guames.

The second group of production systems is a variety of land-based ponds, pools, and raceways of simple cement or earthen construction (Figures 3–5). There is considerable physical variation within this group, and it is common for there to be some confusion or lack of specificity in their terminologies in general literature. For example, the term "estanques" in Spanish, which translates directly as "ponds," is often also used for systems typically considered to be raceways or tanks in English. The term "canales," translated directly as "channels," is also commonly used to refer to raceways, and the surveys of farms conducted by SEPEC[5] also refers to "piletas en cemento," which translates as "cement pools."

Although it is likely that some of these systems will reuse water either routinely or on occasion (e.g., routinely by gravitational flow from one raceway into another, or occasionally by pumping during the summer when natural water flows are reduced), these systems are typically operated as flow-through systems (Daza and Para 2019)(Sanchez-Fajardo et al. 2015). According to the surveys of farms conducted by SEPEC, there is also some production of rainbow trout in above-ground tanks, but the quantity is limited, and the basic function of the system is considered to be similar to cement pools, ponds, or raceways for the purposes of this assessment. Therefore, for the purposes of this assessment, the broader group of ponds, pools, raceways, and tanks is considered to have broadly similar water flow, effluent, and other key production characteristics, and is therefore assessed collectively here as "ponds and raceways."

Figure 3: Examples of cement raceways in Colombia. Image reproduced from Roca-Lanao et al. (2020) and http://www.eldiviso.com/.

[5] Referenced here as Roca-Lanao et al., 2018, 2019, 2020 2021a,b; Sánchez-Fajardo and Cuello (2015).

Figure 4: Examples of cement pools in Colombia. Images reproduced from Roca-Lanao et al. (2021a).

Figure 5: Examples of earthen ponds in Colombia. Images reproduced from Sánchez-Fajardo and Cuello (2015) and AMPROCAM (https://www.facebook.com/people/Amprocam/100070444466734/).

Ponds and raceways for trout are located in several departments of Colombia, with the bulk of production coming from Cauca and Antioquia, with lesser volumes from Tolima, Cundinamarca, and Risaralda (MADR, 2019). See Criterion 3—Habitat for more information on the locations of trout farms in Colombia.

Therefore, considering the two primary groups of production systems described above (and shown in Figures 1–5), this assessment of trout farming in Colombia is split into two parts: 1) net pens, and 2) flow-through ponds and raceways. Note that Seafood Watch has a separate recommendation for fish produced in fully recirculating indoor systems,[6] which may occur in

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

small volumes in Colombia. General information about raceways and other aquaculture production systems is available from Seafood Watch.[7]

Production locations

As discussed further in Criterion 3—Habitat, trout production in Colombia is associated with high attitude locations where suitable water temperatures are available for trout. The government's "Information System of the Colombian Fishing Statistical Service" (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC[8]) provides a layer on Google Maps of the location of aquaculture production units (UPAs[9]) in Colombia. The map provides the specific locations of each unit and the species produced; however, it must be noted that the UPAs listed are only those that have been assessed during annual surveys by SEPEC (as published in Roca-Lanao et al., 2018, 2019, 2020, 2021a,b; Sánchez-Fajardo and Cuello, 2015). Unfortunately, the information from SEPEC does not include the production system, but this can typically be seen visually, or assumed based on the characteristics of the landscape (i.e., a large lake indicates net pens, or terrestrial locations indicate ponds and raceways).

Net pens

According to Fedeacua (2016), of the 47 reservoirs, lakes, and lagoons in Colombia, only 4 are used for aquaculture (the Betania Reservoir in the department of Huila; Lake Tota in Boyacá; Lake Cocha in Nariño; and Lagoon Guájaro in Atlántico). Of these, only Lake Tota and Lake Cocha (also known as Laguna/Lago Guamuez) are at high altitude. A search for recent literature or general information relating to trout production in net pens ("jaulas" in Spanish) returns the same two locations, with no indications that further locations have been added. Therefore, these two natural lakes are the focus of this assessment for net pens, and Criterion 3—Habitat has more information on these locations.

Ponds and raceways

Based on a 2017 summary of trout production in Colombia from the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), trout production is primarily located in six departments (Figure 6). The two departments already associated with net pen production (Boyacá and Nariño) also have some pond/raceway production, but Cauca and Antioquia both have substantial pond/raceway figures (1,000 to 2,999 mt per year). There is also significant production (200–999 mt per year) in Tolima and Cundinamarca. It is considered that there is some rainbow trout production in other departments where suitable high altitudes and low water temperatures are present, but the focus of this assessment is on these six dominant departments.

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

[8] Sistema del Servicio Estadístico Pesquero Colombiano - SEPEC (aunap.gov.co)

[9] Aquaculture production units - Unidades de Producción de Acuicultura—UPAs.

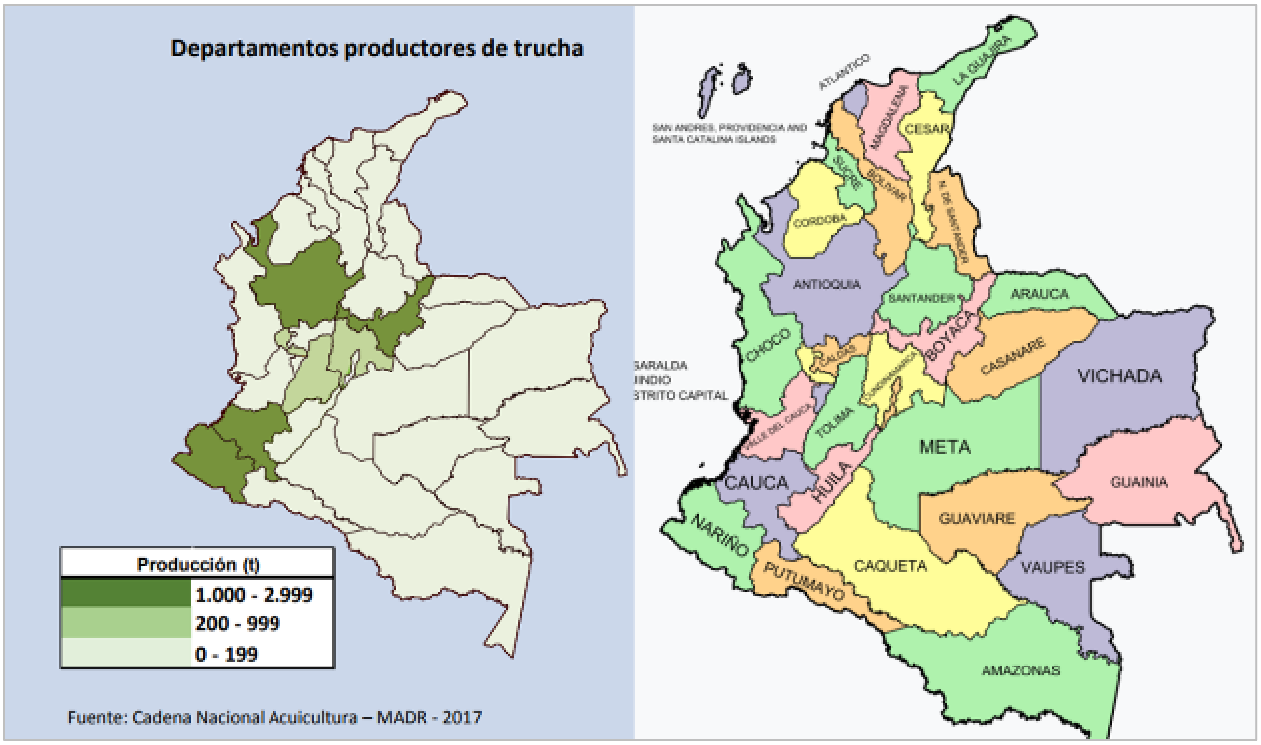

Figure 6: Map of the primary departments of Colombia that produce rainbow trout. Images reproduced from MADR and Wikipedia.

Production Statistics

Aquaculture in Colombia is dominated by three types of fish, two of which are the warm-water tilapia (*Oreochromis* species) and cachama (*Colossoma macropomum*), and the other is the cold-water rainbow trout. Combined, these three groups of fish represented >90% of Colombian aquaculture in 2020 [tilapia = 58%, cachama = 19%, and rainbow trout = 16%; (MADR 2021)(Carrera-Quintana 2022)]. Colombia's total finfish aquaculture production in 2021 was 188,658 metric tons (mt); therefore, trout production was approximately 30,185 mt. The 2020 data remain the most recent available from MADR (accessed November 6, 2023).[10]

Although production of rainbow trout in Colombia began with its introduction in 1930, the focus was on raising fingerlings (from imported eggs) for stocking into Colombia's high-altitude cold-water lakes (Carrera-Quintana 2022). Data from the UN FAO (FishStatJ database) show that by 1980 (the earliest data available) production of rainbow trout for food was still limited, with only 85 mt per year. This increased to 9,000 mt in 2000, but declined to 1,000 mt in 2008, before increasing rapidly to 30,185 mt in 2021 (Figure 7).

[10] https://sioc.minagricultura.gov.co/Acuicultura/Pages/Documentos.aspx

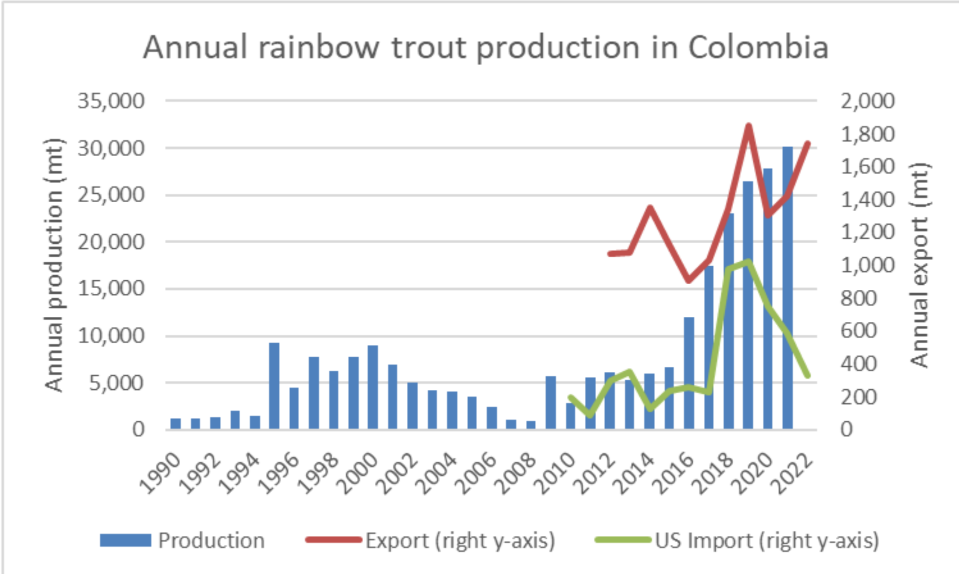

Figure 7: Annual production of rainbow trout in Colombia (blue bars and left y-axis). Also shown are total exports (red line—right y-axis) and the imports to the United States (green line—right y-axis). Production data from FAO FishstatJ. Export data from MARD (2021), and from Fedeacua for 2022. U.S. import data are from NOAA.

According to the FAO data, global production of rainbow trout in 2021 was 952,690.8 mt, indicating that Colombia is a small producer with approximately 3.2% (or 4.1% of trout grown in freshwater).

Import and Export Sources and Statistics

According to the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), Colombia's total export of trout has varied between 900 mt and 1,800 mt over the last decade (red line in Figure 7). The most recent figure available (from Fedeacua[11]) shows a total of 1,745 mt of trout exports in 2022. Of this total export, U.S. import figures from NOAA[12] show that approximately half is destined for the United States, with an average of 51.5% or 790 mt between 2019 and 2021. There is considerable variability (the reason for which is not clear), and 2022 import data show only 328.5 mt of trout were imported from Colombia in 2022.

Common and Market Names

Scientific Names	*Oncorhynchus mykiss*
Common Names	Rainbow trout
Spanish	Trucha arcoiris
French	Truite arcenciel
Japanese	虹鱒 (Torauto)

[11] Acuicultores magazine, Jan/Feb 2023. Number 8. https://fedeacua.org/files/acuicultores_8-comprimido.pdf
[12] https://www.fisheries.noaa.gov/national/sustainable-fisheries/foreign-fishery-trade-data

Product forms

The primary product forms appear to be single fillets or butterfly fillets (head on or head off).[13] According to Fedeacua,[14] in 2022, approximately half the trout exported was in the form of frozen fillets, one-third as fresh fillets, 14% as frozen whole fish (gutted), and 2% as fresh whole fish (gutted). It is likely that a smoked form is also available.

[13] This information was observed in industry informational videos, e.g., https://www.youtube.com/watch?v=Z7bh-9kb7Os, or https://www.youtube.com/watch?v=dCo6pgqsh0M

[14] Acuicultores magazine, Jan/Feb 2023. Number 8. https://fedeacua.org/files/acuicultores_8-comprimido.pdf

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	
	Net pens	Raceways/ponds
Production	5.0	5.0
Management	5.0	5.0
Effluent	7.5	5.0
Habitat	7.5	5.0
Chemical Use	5.0	5.0
Feed	5.0	5.0
Escapes	5.0	5.0
Disease	2.5	2.5
Source of Stock	10.0	10.0
Wildlife Mortalities	2.5	2.5
Introduction of Secondary Species	5.0	5.0
C1 Data Final Score (0–10)	**5.46**	**5.00**

Brief Summary

Data availability in Colombia has improved with increasing amounts of information available from a variety of sources, particularly the government, as well as industry; for example, from the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), the National Authority on Aquaculture and Fisheries (Autoridad Nacional de Acuicultura y Pesca—AUNAP), the Institute of Agriculture (Instituto Colombiano Agropecuario—ICA), the Information System of the Colombian Fishing Statistical Service (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC), and the industry body Fedeacua (Federación Colombiana De Acuicultores). Nevertheless, many of the criteria in this assessment suffer from limited relevant data, and the specific roles of additional organizations regarding aquaculture (for example, the Ministry of Environment and Sustainable Development; Ministerio de Ambiente y Desarrollo Sostenible—MADS) are not easy to determine. From a list of 1,342 aquaculture farms available from AUNAP, 67 were identified as trout producers (by name or location) and contacted by email. Four companies responded and provided useful information and data, but understanding typical production practices and the nature of their impacts (if any) across the large number of farms in the country remains challenging. The industry organization Fedeacua also provided some information and facilitated some specific feed data from two companies. While many academic studies provided useful information, some were specifically misleading, and many research gaps remain. Overall, the Data score for net pens is slightly higher than that of ponds (there are only two lakes in which net pen trout production is permitted), and the final scores for Criterion 1—Data are 5.5 out of 10 for net pens and 5.0 for raceways and ponds.

Justification of Rating

Data availability in Colombia has improved with increasing amounts of information available from a variety of sources, particularly the government, as well as industry; for example, from the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), the National Authority on Aquaculture and Fisheries (Autoridad Nacional de Acuicultura y Pesca—AUNAP), the Institute of Agriculture (Instituto Colombiano Agropecuario—ICA), the Information System of the Colombian Fishing Statistical Service (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC), and the industry body Fedeacua (Federación Colombiana De Acuicultores). Nevertheless, data availability is highly variable by topic, and many of the criteria in this assessment suffer from limited specific data. An attempt was made to contact MARD, but a response was not received. AUNAP provides a list[15] of 1,342 aquaculture producers (presumably those that are formally registered), of which 67 companies were both identifiable as trout farms and included contact details. These 67 companies were contacted by email with basic information about the assessment and an initial request for expressions of interest in helping to provide information. Three companies responded and provided further information or data on their practices. These direct communications with farming companies (and with Fedeacua) provided quite useful information, and it was disappointing that further contacts could not be made. Understanding the regulatory and management system, and particularly its practical implementation at small farms, remains a challenge. And while many academic studies provided useful information, many research gaps remain. Overall, the final score for Criterion 1—Data is 5.46 out of 10 for net pens and 5.0 out of 10 for raceways and ponds. Some criteria were scored in a precautionary manner because of the limited data availability.

Industry or Production Statistics

The primary source of aquaculture production data at the country level in Colombia is the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MARD), particularly its quarterly bulletins,[16] published through the Management and Performance Information System for Chain Organizations (Sistema de Información de Gestión y Desempeño de las Organizaciones de Cadenas—SIOC). Although variable in content, these bulletins generally include national and departmental production of each species in addition to

[15] ACUICULTURA.xlsx (live.com)

[16] https://sioc.minagricultura.gov.co/Acuicultura/Documentos/Forms/AllItems.aspx

various figures on export and certification. There is a considerable delay in publication, with September 2021 being the last bulletin as of November 2023 (accessed November 6, 2023). According to the industry trade body (Federación Colombiana De Acuicultores—Fedeacua), the production figures are based on feed sales data from feed companies and estimates of feed conversion ratios (FCR) from farmer surveys (pers. comm., Cesar Pinzon, Fedeacua, September 2022). Therefore, national and departmental figures obtained from Fedeacua, AUNAP, or MARD are considered to be estimates only. Nevertheless, they give a useful indication of the scale of production and trends. No specific information could be found on the scale of production in specific locations such as Lakes Tota and Cocha. The FAO FishstatJ database does provide annual production data for rainbow trout, but the source of these figures also seems likely to be similar estimates. The MARD bulletins also include the total number of aquaculture farms in Colombia (i.e., of all species) and show the proportions of production by species and by department, but it is not possible to directly translate these to the numbers of rainbow trout farms.

Regarding the locations of farms, the governmental organization responsible for aquaculture in Colombia (within MARD) is the National Authority for Fisheries and Aquaculture (Autoridad Nacional de Acuicultura y Pesca—AUNAP), and its "Information System of the Colombian Fishing Statistical Service" (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC[17]) provides a layer on Google Maps of the location of aquaculture production units (UPAs[18]) in Colombia. The map provides the specific locations of each unit and the species produced; however, it must be noted that the UPAs listed are only those that have been assessed during annual surveys by SEPEC (as published in Roca-Lanao et al. 2018, 2019, 2020, 2021a,b; Sánchez-Fajardo and Cuello, 2015). Overall, there are robust transparency efforts regarding industry production characteristics, but it continues to be hampered by large numbers of poorly documented farms. The Data score for Industry or Production Statistics is 5 out of 10.

Management

Fedeacua has good information documenting and listing the regulatory structures in Colombia; for example, Fedeacua and AUNAP have produced a series of booklets[19] describing the regulatory requirements in five departments of Colombia. Specific information can often be found in relevant government departments, such as the Institute of Agriculture (Instituto Colombiano Agropecuario—ICA[20] [21]). Another useful resource is the review of the legal framework for aquaculture in Colombia (and of the primary organizations and institutions) in Jamarillo et al. (2022). As is typical of regulatory documentation, understanding the practical implementation of the various resolutions and their supporting legislation is challenging.

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[17] Sistema del Servicio Estadístico Pesquero Colombiano - SEPEC (aunap.gov.co)

[18] Aquaculture production units - Unidades de Producción de Acuicultura—UPAs.

[19] https://fedeacua.org/page/eduaqua

[20] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/normatividad-aplicable

[21] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/resoluciones-prohibicion-o-restriccion-de-sustanci

Similarly, the specific role (regarding aquaculture) of the Directorate of Territorial Environmental Planning and National Environmental System (Dirección de Ordenamiento Ambiental Territorial y Sistema Nacional Ambiental—SINA[22]) within the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS[23]) is unclear, as is the relevance of the National Authority for Environmental Licenses (Autoridad Nacional de Licencias Ambientales—ANLA[24]) to aquaculture. A significant challenge in understanding the industry's management is also the limited level of "formalization" of farms (i.e., those that have the appropriate permits and registrations). Fedeacua's magazine ("Acuicultores") has some useful articles and general information on the industry, and after a break of several years after 2016, the magazine was published again in August 2022.[25] Overall, the Data score for Management and Regulations is 5 out of 10.

Effluent
Water-quality monitoring data were provided from one net pen farm in Lake Tota and a raceway farm (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023). IDEAM has a water-quality monitoring program across Colombia, but the results are challenging to apply to aquaculture (i.e., regarding identifying any potential impacts from effluent discharges). For example, in Lakes Tota and Cocha, there has been only one sampling point in each lake, and some gaps in the annual data. There are a few more water quality datapoints in Lake Tota from the occasional regional environmental authority (Corpoboyacá[26]), including at a trout farm, but they are of limited temporal coverage. One company in Lake Tota provided details of the "hopper" system for the collection of particulate wastes under the net pens (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023). For net pens more broadly, there are several useful academic studies on the effluent impacts of trout aquaculture in the lakes and including the scale of their contribution compared to agriculture or municipal wastes. Some studies of Lake Tota before the development of trout farming (e.g., CorpoBoyacá 1983, 1984) help understand the contributions of aquaculture to the nutrient status of the lakes. Overall, the Data score for Effluent in net pens is 7.5 out of 10.

For raceways and ponds, examples of departmental water quality monitoring are useful (e.g., from CARDER in Risaralda [La Corporación Autónoma Regional del Risaralda[27]]), and in some cases, sampling points near individual farms can be identified, but extensive analysis is unwieldy and impractical (e.g., by locating farms from the SEPEC database). Similarly, the IDEAM data for various rivers undoubtedly also overlap with some farm locations in some instances but are also unwieldy to analyze and associate specifically with farms. Specific effluent studies relating to raceways and ponds are limited, but some are quite useful (e.g., Calcetero Barato 2022; Luna-Imbacuán et al. 2016; González Acosta 2012). The educational

[22] https://www.minambiente.gov.co/ordenamiento-ambiental-territorial-y-sistema-nacional-ambiental-sina/
[23] https://www.minambiente.gov.co/
[24] https://www.anla.gov.co/
[25] https://www.fedeacua.org/page/revista
[26] https://www.corpoboyaca.gov.co/proyectos/manejo-integral-del-recurso-hidrico/calidad-hidrica/
[27] https://www.carder.gov.co/informe-de-monitoreo-del-recurso-hidrico-de-risaralda/

booklets from Fedeacua[28] comprehensively describe the regulatory systems in place, and Fedeacua (2018, 2022) helps understand the uptake of permits in the enforcement aspect. The Effluent Data score for ponds is therefore 5 out of 10.

Habitat

There is abundant information to broadly recognize the importance of Colombia's diverse habitats and its status as a "megadiverse" country (e.g., from the Convention on Biological Diversity). Studies such as Roldán (2020) also highlight the importance of Colombia's rivers, lakes, lagoons, swamps, and estuaries. The government's aquaculture zoning study (AUNAP, 2013), in addition to the basic geography of Colombia's high-altitude areas (and department-specific indications of the scale of trout production), can be used to identify the general locations of trout farms in Colombia. The Human Spatial Footprint Index (El índice de huella espacial humana—IHEH[29]) published in Correa-Ayran et al. (2020) shows the general degree of human impact (from all human activities) between 1970 and 2015, but cannot be specifically related to aquaculture other than broad generalizations about the timeframes of the development of trout farming.

For the net pen farms, the specific locations within Lakes Tota and Cocha and the simple nature of the floating net pens allow a relatively straightforward assessment of their impacts on ecosystem services. For example, the farms are visible on satellite images, and as the two largest natural lakes in Colombia, there is some academic and general interest in their ecosystem services. For raceways and ponds, the specific locations of many trout farms are available from the SEPEC[30] mapped database yet challenging to use without an ability to see or manipulate any specific data (e.g., to select trout farms as a group as opposed to one by one across the map). But combined with the historic image function of Google Earth Pro, it is possible to make an estimate of the typical habitats where trout farms have been built in Colombia. Some educational information for farmers on land and forestry permits is also available from Fedeacua (e.g., Fedeacua 2018a). Overall, although studies such as Ricaurte et al. (2017) provide some useful information on land-use change regarding wetlands in Colombia, it remains challenging to have any detailed understanding of any changes in ecosystem services resulting from raceway and pond farms. The Habitat Data score for net pens is 7.5 out of 10, and for raceways/ponds is 5 out of 10.

Chemical Use

There do not appear to be any readily available data on chemical use in Colombia, and no academic studies could be found that robustly defined their use (or non-use). Individual examples of companies with public policies for antimicrobial-free production can be found but cannot be considered to be representative of the broader industry. Some academic studies alluding to chemical use are entirely misleading (e.g., Torres-Barrera and Grandas-Rincón 2017),

[28] https://fedeacua.org/page/eduaqua

[29] A project from the Alexander von Humboldt Biological Resources Research Institute: El cambio en la huella espacial humana como herramienta para la toma de decisiones en la gestión del territorio | Biodiversidad 2018 (humboldt.org.co)

[30] Ubicación Geográfica de las Unidades de Producción de Acuicultura - SEPEC (aunap.gov.co)

being based on references from studies in other aquaculture industries or counties). For this assessment, a representative of two grow-out companies (one using net pens in Lake Tota and one using raceways in the Risaralda department) and a representative of a hatchery/fingerling producer provided information on their typical antimicrobial treatment practices. Information on the regulatory measures is available from the Colombian Agricultural Institute (Instituto Colombiano Agropecuario—ICA[31] [32]). The ICA also has a list of registered veterinary products[33] from which those for fish can be extracted. This list was also obtained directly from ICA (pers. comm., Anon., Instituto Colombiano Agropecuario, November 1, 2022). Colombia has a Program for the Integrated Surveillance of Antimicrobial Resistance (Programa Colombiano para la Vigilancia integrada de la Resistencia Antimicrobiana—COIPARS), operated by the Corporación Colombiana De Investigación Agropecuaria (AGROSAVIA[34]), but there do not appear to be any data of relevance to aquaculture. Information on import rejections is available from the United States Food and Drug Administration (FDA), and a representative of a company with rejected products (in 2017) provided further explanatory information. Overall, the Data score for Chemical Use is 5 out of 10.

Feed

Four feed companies (with six brands in total) can readily be found in internet searches in Colombia: Solla[35]/Agrinal,[36] Contegral[37]/Finca,[38] CIPA,[39] and Italcol.[40] It was also noted that feed may be imported from the Nicovita[41] company in Peru. These companies have variable amounts of data available on their websites, and feed producers typically consider detailed formulation data to be proprietary (Boyd et al. 2021). But with the assistance of Fedeacua, some responses to a feed data request were provided by two companies on the condition that the data be aggregated and anonymous. Some specific parameters such as feed protein content were fully available from the feed company websites, and other information such as lists of other feed ingredients could be obtained from online images of feed bags. The reference feed in the review of trout nutrition by Kamalan et al. (2020) was also useful. Although specific information is limited, a reasonable approximation for trout feeds in Colombia can be made, and the Data score for feed is 5 out of 10.

Escapes

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[31] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/normatividad-aplicable
[32] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/resoluciones-prohibicion-o-restriccion-de-sustanci
[33] The most recent list is available here: https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios.aspx
[34] https://www.agrosavia.co/
[35] https://www.solla.com/acuicultura/
[36] https://www.sollanutricionanimal.com/marca-agrinal
[37] https://www.contegral.co/
[38] Finca | Alimentos concentrado para animales
[39] Piscicultura - Cipa
[40] Acuicultura Trucha | Italcol
[41] Nicovita Classic Trucha Perú » Nicovita

No reports, records, or data relating to the escape of trout in Colombia (or their recapture) could be readily found. A fish containment plan provided by one company in Lake Tota was useful, but no assumptions can be made about similar activities in other companies, nor of the plan's effectiveness. Therefore, the escape risk must be evaluated according to the fundamentals characteristics of the production systems (for which a substantial amount of circumstantial information is available). Anecdotal examples of individual fish escaping from net pen farms in Lake Tota (and thereby demonstrating their vulnerability) can be seen in online videos (e.g., YouTube). Resolution 2879 of 2017 lays out the escape minimization requirements, but it is not known how extensively these requirements are applied in practice. Regarding recaptures, there is evidence of considerable angling activity in the lakes and communications and recapture arrangements with local fishers, but no specific evidence of recapture numbers. There is a substantial body of literature on the introduction and establishment of rainbow trout in Colombia and South America in general (e.g., Arismendi et al. 2014, 2019), on the status of the species as "invasive," and on its associated impacts to wild species. In addition, CONPES (2014) describes an important decline in the established populations after the cessation of stocking in 2008. Therefore, although specific escape data are not available, there is a moderate amount of information with which to assess the risk, and the Data score for Escapes is 5 out of 10 for all production systems.

Disease

There do not appear to be any readily available data on disease occurrences and/or mortality rates in Colombia trout aquaculture (either in total, or disease-specific), either in the lakes or in raceways and ponds. Anecdotal reports from the ICA note some occasions of disease outbreaks. There is a substantial global literature on diseases in farmed trout, but a limited number of academic studies provide information on the pathogens and their history in Colombia. There are no useful data on the occurrences of relevant pathogens in wild fish in Colombia (nor in previously introduced examples of rainbow trout in Colombia). The ICA (and Fedeacua) provide information on biosecurity best-management practices (including a certification scheme) in Colombia, but there are no data on their rate of implementation. A biosecurity management plan was also provided by one company in Lake Tota. With substantial general (global) information on trout diseases but limited specific and ongoing information from Colombia, the Data score for the Disease criterion for all production systems is 2.5 out of 10.

Source of Stock

The global domestication of rainbow trout for aquaculture production is well established and documented in academic literature. In Colombia, Esquivel et al. (2014) and Beleño (2017) indicated that a U.S.-based company has been the primary source of eggs and the only producer authorized by the ICA; however, the ICA provided information on import arrangements with other countries via the SISPAP database (Health Information System for Import and Export of Agricultural and Livestock Products; Sistema de información sanitaria para importación y exportación de productos agrícolas y pecuarios—SISPAP). The websites of egg importers and distributors in Colombia provide further details, including personal communication from one large egg importer and fingerling producer, which confirmed the two international sources of eggs (pers. comm., Eduard Sarmiento, Truchas Surula, June 2023).

Overall, the use of domesticated trout stocks is not in doubt and the Data score for Source of Stock is 10 out of 10.

Wildlife Mortalities

Data availability for wildlife mortalities in Colombia is quite limited. One now-dated study by Bechard and Marquez-Reves (2003) provides some information relating to aquaculture farms in Colombia, and an academic industry expert provided an opinion on the current use of lethal control. There are no farm-level records of wildlife mortalities for the production systems and locations of interest. Some information on typical species of relevance can be gleaned from academic studies (particularly in Lake Tota and from Ramsar documents for Lake Cocha) or more broadly in Colombia for important species groups, such as birds as of 2014 (e.g., the report on the State of the Birds in Colombia; Fundación ProAves, 2014), but these few examples cannot be considered directly relevant to the large number of trout farms across the high-altitude areas of Colombia. Some information is available on the regulatory requirements for predator deterrents, and visual examples of the use of predator nets are available, but again, these cannot be translated to typical practices. Confounding the challenge of understanding any impacts of interactions with trout farms is the (somewhat dated) evidence from Niño and Zambrano (2009) that birds and their eggs (mostly of waterfowl) are exploited for artisanal human consumption. The Data availability score for Wildlife Mortalities is 2.5 of 10.

Introduction of Secondary Species

Academic studies such as Martinez-Silva et al. (2018) and Vásquez-Machado et al. (2020) provide examples of the potential aquaculture-related introductions of secondary species in Colombia. The websites of various trout egg importers and distributors in Colombia, in addition to articles such as Alvis (2006), Esquivel et al., (2014) and Beleño (2017), show that Colombia has been dependent on international movements (imports) of trout eggs. An ICA article[42] indicates that the "vast majority" of trout production in Colombia is produced from imported eggs. The websites of the international egg producers Troutlodge[43] and Troutex[44] provide details of their biosecurity and disease-free certifications. The ICA provided a link to the SISPAP database[45] mentioned above and also provided the specific biosecurity requirements for egg imports from the four countries with import authorizations (pers. comm., Juan Diego Morales Patiño, ICA, May 2023). The websites of egg and fingerling producers in Colombia (e.g., Truchas Suralá,[46] Acuagranja,[47] Truchas el Paraiso[48]) indicate that there must also be substantial movements of fingerlings within Colombia. One fingerling producer provided detailed information on biosecurity practices for live fish movements and details of the ICA biosecurity program (pers. comm., Eduard Sarmiento, Truchas Suralá, June 2023). While other fingerling distributors indicate that fish health certificates are provided for trout movements within

[42] https://www.ica.gov.co/getdoc/b082c759-18c7-47da-bed6-0ebe76b48fe0/acuicolas-(1).aspx/
[43] https://www.troutlodge.com/en/trout-genetics/trout-eggs/
[44] https://troutex.dk/
[45] https://www.ica.gov.co/servicios_linea/sispap_principal.aspx
[46] Inicio - Truchas Suralá (truchasurala.com)
[47] https://acuagranja.com.co/
[48] Truchas el paraíso—Truchas el paraíso (truchaselparaiso.com)

Colombia, less is known about their biosecurity. Overall, with little readily available data or information on movements within Colombia, the Data score for the Introduction of Secondary Species is 5 out of 10.

Conclusions and final score

Data availability in Colombia has improved with increasing amounts of information available from a variety of sources, particularly the government, as well as industry; for example, from the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR), the National Authority on Aquaculture and Fisheries (Autoridad Nacional de Acuicultura y Pesca—AUNAP), the Institute of Agriculture (Instituto Colombiano Agropecuario—ICA), the Information System of the Colombian Fishing Statistical Service (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC), and the industry body Fedeacua (Federación Colombiana De Acuicultores). Nevertheless, many of the criteria in this assessment suffer from limited relevant data, and the specific roles of additional organizations regarding aquaculture (for example, the Ministry of Environment and Sustainable Development; Ministerio de Ambiente y Desarrollo Sostenible—MADS) are not easy to determine. From a list of 1,342 aquaculture farms available from AUNAP, 67 were identified as trout producers (by name or location) and contacted by email. Four companies responded and provided useful information and data, but understanding typical production practices and the nature of their impacts (if any) across the large number of farms in the country remains challenging. The industry organization Fedeacua also provided some information and facilitated some specific feed data from two companies. While many academic studies provided useful information, some were specifically misleading, and many research gaps remain. Overall, the Data score for net pens is slightly higher than that of ponds (there are only two lakes in which net pen trout production is permitted), and the final scores for Criterion 1—Data are 5.5 out of 10 for net pens and 5.0 for raceways and ponds.

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

Net Pens

Evidence-based Assessment

C2 Effluent Final Score (0–10)	**4**	**Yellow**

Ponds and raceways

Risk-based assessment

C2 Effluent parameters	Value	Score
F2.1a Waste (nitrogen) production per of fish (kg N ton^{-1})	63.44	
F2.1b Waste discharged from farm (%)	80.0	
F2.1b Boundary adjustment (0–1)	n/a	
F2.1 Waste discharge score (0–10)		4
F2.2a Content of regulations (0–5)	3	
F2.2b Enforcement of regulations (0–5)	2	
F2.2 Regulatory or management effectiveness score (0–10)		2.4
C2 Effluent Final Score (0–10)		**4**
Critical?	No	**Yellow**

Brief Summary

It is clear that the production of trout in net pens (which is based on the addition of external formulated feeds) represents a direct source of soluble and particulate nutrient wastes into freshwater lakes, and the ecological importance of maintaining high water quality in these lakes is recognized. But, even though the two Lakes Tota and Cocha have some similar characteristics and conditions, the nutrient dynamics of both lakes are complex and affected by many factors. In Lake Tota, nutrient studies show that the intensive onion-farming industry (and particularly its poorly controlled fertilizer applications) to be the dominant nutrient source in the lake, followed by the municipal wastes from the town of Aquitaine, which has not had an operational wastewater treatment plant for decades. There were concerns that the lake was becoming eutrophic from these nutrient inputs in the early 1980s, before the development of trout farming in the lake. Nevertheless, it is clear from both lakes that intensive trout production will have a local impact on the water column and the benthos, and some nutrient dynamics in these lakes (e.g., of phosphorous) remain unclear. Because of these concerns, since 2018, all producers in Lake Tota are required to use collector devices under the net pens to remove particulate waste from the lake, but no evidence could be found that this is also done in Lake Cocha. The soluble portion of the total waste is still released into the lakes. Overall, the available monitoring data show that the water quality in both lakes is acceptable, but there are clear concerns regarding a trend toward eutrophication with the long-term accumulation of anthropogenic nutrients in lakes with long hydraulic retention times. The relevance of several nutrient studies relating to the farms is limited by fieldwork conducted before the installation of the collectors in Lake Tota. Nevertheless, given the importance of both lakes in Colombia and the desire to limit any further progress toward eutrophication, the direct contribution of nutrients from net pen trout farms to the lake is inevitably a concern. Although the nutrient inputs from trout farms may be minor compared to other sources, and studies show that the direct impacts are limited, there is considered to be a clear potential for cumulative impacts at the waterbody scale. Thus, the score for Criterion 2—Effluent for net pens is 4 out of 10.

Influent and effluent monitoring data from a raceway farm, in addition to specific effluent studies (e.g., of three trout farms on the Siecho River) show that the effluent concentrations are low, and impacts may be minor. But without sufficient data to understand the impacts (or lack thereof) of raceway and pond farms more broadly in Colombia, the risk-based assessment was used. Considering the typical feed use, it is estimated that there is a total nitrogen input of 88.6 kg N/mt of trout. After the removal of nitrogen in harvested trout, the total waste nitrogen produced is 63.4 kg N/mt. Given the typical flow-through nature of the production systems, 80% of the waste produced is considered to be discharged to the environment (50.8 kg N/mt, and a score of 4 out of 10 for Factor 2.1). Educational information produced by Fedeacua and the government describes a substantial regulatory permitting framework, but there do not appear to be specific effluent limits in place for individual farms. There continues to be a low uptake of permits because of the large majority of farms operating in an “informal” manner. Considerable efforts are being made to increase this, but the costs of compliance are a challenge for small producers, and the goal of 50% of formalized producers by 2032 shows that progress is slow. Thus, with limitations in the regulations and low effective enforcement, the effluent management score (Factor 2.2) is 2.4 out of 10. The scores for Factors 2.1 and 2.2 combine to give a final score for Criterion 2—Effluent for raceways and ponds of 4 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 that, due to the open nature of the production system (net pens and flow-through raceways) will, at least in part, be discharged to the natural receiving waters of the farm (Aubin et al. 2011).

<u>Net pens</u>

Lakes Tota and Cocha remain the only waterbodies used for net pen rainbow production in Colombia (pers. comm., Cezar Pinzon, Fedeacua, September 2022). Given their status as the two largest freshwater bodies in Colombia and the importance of their ecosystem services to the country, they have both received considerable academic and socio-political interest regarding their environmental condition. In addition, the Institute of Hydrology, Meteorology and Environmental Studies (Instituto de Hidrología, Meteorología y Estudios Ambientales—IDEAM[49]) conducts monitoring on an approximately annual basis in both lakes. Nevertheless, Aranguren-Riaño et al. (2018) noted that, despite their size and importance, no consistent sampling program is in place for monitoring water quality. Although it is noted here that direct monitoring data are limited and many publications recommend further studies to better understand the complex physiochemical dynamics of each region, for the purposes of this assessment, there are considered to be sufficient data points and studies of the primary nutrient dynamics in both lakes to use the evidence-based assessment (i.e., the Criterion 1—Data score of 7.5 or 10 of 10 for the effluent category).

It is clear that the production of trout in net pens (which is based on the addition of external formulated feeds) represents a direct source of soluble and particulate nutrient wastes into freshwater lakes. According to Fedeacua's series of educational booklets for fish farmers,[50] a discharge permit is not required when the discharge is diffuse, as in the case of net pens located in lakes, lagoons, reservoirs, or other lentic bodies of water (Fedeacua 2018c).

As discussed below for each lake, the nutrient dynamics are complex and affected by many factors. Before considering each lake separately, the government (IDEAM) monitoring data provide a useful (albeit limited) initial view of the general water quality status of both lakes. Two monitoring stations (one in Lake Tota[51] and one in Lake Cocha) form part of the National Reference Network for Water Quality, which comprises 160 monitoring points, from which approximately 40 water-quality variables are analyzed. The frequency of sampling in the two lakes appears to be mostly annual, although some years are missing from the 2005 to 2021 data series. While data from individual parameters are available from IDEAM[52] (for example, nitrogen and phosphorous are discussed further below), the Water Quality Index (Índice de Calidad del Agua—ICA) provides an aggregated value (from 0 to 1) based on six basic physicochemical variables[53] (Figure 8). The ICA indicator is differentiated into five categories, where "Very Poor" water quality is below 0.25, "Poor" is from 0.26 to 0.50, "Regular" is from 0.51 to 0.70, "Acceptable" is from 0.71 to 0.90, and "Good" is from 0.91 to 1.0.

[49] IDEAM - IDEAM
[50] https://fedeacua.org/page/eduaqua
[51] According to the grid reference provided by IDEAM, the sampling point is at the extreme southern end of the lake, whereas the trout farms are in the northern half of the lake. In addition, it is somewhat distant from the municipal waste inputs from the town of Aquitania.
[52] http://www.ideam.gov.co/web/ecosistemas/agua
[53] Dissolved oxygen, total suspended solids, chemical oxygen demand, electrical conductivity, hydrogen potential, and total nitrogen/total phosphorus ratio.

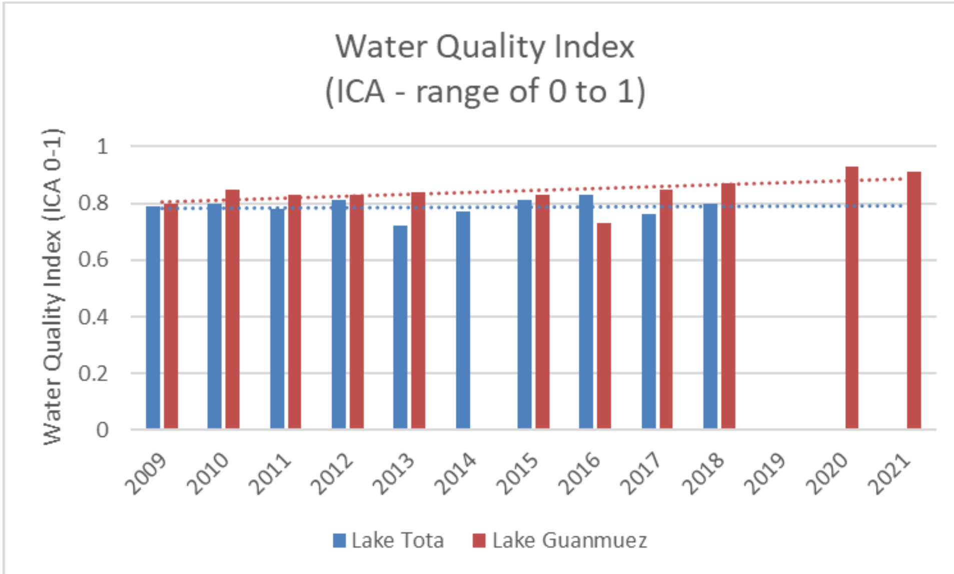

Figure 8: Water Quality Index (Índice de calidad del agua—ICA) values for Lake Tota (blue bars) and Lake Cocha (red bars) from 2009 to 2021. Note there are no data from Lake Tota from 2019 to 2021. Dotted lines show simple linear trendlines fitted by Excel. Data from IDEAM.

Figure 8 shows that the ICA values are in the "Acceptable" category in both lakes and all sampling years except 2020 and 2021 in Lake Cocha, which are both in the "Good" category (ICA values of 0.93 and 0.91). The water quality in Lake Cocha is consistently better than in Lake Tota (average ICA value over the time period of 0.84 in Lake Cocha versus 0.79 in Lake Tota). The simple trendlines (fitted by Excel) show a very slight increasing trend in Lake Tota (i.e., improving water quality: $y = 0.0007x + 0.7833$) and a stronger improvement in Lake Cocha ($y = 0.0069x + 0.7961$).

But a closer examination of two important parameters, both regarding aquaculture effluent and potential effects on the trophic status of the lake, shows a more complex picture. Figures 9 and 10 show the same IDEAM data for the single parameters of nitrogen and phosphorous from 2006 to 2021. Note that one nitrogen outlier value (3.43 mg/l in Lake Tota in 2013) and two phosphorous values (0.5 mg/l in Lake Tota in 2011 and 0.4 mg/l in Lake Cocha in 2017) are likely to be sampling errors and have been excluded from these graphs.

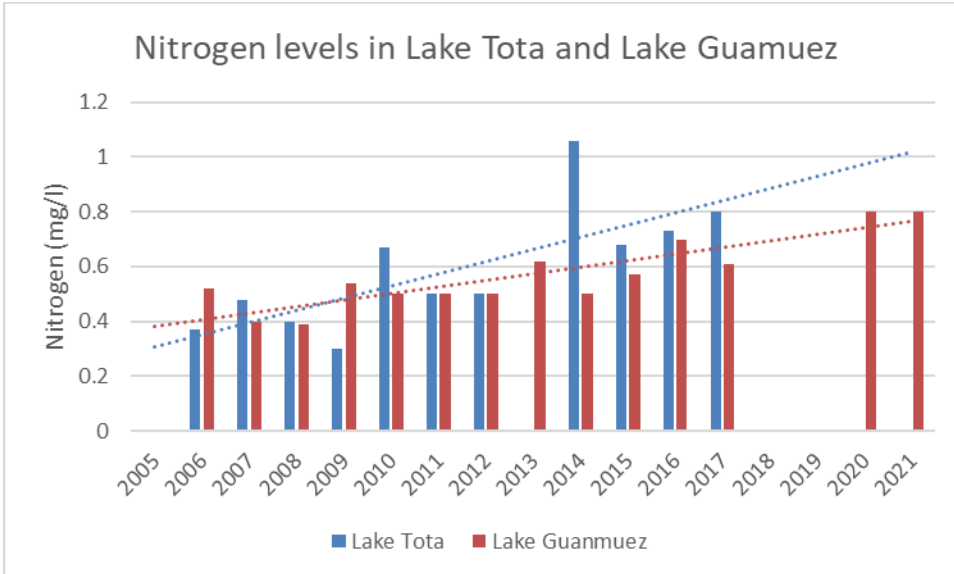

Figure 9: Nitrogen levels in mg/l in Lake Tota and Lake Cocha from 2006 to 2021. Dotted lines show simple linear trendlines fitted by Excel. Data from IDEAM.

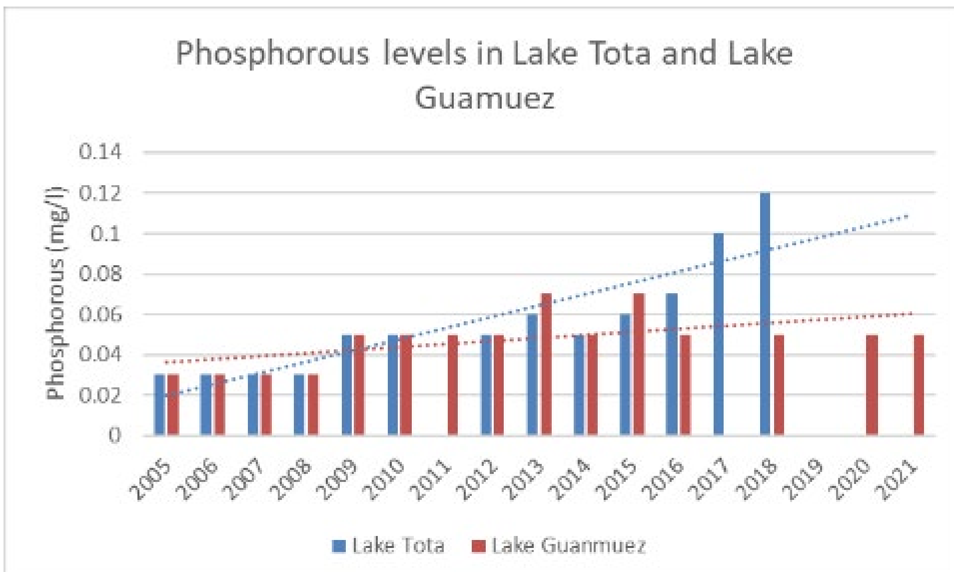

Figure 10: Phosphorous levels in mg/l in Lake Tota and Lake Cocha from 2005 to 2021. Dotted lines show simple linear trendlines fitted by Excel. Data from IDEAM.

Figures 9 and 10 show that nitrogen and phosphorous levels in both lakes have increased over this period, with a faster rate of increase in Lake Tota. In addition, the regional authority Corpoboyacá conducted water quality sampling at 11 locations in Lake Tota in December 2020, of which 1 location was next to the net pens of the Aqua Trucha trout farm (the largest farm) in the northeast corner of the lake. The other 10 sampling locations were clustered near the west shore, which reduces their value as a representative group of samples for the lake as a whole, but the results show that the water quality at the farm site was quite similar to these other 10 locations (Table 1).

Table 1: Water quality testing results from Lake Tota in December 2020, conducted by Corpoboyacá. Of the locations, 1 sampling location was next to the net pens of the Aqua Trucha trout farm (farm site) and 10 other samples were taken at locations near the western shore of the lake. Data from Corpoboyacá.

Parameter	Farm site	Other sampling locations
Dissolved oxygen (mg l^{-1})	4.4	4.7
Ammoniacal nitrogen (mg N $l^{-1)}$	0.5	0.5
Biological oxygen demand (mg O_2 l^{-1})	2.0	3.4
Chemical oxygen demand (mg O_2 l^{-1})	17.0	26.4
Conductivity (µS cm^{-1})	117.5	119.3
Nitrite (mg l^{-1})	<0.007	0.013
Nitrate (mg l^{-1})	0.40	0.38

A lower dissolved oxygen level at the farm is to be expected due to the respiration of the fish, but the lower values for ammoniacal nitrogen, biological oxygen demand, chemical oxygen demand, and nitrite (which indicate better water quality at the farm site) are surprising, because higher values are typically associated with the nutrient wastes released from the fish farms.

Although there are some similarities between the two lakes considered here, the nutrient dynamics in each lake are complex and the production practices differ between them; therefore, they are discussed separately below. These discussions refer to carrying capacity and eutrophication, of which the former describes the point when the natural purification rate of the water body becomes insufficient to maintain equilibrium (i.e., the carrying capacity), which is the initiation of the process of eutrophication (Carrera and Daza 2021).

Lake Tota

Lake Tota is the largest natural freshwater reserve in the country. It has a surface area of 55 km^2, an average depth of 30 m, a hydrological renewal time of 30 years, and is in the department of Boyacá, 200 km northeast of Bogota at an altitude of 3,015 m above sea level (Torres-Barrera and Grandas-Rincón 2017)(Másmela-Mendoza and Forero 2021)(Aranguren-Riaño et al. 2018). After the introduction of trout to the lake in the 1930s and the production of fingerlings for stocking, a pilot program to produce 24 mt of trout in net pens in the lake and to study the environmental impact began in 1984 (Corpoboyacá 1984). The scale of production after 1984 is not readily apparent, but Torres-Barrera and Grandas-Rincon (2017) considered that commercial intensive trout farming began in approximately 2005, and according to a local media article[54] (referencing the Association of Fish Farmers of Boyacá), the average annual production in 2014 was 1,430 mt. Seven companies are currently present (Corpoboyacá 2021).

According to Torres-Barrera and Grandas-Rincón (2017), the maximum production permitted in the lake by AUNAP is 984 mt per year, and those authors considered that the farms were likely to have reached this level by 2019 or 2020; however, though this figure is repeated in other

[54] https://www.boyacaradio.com/noticia.php?id=13945

publications, no formal record of this maximum authorized production limit could be found. Instead, this figure appears to be an estimate of annual production in 2013 from the authorized farms in the lake in a study on the integrated management of the lake by the National Council for Economic and Social Policy (Consejo Nacional de Política Económica y Social) (CONPES 2014). According to a representative of one of the seven companies operating in the lake, there is no official production capacity for the lake, but each company is regulated by the regional environmental authority (Corpoboyacá) based on the number of permitted cages and the stocking density (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023).

The net pen trout farms in Lake Tota are unusual in that they have established a collection system for particulate wastes below the net pens, and this is now required under Resolution 1310 of 2017 (from Corpoboyacá), which laid out various measures to protect Lake Tota. It specifically requires the seven trout farming companies to install collectors for particulate wastes (uneaten feed and feces) directly below the net pens with a requirement to collect "close to 100%" of the wastes. The 2017 regulation noted that a pilot study collected 71% of organic matter and urged ongoing improvement. The system currently consists of a hopper arrangement (called a Tolvo in Spanish) made of a square metal frame and conical membrane that is suspended directly below the net pen. Collected sediments are pumped out weekly (via a hose connector at the bottom of the cone) into dewatering and drying tanks on land, and the dried sediment is used as a soil conditioner (pers. comm., Oscar Murillo, TroutCo/PezFresco, May 2023). According to one of the trout companies in Lake Tota, all farms in the lake have used a collection system since the regulation was enacted in 2018 (pers. comm., Oscar Murillo, TroutCo/PezFresco, May 2023). This aspect is discussed in the relevant sections below.

Water quality data provided by one of the companies in Lake Tota from May 2023 show that samples are taken in the cages, and at increasing distances from the cages; e.g., 50 m, 200 m, and 500 m. Testing results from an independent laboratory show that six parameters are measured in the field (conductivity, dissolved oxygen, temperature, pH, smell/odor, and transparency), and a further four parameters are tested at the laboratory (chemical oxygen demand—COD, biological oxygen demand—BOD, total phosphorous, and ammonia nitrogen). Figure 11 shows the results for four parameters that are most relevant to this assessment (dissolved oxygen, combined COD/BOD, total phosphorous, and ammonia-N).

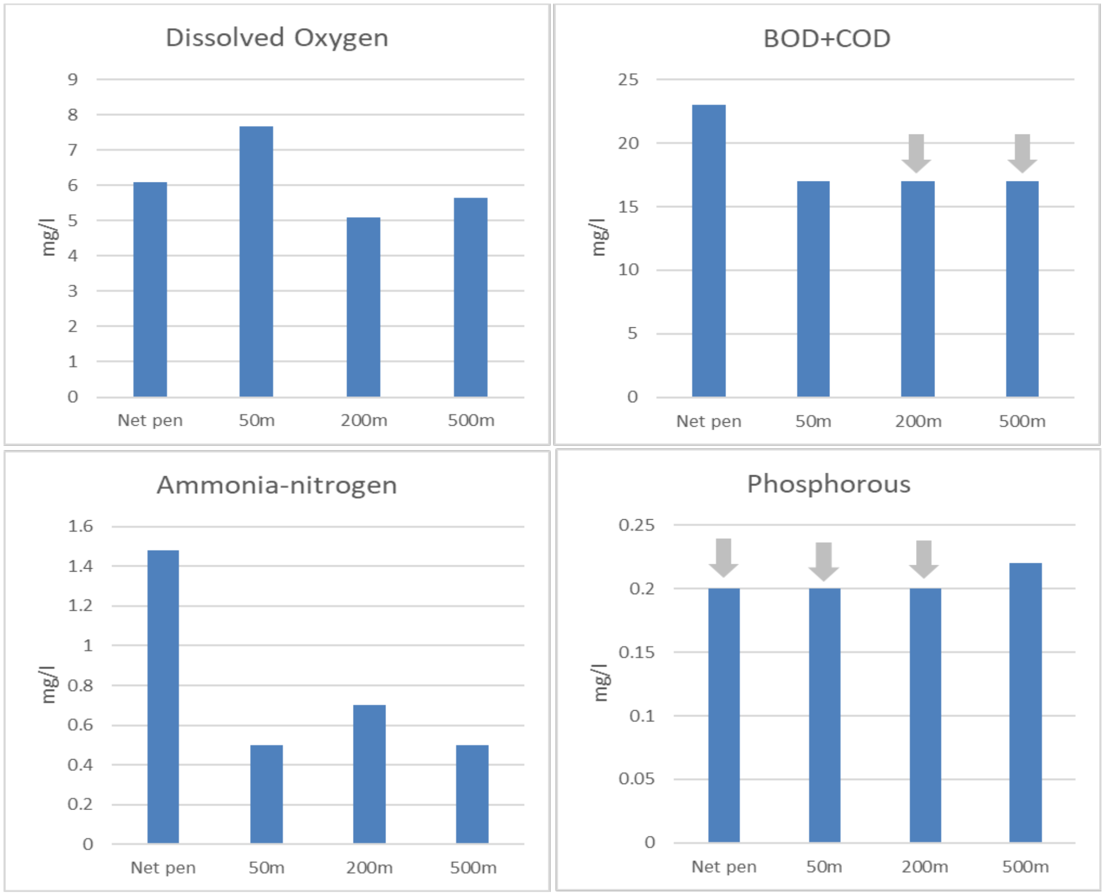

Figure 11: Water quality parameters in Lake Tota from within a trout farm, and at increasing distances from it. Grey arrows indicate testing results expressed as "less than" values; e.g., the laboratory result for phosphorous in the net pen was <0.2 mg/l. Data from TroutCo (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023).

The results for dissolved oxygen and phosphorous show no relationship with distance from the farm, but nitrogen and the BOD+COD parameters show sharp declines, apparently to background levels, within the first 50 m from the cages. The laboratory testing results indicate that there is no established acceptable level for these parameters in Lake Tota. For reference, the U.S. Environmental Protection Agency has Aquatic Life Ambient Water Quality Criteria for Ammonia in Freshwater,[55] for which the limit for chronic exposure is 1.9 mg/l ammonia-nitrogen. It can be seen that the level in the net pen at the farm (1.48 mg/l) is still considerable but declines rapidly to 0.5 mg/l at 50 m from the net pen. This value is similar to the results of the IDEAM monitoring in the lake (Figure 9).

A similar U.S. EPA value is not readily available for phosphorous, and the applicability of any U.S. EPA limits to the sustainable use of Lake Tota are unclear, but the study by Aranguren-Riaño et al. (2018) noted that average values of total nitrogen and phosphorous in Lake Tota were 1.5 mg/l and 0.06 mg/l, respectively. This phosphorous level is apparently much lower than the values for phosphorous of 0.22 mg/l at 500 m from the farms, but is not possible to

[55] https://www.epa.gov/wqc/aquatic-life-criteria-ammonia#:~:text=Ammonia%20is%20one%20of%20several,toxic%20effects%20on%20aquatic%20life.

compare to the values closer to the farm due to the reporting of the values as <0.2 mg/l. Other phosphorous values (not shown in Figure 11) from the north and south end of the farm were also reported as <0.2 mg/l. It is possible that the single value of 0.22 mg/l is a testing anomaly. Másmela-Mendoza and Forero (2021) also reported much lower values of total phosphorous in Lake Tota and noted that values were higher in fish farming areas; however, their average values were 0.070 mg/l in the open lake, and 10% higher at 0.077 mg/l near fish farms. The values from the IDEAM monitoring (Figure 10) are in a similar range from 0.03 mg/l to 0.12 mg/l. It is important to note that the sampling for the study of Másmela-Mendoza and Forero (2021) was done in 2015, which was a few years before the requirement for the installation of the particulate waste collectors under the net pens of the trout farms in 2018. The most recent IDEAM monitoring value was also from 2018.

Tropical high mountain lakes tend to be stable, quite transparent, and with low nitrogen concentration, and are typically referred to as oligotrophic (Muñoz-López et al. 2017)(Aranguren-Riaño et al. 2018). But a 1983 CAR[56] report (i.e., before the development of aquaculture in the lake) determined that the oligotrophic state of Lago de Tota was at risk because of increased nutrient inputs, particularly from agriculture, noting that parts of the lake were eutrophic as indicated by problematic growth of aquatic plants (CAR 1983). The open water of the lake was not considered to be eutrophic (Corpoboyacá 1983). A subsequent 1984 report from CAR (which focused on evaluating the environmental impact of a pilot test of rainbow trout production in net pens in Lake Tota) went further, considering that the lake was already eutrophic due to the excessive runoff of nutrients from agriculture (Corpoboyacá 1984). For example, the rapid growth of aquatic plants of the genus *Elodea* (seen as an indicator of eutrophication) was considered to be largely the result of excess nutrients that the lake receives from the exaggerated fertilization of crops (Corpoboyacá 1984).

More recently, multiple studies show an ongoing concern but also some uncertainty in the current trophic status of the lake. In 2018, Aranguren-Riaño et al. reported a 32% reduction of transparency over the previous 15 years with increased planktonic and bacterial growth, but they (and others) considered the lake to be mesotrophic (i.e., having moderate nutrient levels between oligotrophic and mesotrophic) (e.g., Másmela-Mendoza and Forero 2021). Nevertheless, in addition to noting an apparent shift in Lake Tota from the natural oligotrophic state to mesotrophy, they noted the trajectory toward eutrophy and a risk of an eventual transition to a persistent eutrophic state (Aranguren-Riaño et al. 2018)(Másmela-Mendoza and Forero 2021). Therefore, despite the concerns regarding eutrophication and the consideration that the lake was indeed eutrophic in 1983–84 (CAR 1983, 1984), the concern is ongoing.

By comparing the nitrogen and carbon signatures of aquatic organisms and surface sediments in Lake Tota, Aranguren-Riaño et al. (2018) indicated that human sources dominate the N and C cycles of the lake. Three potential sources were identified: first (in no particular order) is onion production, fertilized mainly with chicken manure (gallinaza); second is untreated municipal

[56] Corporación Autónoma Regional de las Cuencas de los Ríos Bogotá (CAR), which became Corporación Autónoma Regional de Boyacá (CORPOBOYACÁ)

wastewater originating from the town of Aquitania (population 15,000) through the outlet of the La Mugre stream on the eastern shore of the lake; the third potential source is the net pen aquaculture of rainbow trout. Jaramillo-García et al. (2020) also note a fourth primary source of contamination in the lakes (although not of nutrients) is of pesticides from agricultural crops.

Agriculture is the primary economic activity in the basin of Lake Tota; for example, 90% of the Colombian long onion (*Allium fistulosum*) production is concentrated in this region and has expanded in recent decades (Salamanca 2021)(Jaramillo-García et al. 2020)(Barrera et al. 2019)(Aranguren-Riaño et al. 2018). The fertilization of the crops in the area is carried out mainly with organic fertilizers such as chicken manure, which contains large amounts of phosphorus, nitrogen, sulfur, and often antibiotic residues (Jaramillo-García et al. 2020). Salamanca (2021) notes that the chicken manure fertilizers (and pesticides) are applied without any control over the dosage and frequency of application, and when applied in excess, nearby water sources may be contaminated by surface runoff because of the inorganic load and the increase in pathogenic organisms that it contains.

Multiple studies identify agriculture and municipal wastes as the primary nutrient inputs into the lake (e.g., Aranguren-Riaño et al. 2018; Sanabria Combariza et al. 2019; Jaramillo-García 2020; Bernal et al. 2016; Niño and Zambrano 2009; and Mesa-Salazar and Mojica 2016). For example, an isotope analysis of nitrogen in aquatic organisms in the lake showed that it was similar to the chicken manure applied to green onion crops in the watershed, which suggests that agriculture may contribute the bulk of nutrients supporting elevated productivity in the lake (Aranguren-Riaño et al. 2018). Similarly, UPTC & Corpoboyacá (2016) showed that chicken manure contributes an average of 86% of the nitrogen found in particulate organic matter (plankton) in the lake; therefore, less than 15% of the nitrogen comes from other sources such as concentrated aquaculture feed and municipal wastewater.

Regarding municipal wastewater, multiple studies note the lack of treatment of municipal wastes, particularly from the town of Aquitaine on the eastern shore of the lake (Castro Fonseca 2018)(Ramirez and Paeres 2004)(Bernal et al. 2016)(Jaramillo-García et al. 2020). Although a wastewater treatment plant was constructed in the 1990s, it was not operational for long, and RPV (2023) noted that the plant has not been in operation “for decades.” Wastewater enters the lake through the Mugre River, which has been shown to be the most polluted tributary of the lake (it also carries excess nutrients from the onion agriculture) (Barrera et al. 2019)(Sierra et al. 2020)(Muñoz-López et al. 2017).

The Corporación Autónoma Regional de Boyacá (Corpoboyacá) is responsible for the oversight of the department and charges a compensation tax (Tasa Retributiva) for “the direct and indirect use of the resource as a recipient of specific discharges and their harmful consequences originated in anthropic activities or caused by man, economic activities, or services, whether or not they are for profit” (translated from Corpoboyacá, 2021). The charge is based on a calculated pollutant load using two indicators: 5-day biological oxygen demand (DBO5 in Spanish) and total suspended solids (SST in Spanish). The program does not appear to include agriculture but provides data of interest regarding the municipal loads and aquaculture, and includes the seven trout farming companies in Lake Tota. Figure 12 shows the scale of the calculated loads from each company and the town of Aquitania. The total aquaculture load is also shown. Although the calculation method is not entirely transparent, these data indicate that the trout farmers in combination produce approximately 23% of the DBO5 and 39% of SST (again noting that this does not include contributions from agriculture).

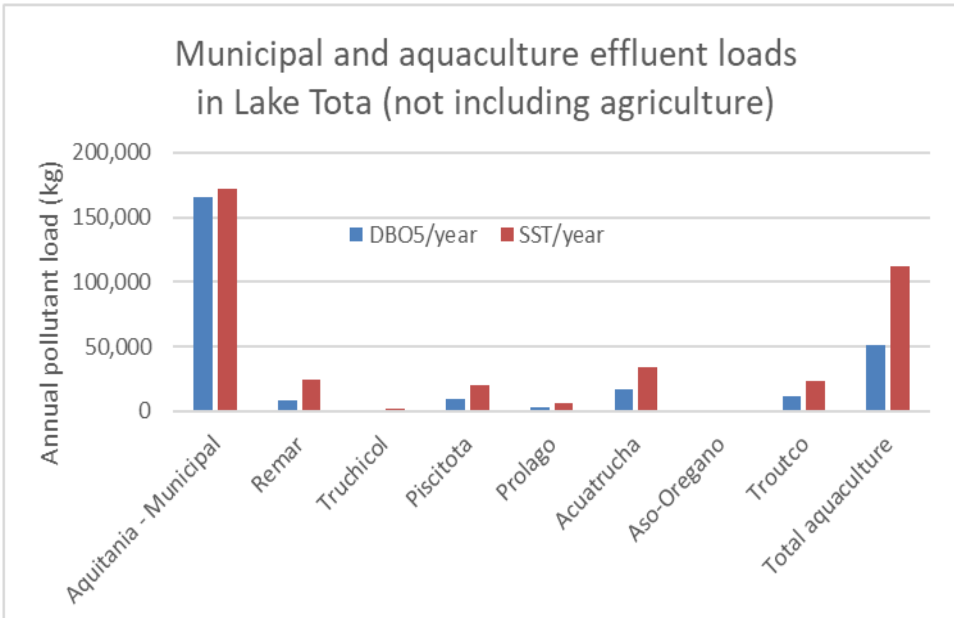

Figure 12: Municipal and aquaculture effluent loads in Lake Tota, not including agriculture, expressed as DBO5 (5-day biological oxygen demand) and SST (total suspended solids). Seven trout farming companies are shown, along with the total aquaculture. Data from (Corpoboyacá 2021).

Regarding aquaculture specifically, although it is not appropriate to compare the figures in the previous sentence directly with the apparent majority (86%) of nitrogen in the lake coming from agriculture (UPTC & Corpoboyacá 2016), it is tempting to consider that the trout farms contribute a relatively minor component of the total anthropogenic nutrient inputs. Nevertheless, studies have associated environmental changes with the addition of feed into the farms and the resulting effluents released into the lake (e.g., Torres-Barrera and Grandas-Rincón 2017; Legarda et al. 2022; and Burbano-Gallardo et al. 2021). Unfortunately, primary studies on net pen trout farms in Lake Tota are somewhat limited in number and quality.

For example, in a seemingly important study to estimate the waste generated by the production of rainbow trout in Lake Tota, Torres-Barrera and Grandas-Rincón (2017) considered that contamination of the lake by waste from the intensive rainbow trout farming process is imminent due to the accumulation of wastes under the cages and the addition of nitrogen compounds to the water column. Yet, rather than direct monitoring of the farms in Lake Tota, this conclusion appears to be based on extrapolations from studies of net pen aquaculture in coastal environments (particularly net pen salmon farms in Chile, referencing Soto and

Norambuena 2004; Troell et al. 1997; and Lotzde et al. 1999), and a study of “excessive” trout production in shallow lagoons in Peru (Mariano et al. 2010).

Similarly, although Legarda et al. (2022) considered Lake Tota to be a “benchmark for environmental problems generated by trout farming, which together with long onion farming, among other agricultural activities, have generated alerts in environmental control entities,” their reference appears to be Burbano-Gallardo et al. (2021), which notes that the organic matter in sediments in Lake Tota is three times higher than in Lake Cocha. But this claim is in turn referenced to the same Torres-Barrera and Grandas-Rincón (2017), which did not involve any direct measurements in Lake Tota and did not mention the same organic matter values quoted by Burbano-Gallardo et al. (2021).

Using typical feeding practices and nutrient retentions in trout, Torres-Barrera and Grandas-Rincón (2017) estimated that, between 2005 and 2016, the trout farms in Lake Tota produced a total of 196 mt of nitrogen and 35 mt of phosphorous (i.e., an average of 16.3 mt of N and 2.9 mt of P per year). Although it can certainly be assumed from other net pen studies (as referenced above) that the concentration of soluble fractions of these nutrients are likely to increase in the water column in Lake Tota close to the pens, and particulate wastes will settle and accumulate on the bottom of the lake beneath them (noting the introduction of a requirement for particulate waste collection below the farms from 2018), direct studies on the actual impacts of net pen trout farms in Lake Tota are quite limited.

Másmela-Mendoza and Forero (2021) and Másmela-Mendoza et al. (2019) studied the denitrifying bacteria from areas of the lake with and without rainbow trout farms and identified a greater number of denitrifying bacteria in the fish farming zones. The study reported slightly higher values of dissolved inorganic nitrogen, dissolved inorganic phosphorus, total phosphorus, electric conductivity, and lower concentrations of dissolved oxygen in the lake’s limnetic (i.e., open water) zones where rainbow trout is farmed. The density of nitrate-reducing bacteria was directly correlated with the total phosphorous, and the study also noted that high densities of denitrifying bacteria are indicative of changes from oligotrophic to eutrophic states in limnetic areas. But as noted above, the study’s fieldwork was done before the introduction of collector devices under the farms, and the study also noted the dumping of sewage from neighboring municipalities and the use of pesticides and fertilizers from agriculture as sources increasing the nutrient concentrations in the lake.

It is also clear that the lake has a complex dynamic of impacts associated with nitrogen and phosphorous inputs, which vary during the year. Muñoz-López et al. (2017) noted an increase in the total nitrogen content in rainy periods (April to November) from increased terrestrial runoff, and an opposite behavior of total phosphorous, which is concentrated in periods of low rainfall and low level. Thus, Aranguren-Riaño et al. (2018) considered that the lake may be more sensitive to internal phosphorus loading, and phosphorus recycling from anoxic sediments may maintain high productivity even if external inputs are limited. Aranguren-Riaño et al. (2018) concluded that, although the nitrogen used by primary producers may be of primarily terrestrial origin, the major sources of P to the lake remain to be determined. It seems likely that trout aquaculture is a component of this internal phosphorous cycle, including contributions to anoxic sediments below net pen farms (perhaps only before 2018 and the installation of collectors).

Considering further the benthic impacts in the lake, there is inevitably a concern about the accumulation of wastes below net pen farms; for example, regarding the phosphorous dynamics of the lake discussed above, it is relevant to note that, according to Sindilariu (2007), between 30% and 84% of the total phosphorous from trout are bound as particulate wastes. But as noted above, the rainbow trout farms in Lake Tota are unusual in terms of their collection devices. Their current efficacy was not readily established for this assessment, but may have improved beyond the 71% retention in the 2017 pilot study (noted in Resolution 1310 of 2017 from Corpoboyacá). The use of these systems is considered to substantially reduce the concerns regarding the accumulation of particulate waste on the bottom of the lake.

Lake Cocha (Lake Guamuez)

Like Lake Tota, net pen farming of trout began in Lake Cocha in the 1980s (Burbano-Gallardo et al. 2021), but unlike Lake Tota, which has only seven rainbow trout farms producing approximately 1,000 mt per year, Lake Cocha has an estimated 114 farms[57] producing approximately 850 mt per year (ICA, 2021, quoting data from the Colombian Fisheries Statistical Service—SEPEC[58]). A visual count of the rainbow trout UPAs in the SEPEC mapped database shows approximately 86 UPAs in the lake, with another 8 on the shores of the lake. But Gonzalez et al. (2018) noted that, of 822 floating net pens in the lake, 561 (68%) were in operation and 261 (32%) were not. The annual production figure of 850 mt is uncertain because Burbano-Gallardo et al. (2021), referencing AUNAP data from 2013, estimated the production to be 2,585 mt per year. Figure 13 shows an example of smallholder trout farms on the western shore of Lake Cocha.

[57] This number was 94 according to Burbano-Gallardo et al. (2021), referencing a 2013 AUNAP census.
[58] It was not possible to identify or obtain these or similar data directly from SEPEC.

Figure 13: Example of smallholder trout farms in Lake Cocha. Image reproduced from Microsoft Bing.

Lake Cocha is the second-largest natural body of water in Colombia, located southeast of the town of Pasto in the department of Narino. It is 25 km long with an area of 41.5 km^2, an average depth of either 40 m (according to Burbano-Gallardo et al. 2021) or 75 m (according to González et al. 2018), and a hydraulic retention time of 6.8 years (Burbano-Gallardo et al. 2021). The hydraulic retention time of Lake Cocha at 6.8 years is several times shorter than the 30 years of Lake Tota (Aranguren-Riaño et al. 2018). Burbano-Gallardo et al. (2021) estimate that the net pens occupy 0.49% of the lake's surface area.

Like Lake Tota, there are several anthropogenic sources of nutrient inputs into Lake Cocha; for example, Burbano-Gallardo et al. (2021) and López & Madroñero (2015) list factors including (in no particular order) rainbow trout farming, domestic and agricultural wastewater, illegal coal exploitation, deforestation, and agricultural runoff. Although agriculture is reported to be the most important activity in the region[59] (Salamanca 2021), there is not the same emphasis in the literature on Lake Cocha compared to that of the intensive long onion industry bordering Lake Tota. Similarly, although domestic wastewater is reported to enter the lake (e.g., Salamanca 2021), there is not the same emphasis in the literature on Lake Cocha compared to that of the untreated municipal waste from the town of Aquitaine entering Lake Tota.

López and Madroñero (2015) evaluated the levels of chlorophyll A in relation to the levels of nitrogen and phosphorus in different areas of Lake Cocha and found that the highest value corresponded to the trout production area, and an earlier study (Lopez et al. 2008) associated higher chlorophyll A concentrations with higher intensity production.

[59] Corn, potatoes, flowers, peas, onions, apples, blackberries, tree tomatoes, plums, wheat, tomatoes, beans, vegetables, coffee, and livestock: guinea pigs, chickens, pigs, cattle, horses, and rabbits, for milk production and rearing.

In two studies of water and sediment quality at trout farms and control points in Lake Cocha, González Legarda et al. (2022, 2018) showed increasing nitrogen and phosphorous inputs with increasing intensity of production, but also showed that, while the aquaculture activities could be measured in the water column, the values analyzed were within the acceptable ranges for the ecology of the lake (i.e., as an oligotrophic waterbody). Similarly, in the sediments, increases (mainly total phosphorus and total nitrogen) were detected but again were considered to be in acceptable ranges. Nevertheless, Legarda et al. (2022) noted that their increase could cause future problems of eutrophication of the lake. It must also be noted that Legarda et al. (2022) observed a notable increase in organic matter in the upper part of the lake because of activities associated with the village of El Motilón, and this pollution increased with rainfall due to runoff; therefore, aquaculture is only one of the multiple factors that could negatively affect the lake. González Legarda et al. (2018) considered that the nutrient inputs from aquaculture were lower than those contributed to lakes and ecosystems by other livestock and agricultural activities.

In their study of macroinvertebrates, González Legarda et al. (2018) showed that aquaculture affected their presence/absence in the farm areas, and thereby a negative impact on the quality of the water and sediments in these areas; however, they considered the general presence of the Chironomidae family to an indicator of mesoeutrophic waters, while the presence of the Hydrobiosidae and Planaridae families to indicate oligotrophic and highly oxygenated waters. Thus, the effects of aquaculture were not extreme or alarming, but the authors recommended further control and monitoring of any future aquaculture developments.

Similarly, on the bottom of the lake, Burbano-Gallardo et al. (2021) showed (as they expected) that particulate wastes accumulate in the benthic zone. They showed significant differences in the levels of organic matter, total phosphorus, total nitrogen, and organic carbon measured in the sediments of the areas with net pens, compared to the control point. These parameters increased in the areas with more intensive production, but were at values that do not significantly affect the lake's water quality nor show a potential risk for the quality of the lake's water (Burbano-Gallardo et al. 2021). Regarding bacterial communities in the sediments, Burbano-Gallardo et al. (2021) determined that there is a high positive correlation of the nitrifying bacteria evaluated with the nitrogenous compounds and the organic matter measured in the sediment, which shows that these microorganisms increase their activity and growth rate to decompose these derivatives of fish farming. With their consideration that an excess of nitrogenous compounds in the environment could inhibit nitrogen fixation by bacterial communities (i.e., causing a change in their abundance, structure, biomass, and density), Burbano-Gallardo et al. (2021) reported that, beyond the impact at the farm site,[60] the sediment of Lake Cocha in general was considered to present adequate characteristics for the growth of nitrifying bacterial groups. Thus, the adverse environmental impacts associated with changes to bacterial communities (e.g., eutrophication) had not occurred in Lake Cocha.

[60] Noting again here that the net pens occupied 0.48% of the lake area.

No evidence could be found that the particulate waste collector system (tolvos) used in Lake Tota is used in Lake Cocha. It seems likely that, given the larger number of small producers (compared to the seven large producers in Lake Tota), these systems are not used in Lake Cocha.

Net Pens—Conclusions and Scoring

It is clear that the production of trout in net pens (which is based on the addition of external formulated feeds) represents a direct source of soluble and particulate nutrient wastes into freshwater lakes, and the ecological importance of maintaining high water quality in these lakes is recognized. But although the two Lakes Tota and Cocha have some similar characteristics and conditions, the nutrient dynamics of both lakes are complex and affected by many factors. In Lake Tota, nutrient studies show the intensive onion farming industry (and particularly its poorly controlled fertilizer applications) to be the dominant nutrient source in the lake, followed by the municipal wastes from the town of Aquitaine, which has not had an operational wastewater treatment plant for decades. Nevertheless, it is clear from both lakes that intensive trout production will have a local impact on the water column and the benthos, and some nutrient dynamics in these lakes (e.g., of phosphorous) remain unclear. Because of these concerns, all producers in Lake Tota are required to use collector devices under the net pens to remove particulate waste from the lake, but no evidence could be found that this is also done in Lake Cocha. The soluble portion of the total waste is still released into the lakes. Overall, the available monitoring data show that the water quality in both lakes is acceptable, but there are clear concerns regarding a trend toward eutrophication with the accumulation of nutrients in lakes with long hydraulic retention times. The relevance of several nutrient studies relating to the farms is limited by fieldwork conducted before installation of the collectors in Lake Tota. Nevertheless, given the importance of both lakes in Colombia and the desire to limit any further progress toward eutrophication, the direct contribution of nutrients from net pen trout farms to the lake is inevitably a concern. Although the nutrient inputs from trout farms may be minor compared to other sources, and studies show that the direct impacts are limited, there is considered to be a clear potential for cumulative impacts at the waterbody scale. Thus, the score for Criterion 2—Effluent for net pens is 4 out of 10.

Ponds and Raceways

With flow-through ponds or raceways, the effluent discharges typically include high volumes containing 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 such effluents are dissolved metabolites, such as ammonia, nitrite, nitrate, and phosphate, and 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).

Monthly water quality monitoring data for the year 2022 were provided by a raceway farm in the department of Risaralda, and included monthly samples taken at two influent locations (i.e., the “clean” incoming water to the farm) and in the effluent before discharge (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023). The results in Figure 14 show (as expected) that, on average, the values of the five most relevant parameters (Biological Oxygen Demand, BOD; Chemical Oxygen Demand, COD; Total Suspended Solids, TSS; total phosphorous, and ammonia-nitrogen) are higher in the effluent than the influent. Note that where results were presented as "less than" values (e.g., BOD is <5 mg/l) the full value was used in the calculation (i.e., in this BOD example, a value of 5 would be used); therefore, the results in Figure 14 are somewhat a worst-case scenario. There was also considerable variation in both the influent and effluent values, as shown by the standard deviations in Figure 14.

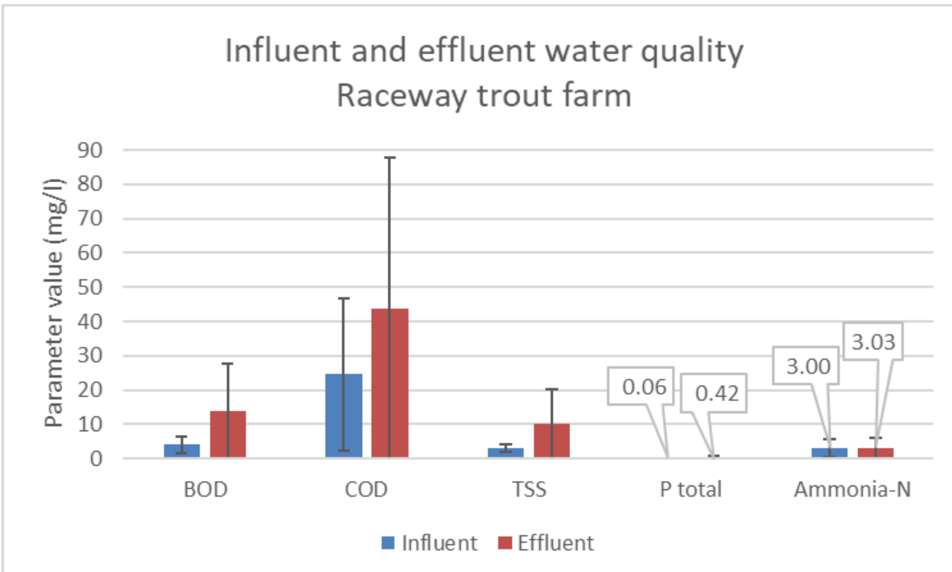

Figure 14: Water quality parameters in influent source water (blue bars) and effluent water (red bars) from a raceway trout farm in Colombia. Error bars show one standard deviation. Data provided by PezFresco (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023).

As discussed further in Factor 2.2 below, there do not appear to be any specified limits for these parameters for trout farms in Colombia. In the laboratory results (an example is provided in Appendix 2), the limits are defined as "not established" (N.E., or "No establicido" in Spanish). Resolutions 615 and 631 of 2015 establish the discharge limits for these parameters into surface waters for a wide variety of industries, but not aquaculture. As an approximately relevant comparison, the Chilean effluent limits[61] for similar parameters from freshwater raceway trout farms are shown in Table 2 along with the average and peak values in the 2022 data from the raceway farm in Colombia. For reference, the PezFresco farm is certified to the Best Aquaculture Practices (BAP) standard and follows their effluent requirements.

[61] 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

Table 2: Influent and effluent values from 2022 for a Colombian raceway rainbow trout farm. For reference (and in the apparent absence of regulatory limits in Colombia), the limits in the Chilean regulations for freshwater raceway trout farms are shown.

Parameter	Chile limit	Colombian raceway trout farm		
		2022 INFLUENT average	2022 EFFLUENT average	2022 EFFLUENT peak
BOD mg/l	35	4.04	13.83	30.00
COD mg/l	No value specified	24.63	43.86	233.00
TSS mg/l	80	3.05	10.15	12
Phosphorous mg/l	10	0.06	0.42	3.94
Ammonia-N mg/l	50 mg/l	3.00	3.03	7.11

These results show that, although the average values in the effluent are substantially higher than the average values in the influent waters, the peak values from 2022 are all below (and mostly substantially below) the Chilean regulatory limits shown here for comparison. Though this single example is illuminating, it is challenging to extrapolate it to all raceway farms in Colombia, and to extrapolate the results to any impact in the receiving waters, or a lack of impact.

The regional environmental authority in the department of Risaralda (La Corporación Autónoma Regional del Risaralda—CARDER) conducts annual water-quality testing in 60 different rivers or waterbodies, including in the Río Otún, which is used by the PezFresco farm described above. The CARDER sampling includes a point just downstream of the farm at the junction with the Rio Barbo (referred to as Rio Otún: R. Barbo. Desembocadura. Después de Pezfresco; see Figure 15). CARDER uses an index of water quality referred to as IFSN, translated as the National Sanitation Foundation Index, which combines the parameters of dissolved oxygen, pH, biological and chemical oxygen demand, nitrates, phosphorous, temperature, turbidity, suspended solids, and fecal coliforms. Results are expressed from 0 to 100 in categories from excellent (Excelente, 91–100) to good (Buena, 71–90), normal (Regular, 51–70), poor (malo, 26–50), and very poor (muy malo, 0–25).

Figure 15: Image of the PezFresco farm and the CARDER water quality sampling point (yellow circle). Image reproduced from Google Maps.

Although CARDER produces annual reports, the most recent one available on their website is from 2018 (an email request to CARDER for more recent results has not yet received a response), but considering the results from 2013 to 2018, the water quality at this sampling point is consistently good, with an average score of 74.75 over this period (noting that there are up to three sampling periods each year). Figure 16 shows the 2018 IFSN values for the Ríver Otún, with the location of the sampling point near the PezFresco farm shown by the vertical red dotted line. This shows that the river has good quality at its source (never "excellent") and it stays good until reaching the municipality of Pereira (population approximately 467,000).

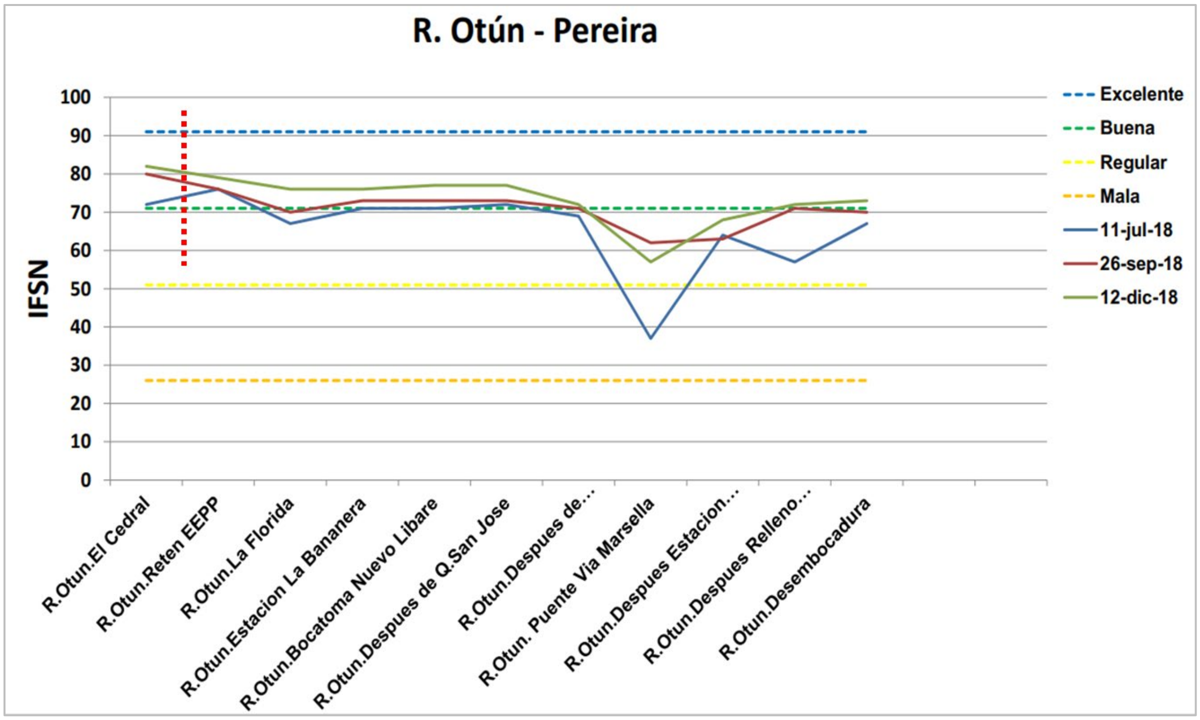

Figure 16: IFSN water quality index for the River Otún at various sampling points near the town of Pereira during three periods in 2018. The river flows from left to right. The sampling point at the PezFresco farm is not labelled but indicated with the vertical dotted red line. Horizontal dotted lines indicate the different categories of the IFSN water quality. Image reproduced from CARDER (2018).

Although similar examples of departmental water quality monitoring are available, and some sampling locations are likely to be of relevance to trout farms under assessment here, it is impractical to identify individual farms and sampling points across the multiple departments in which there are trout farms. Therefore, although these results relating to the PezFresco farm may be similar to those of other farms in Colombia, a simple extrapolation cannot be made.

Similarly, the IDEAM water quality monitoring (discussed in relation to net pen farms above) is also of limited use in understanding the effluent impacts from hundreds or potentially thousands of small trout farms. For example, an analysis of Water Quality Index from all the IDEAM monitoring points at altitudes >1,700 m from 2005 to 2021 shows that 73.9% of the results are in the Acceptable or Normal range, with 22.9% categorized as Poor (Figure 17). A further analysis (not shown) indicates that the average annual values have been largely stable, mostly varying between 0.6 and 0.7 (out of 1.0) in the “Normal” category. But given the dispersion of farms and the relatively small number of relevant monitoring stations at these altitudes (approximately 35 across Colombia), these data cannot be assumed to have any relevance to the water quality upstream or downstream of trout farms.

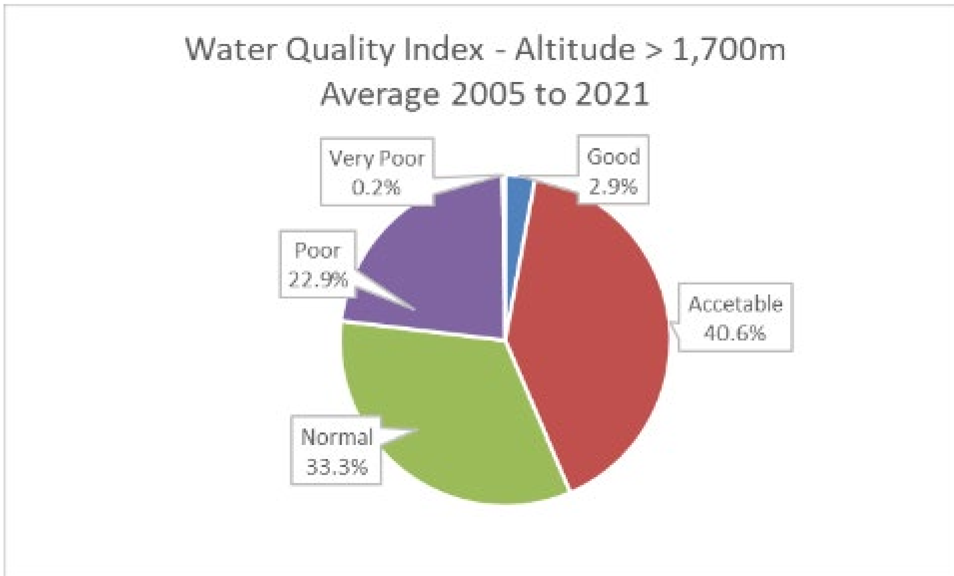

Figure 17: Average Water Quality Index (ICA) values from all monitoring stations at altitudes >1,700m from 2005 to 2021. Data from IDEAM.

Although there are some highly relevant examples of studies of the effluent dynamics of pond/raceway trout farms in Colombia (e.g., Calcetero Barato, 2022—discussed further below), given the spread of rainbow trout farms across large areas and multiple departments in Colombia and the limited direct monitoring data, there are considered to be insufficient data to use the evidence-based assessment. Therefore, the risk-based assessment has been used.

Risk-Based Assessment
This method involves assessing the amount of waste produced by the fish (based on feed inputs and harvested fish outputs) and then the amount of that waste that is discharged from the farm. The effectiveness of the regulatory system in managing waste from multiple farms is used to assess the potential cumulative impacts from the industry as a whole.

It is noted that phosphorous may be a more important limiting nutrient in freshwater systems, but this assessment is based on nitrogen because this is the most data-rich proxy indicator for aquaculture nutrient inputs and waste outputs (using protein in feeds and in harvested fish).

Factor 2.1 Waste Discharged per ton of Fish Production

Factor 2.1a—Biological Waste Production per ton of Fish
Regarding nutrient inputs in feed, as discussed in Criterion 5—Feed, an economic feed conversion ratio (eFCR) of 1.35 has been derived from various anecdotal sources, and the weighted average feed protein content for ponds is 41.0% (see Criterion 5—Feed). Nutrient inputs in the form of fertilizer are also included in the calculations here, but given the flow-through nature of ponds and raceways, it is not considered to be used in these systems (as it would not be retained in the systems long enough to stimulate any primary productivity). Because protein is 16% nitrogen, the total nitrogen input per mt of trout production is 85.3 kg.

For nitrogen outputs, the protein content of a whole harvested farmed trout is 15.7% (Dumas et al (2007), and this equates to 25.1 kg N/mt (using the same 16% nitrogen in protein). The nitrogen waste produced by the fish is therefore calculated as the inputs minus the outputs, or 63.4 kg N/mt.

<u>Factor 2.1b—Production System Discharge</u>

The amount and concentration of this waste that is discharged beyond the farm is affected by any water treatment and by the water exchange rate.[62] The national water study of 2018 (IDEAM 2019) notes that Colombia's fish farming sector does not have an information system that allows reliable calculations of its water use and considers that water exchange rates (for all aquaculture species) is relatively high. In their detailed analysis of the water footprint of three aquaculture species in Colombia, Rincon et al. (2017) showed that rainbow trout has a high direct water footprint (i.e., the amount of water consumed directly in the production of the product) compared to cachama (*Colossoma macropomum*) and tilapia (*Oreochromis* spp.). Figure 18 shows that this is primarily due to the "grey" component, which is the volume of water required to dilute the effluent wastes in order to achieve the required water quality (Rincon et al. 2017). This can be considered to be an indicator of the water exchange, and the more common use of high-exchange and flow-through production systems (e.g., raceways) for trout has a much higher grey water footprint (16,097 m^3/mt) compared to cachama (1,678 m^3/mt) and tilapia (28 m^3/mt). The production systems assessed here are therefore considered to be flow-through systems, and the initial score for Factor 2.1b is 1.0, indicating that, unless other treatment processes are in place, 100% of the wastes in Factor 2.1a could be discharged from the farm.

[62] Given the flow-through nature of the ponds or raceways, there is not considered to be sufficient time for natural processes to break down any of the nitrogenous wastes before discharge. Water treatment such as the use settling ponds do have the potential to reduce particulate wastes and are discussed above.

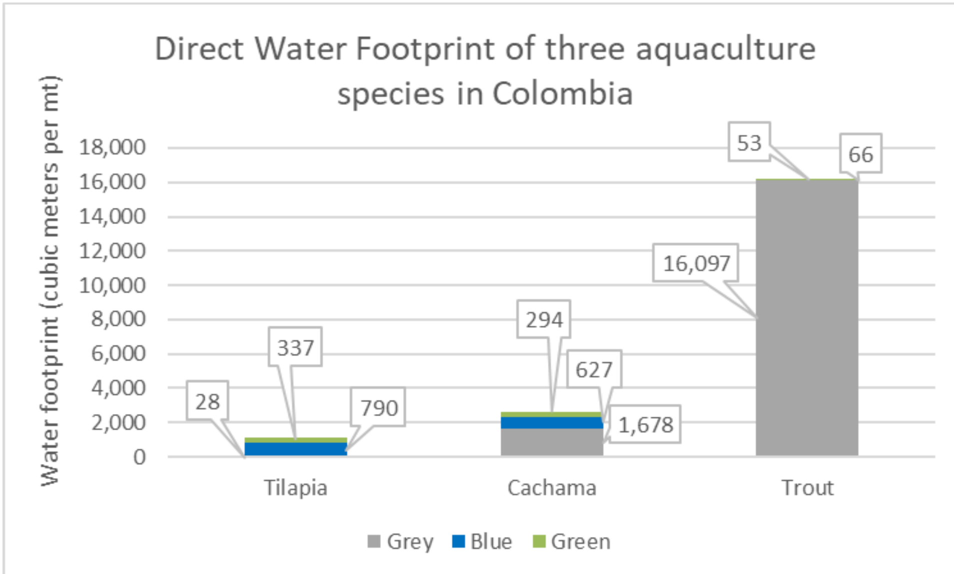

Figure 18: Comparison of the direct water footprint of three aquaculture species in Colombia. Grey bars represent the volume of water required to dilute the effluent loads, which is an indicator of water exchanges. Blue bars represent the volume of fresh water collected from surface or underground sources that evaporates in the production or is incorporated in the product, and green bars represent the volume of water from precipitation, which would reach the natural ecosystem but instead is captured and consumed in the fish production process. Graph reproduced from data in Rincon et al. (2017).

Regarding the collection and disposal of particulate wastes from ponds and raceways, the (now-dated) review of sediment management in fish farms in Colombia by González Acosta (2012) noted that all fish farms are required to allocate areas to the collection and storage of sediment (sludge) collected from the production units. For the collection of particulate wastes, the size and function of the sedimentation area must be sufficient to remove 80% of the solid waste (González Acosta 2012). With more recent changes to regulations (see Factor 2.2a below), which are based on compliance with water quality requirements as opposed to simply having treatment measures in place, it does not appear that there is a specific requirement for any specific types of water treatment; rather, the treatment process as a whole is considered more holistically. Nevertheless, some kind of particulate waste collection is considered here to typically be a component of the system.

An initial collection of particulate wastes typically occurs in the ponds or raceways themselves; for example, Figure 19 (from a raceway trout farm in Chile) shows that 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, and Luna-Imbacuán et al. (2016) noted that such sedimentation areas within raceways or ponds were cleaned every 3 days and calculated that 68.5% of the total particulate was retained inside the pond and subsequently evacuated in the washing process. But the concentration of organic matter in the washing effluent is obviously high compared to the regular water exchange, and Luna-Imbacuán et al. (2016) noted that they must be treated in order not to generate adverse effects on the receiving water bodies (discussed further below).

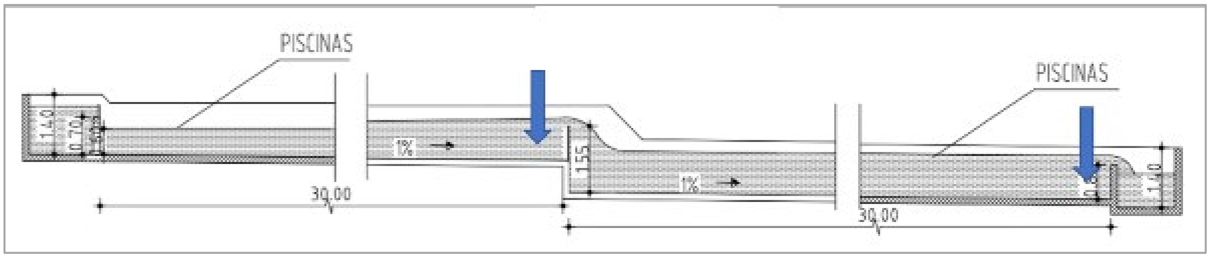

Figure 19: Longitudinal cross section of a raceway (piscina or canale), showing the two settlement zones (blue arrows). Image reproduced from the SEIA.[63]

Secondly, these production systems can also use external sedimentation areas outside the fish holding ponds or raceways to collect additional particulate wastes; an example of a sediment collector for a small pond in Colombia is shown in Figure 20 (Sánchez-Fajardo and Cuello 2015).

Figure 20: Example of a simple sedimentation filter to collect particulate wastes from a small pond (seen in the background). Image reproduced from Sánchez-Fajardo and Cuello (2015).

The sedimentation filter in Figure 20 is small in size, and the use of larger settling ponds in raceway farms is also considered to be somewhat typical in flow-through systems, but the frequency of their use and the retention times are not readily apparent in Colombia (although noting again the apparent requirement to collect 80% of particulate wastes). In a now-dated review of sediment management in fish farms, González Acosta (2012) implied that settling (or sedimentation) ponds were required and noted that the primary role of the Regional Autonomous Corporations (as the enforcement organizations for environmental regulations) was to verify their existence. But this has not been verified.

As an example of the overall effectiveness of the capture of particulate wastes, Calcetero Barato (2022) studied three trout farms on the same section of the Siecho River in the department of Cundinamarca, approximately 900 m apart. Although the chemical and biological oxygen demands (BOD, COD, or DBO and DQO in Spanish) increased in each of the farms

[63] Declaración de Impacto Ambiental "Centro de Cultivo Huite": https://seia.sea.gob.cl/busqueda/buscarProyectoAction.php

individually (i.e., between the inlet and outlet of each farm), the effluent water was considered to have very little contamination, and there was an overall decrease down the river (i.e., no accumulation from the three farms in total). Most of the other parameters measured had no consistent patterns, but there was a significant increase in phosphorus and a low increase in Total Organic Carbon across the three farms. Nevertheless, when comparing the water above the first farm to below the third farm, Calcetero Barato (2022) concluded that the management of organic matter in the farms was adequate and there was only a low-magnitude environmental impact. Calcetero Barato (2022) attributed this to the adequate design and operation of the settlement/oxidation lagoons of the three farms.

It is important to note that the collection of particulate waste is only the first step in avoiding any significant environmental impact. Thus, González Acosta (2012) also noted that it is a requirement that all fish farms allocate areas for the storage of the collected sediments and where organic degradation can take place. González Acosta (2012) and Luna-Imbacuán et al. (2016) both noted the potential use of sludge as soil conditioners and fertilizers as a dehydrated material for disposal and use on land. Alternatively, it can be used to reinforce pond banks or for other construction (González Acosta 2012). Although there is some uncertainly in the use of appropriate collection and disposal methods for particulate wastes across all trout farms in Colombia, there is considered to be sufficient evidence to apply the relevant adjustment of –0.2 (representing 20% of the total waste production in Factor 2.1a).

The remaining 80% of the waste produced by the trout (calculated in Factor 2.1a) is therefore considered to be discharged from the farms, albeit at low concentrations in relatively high volumes of flow (as indicated by the example of the three farms studied by Calcetero Barato 2022, and the example of the raceway farm data shown in Figure 14). The score for Factor 2.1b is therefore 0.8 out of 1.0.

With 63.44 kg N produced per mt of rainbow trout (Factor 2.1a), 80% or 50.8 kg N/mt is considered to be discharged. This equates to a Factor 2.1 score of 4 out of 10.

Factor 2.2 Management of Farm-Level and Cumulative Impacts

<u>Factor 2.2a: Content of Effluent Management Measures</u>

In their efforts to educate farmers and increase the level of formalization in Colombia, Fedeacua has produced a series of booklets[64] describing the regulatory requirements in five departments of Colombia. Booklet 2 (Cartilla Didáctica 2—Concesión de Agua) describes the steps necessary to obtain a water concession (i.e., to use surface or groundwater sources for aquaculture), and booklet 3 (Cartilla Didáctica 3—Permiso de Vertimiento) describes the measures relating to discharging effluent water and obtaining a discharge permit for point-source discharges.[65] The broader formalization process also requires a livestock registration for each aquaculture production unit with the Colombian Agricultural Institute (ICA) (specifically,

[64] https://fedeacua.org/page/eduaqua

[65] As noted previously, discharge permits are not required when the discharge is diffuse, as in the case of net pens located in lakes, lagoons, reservoirs, or other lentic bodies of water (Fedeacua, 2018c).

the Livestock Registry of Aquaculture Establishments or the Registro Pecuario de los Establecimientos de Acuicultura—RPEA) (Fedeacua 2018). Colombia also has a General Registry of Fisheries and Aquaculture (El Registro General de Pesca y Acuicultura—RGPA[66]) but its specific role in the formalization process is unclear. (Note that the aspects of the formalization process relating to Land Use and Forest Permits are discussed in Criterion 3—Habitat.)

It can be seen that the process for obtaining a discharge permit is comprehensive (Fedeacua 2018c, using the department of Boyacá as an example). It is based on Decree 1076 of 2015 (Regulatory Decree of the Environment and Sustainable Development) and eight other decrees and resolutions (listed on page 9 of Fedeacua 2018c). Permits are considered and granted by the regional environmental authorities; for example, in Boyacá, this is the Regional Autonomous Corporation (Corporación Autónoma Regional de Boyacá—Corpoboyacá).[67] The intent of the process is to "seek to evaluate whether the discharge of fish farming water can cause any environmental damage to the receiving water body, with a view to establishing preventive, corrective and/or compensatory measures." The discharge permit is described as a mechanism that allows the fish farmer to comply with current environmental regulations.

The application process involves a number of stages, including environmental assessments of the receiving waterbody's quality upstream and downstream of the discharge point (using a variety of physical and chemical indicators), consideration of the volume, frequency, and continuous/intermittent nature of the discharges, and consideration of other discharges in the vicinity. A professional topographic survey (of the physical, geographical, and geological characteristics) of the farm site is required, in addition to specifications and engineering reports for any wastewater treatment facilities. These are all relevant to the assessment of the impacts that may arise from specific discharges to the body of water, and the requirement to specify contingency measures to avoid them. Despite all these measures, there does not appear to be any specific regulatory limits for relevant effluent parameters. As discussed above, Resolutions 615 and 631 of 2015 establish the discharge limits for these parameters into surface waters for a wide variety of industries, but not aquaculture, and in the water quality testing results provided from one raceway farm, the limits are defined as "not established" (N.E., or "No establicido" in Spanish). The primary mode of operation of these measures therefore appears to be on risk assessments and on requirements for the use of treatment devices such as settling ponds that are intended to ensure that effluent waters are of suitable characteristics to prevent a significant impact.

Colombia also has a Directorate of Territorial Environmental Planning and National Environmental System (Dirección de Ordenamiento Ambiental Territorial y Sistema Nacional Ambiental—SINA[68]) within the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS[69]), but the specific role of SINA (or

66 https://rgpacolombia.gov.co
67 https://www.corpoboyaca.gov.co/
68 https://www.minambiente.gov.co/ordenamiento-ambiental-territorial-y-sistema-nacional-ambiental-sina/
69 https://www.minambiente.gov.co/

MADS) regarding aquaculture is not readily transparent from its publicly available information (website).

As discussed previously (examples in Figures 8–10 and 12), IDEAM, in cooperation with the regional environmental authorities, has a water quality monitoring system across Colombia (the National Reference Network for Water Quality, made up of 160 monitoring points, from which approximately 40 water quality variables are analyzed). Each department also has water quality monitoring (example in Figure 16 from the department of Risaralda) conducted by the regional environmental authorities. These results are considered to provide feedback to discharge permits regarding the consideration of cumulative impacts from other aquaculture producers, but also from other industries and municipal wastes. But this process is not readily transparent. Overall, though the uptake of this system by the thousands of trout farmers in Colombia may be low (as discussed in Factor 2.2b below), the management measures in place, as described by Fedeacua (2018c), are considered to be well-intended and comprehensive. But with no apparent specific effluent limits for individual farms (and for aquaculture more generally), in addition to some uncertainties regarding the incorporation of cumulative impacts from other industries, the score for Factor 2.2a—Content of Effluent Management Measures is 3 out of 5 for ponds.

Factor 2.2b: Enforcement of Effluent Management Measures

The apparently comprehensive nature of the application process for a water concession and an effluent discharge permit is likely to be one of the main challenges regarding uptake and enforcement because of the inevitable costs involved—not just in the permit fees, but in the preparation of materials for the application. Fedeacua and AUNAP acknowledge this challenge (as noted by Fedeacua 2018a and Roca-Lanao et al. 2021). Probably the starkest indicator of poor enforcement in this regard is the quite limited number of "formalized" farms that have the appropriate permits and registrations, and therefore the high number of "informal" farms. "Formalización" is the term given to the permitting and registration process in Colombia. According to Carrera-Quintana et al. (2022), most of the fish farmers in Colombia operate legally, but according to Fedeacua (2018a), formalization is the first step for all fish farmers to legally carry out their productive activity. Colombia has a National Authority for Environmental Licenses (Autoridad Nacional de Licencias Ambientales—ANLA[70]), but information relating to aquaculture does not appear to be readily available.

According to Roca-Lanao et al. (2021a), Colombian aquaculture is an economic activity that is developed to a greater degree independently and informally, and this is perhaps not surprising considering that such permissions or formalities are not required for Colombians to plant crops or keep other types of livestock such as chickens or cattle (Fedeacua 2022). Previously, Flores-Nava (2012) noted that the limiting factor in this formalization process is the lack of support, because many of the producers are unaware of the mechanisms required to carry out the activity. Since then, it is considered that the efforts made by Fedeacua, AUNAP, and others

[70] https://www.anla.gov.co/

(e.g., the series of educational booklets[71] and other promotional activities) are a big improvement in this aspect. Nevertheless, the rate of formalization remains quite low. According to Fedeacua (2018), a census of aquaculture farms was made in 2014, but as of 2018, only 2% of those surveyed farms at the national level were formalized. This varies by department; for example, in Huila it was 8.3% in 2018 (Fedeacua 2018). Fedeacua, AUNAP, and the regional authorities are leading the process to increase the number of formalized farms, and in 2022, Fedeacua (2022) claims significant progress, with 15.4% of the estimated 35,000 farms formalized.

The recent progress has been the most substantial, with 10.6% of farms formalized between October 2021 and May 2022, in contrast to the 4.8% of farms that had been formalized at any point since the establishment of AUNAP in 2011 (Fedeacua 2022). According to Fedeacua (2018a), the goal is for 50% of producers to be formalized by 2032, but also notes that the process is costly for small farmers.

Regarding the registration component of the formalization process (i.e., with the RPEA or RGPA), the apparent number of registered farms is also low. For example, while a list of farms in the RPEA does not appear to be readily available, the RGPA lists only 478 farms (accessed July 31, 2023).[72] Nevertheless, the ICA can also be seen to be active in promoting the formalization of farms in various departments (for example in Cauca in 2019[73] and Cordoba in 2018[74]). The fisheries statistical service (SEPEC[75]) is also actively characterizing farms with annual surveys covering thousands of farms (a total of approximately 8,700 since 2016; Roca-Lanao et al. 2016, 2018, 2019, 2020, 2021a,b), but it is not immediately clear how this relates to the formalization process.

In describing the permitting process, Fedeacua (2018c) notes that a producer who generates discharges without having the respective permit must assume the imposition of preventive measures by the regional environmental authority. These measures can include the preventive confiscation of products, elements, means, or implements used with which the infraction is committed, a written warning, or suspension of the activity when damage or danger to the environment, natural resources, the landscape, and human health arises. But given the large numbers of farms operating without discharge permits, it seems clear that enforcement in this regard is minimal.

Overall, it appears that the large majority of aquaculture farms in Colombia are still not formalized, and with a goal of 50% formalization by 2032, this appears likely to continue for some time. In terminology, it is clear that the large majority of farms are "informal"; however, although the formalization process is required to operate legally in Colombia, it may not be

[71] https://fedeacua.org/page/eduaqua
[72] https://www.aunap.gov.co/rgp/
[73] https://www.ica.gov.co/noticias/producers-aquaculture-competitiveness-valley
[74] https://www.ica.gov.co/noticias/ica-registro-predios-acuicolas-bioseguros-cordoba
[75] Information System of the Colombian Fishing Statistical Service" (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC

correct to state that these farms are operating illegally. Nevertheless, substantial efforts are being made by many organizations to increase the numbers of formalized farms, and it is considered likely that there would be active enforcement of the permitting process for any new farms. Therefore, enforcement measures are considered to be limited, with limited monitoring and compliance data. The score for Factor 2.2b—Enforcement of Effluent Management Measures for ponds is 2 out of 5. Factors 2.2a and 2.2b combine to give a final score for Factor 2.2—Management of Farm-Level and Cumulative Impacts of 3.2 out of 10.

Ponds and Raceways—Conclusions and Final Score

Influent and effluent monitoring data from a raceway farm in addition to specific effluent studies (e.g., of three trout farms on the Siecho River) show the effluent concentrations are low, and impacts may be minor. But without sufficient data to understand the impacts (or lack thereof) of raceway and pond farms more broadly in Colombia, the risk-based assessment was used. Considering typical feed use, it is estimated that there is a total nitrogen input of 88.6 kg N/mt of trout. After the removal of nitrogen in harvested trout, the total waste nitrogen produced is 63.4 kg N/mt. Given the typical flow-through nature of the production systems, 80% is considered to be discharged to the environment (50.8 kg N/mt, and a score of 4 out of 10 for Factor 2.1). Educational information produced by Fedeacua and the government describes a substantial regulatory permitting framework, but there do not appear to be specific effluent limits in place for individual farms, and there continues to be a low uptake because of the large majority of farms operating in an "informal" manner. Considerable efforts are being made to increase this, but the costs of compliance are a challenge for small producers, and the goal of 50% of formalized producers by 2032 shows that progress is slow. Thus, with limitations in the regulations and low effective enforcement, the Effluent Management score (Factor 2.2) is 2.4 out of 10. The scores for Factors 2.1 and 2.2 combine to give a final score for Criterion 2—Effluent for raceways and ponds of 4 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

	Value	Score	Value	Score
C3 Habitat parameters	**Net pens**		**Ponds**	
F3.1 Habitat conversion and function (0–10)		8		7
F3.2a Content of habitat regulations (0–5)	4		3	
F3.2b Enforcement of habitat regulations (0–5)	3		2	
F3.2 Regulatory or management effectiveness score (0–10)		4.80		2.40
C3 Habitat Final Score (0–10)		**6.93**		**5.47**
Critical?	No	**Green**	No	**Yellow**

Brief Summary

Colombia is listed as one of the world's "megadiverse" countries, but according to the Human Spatial Footprint Index, many areas have had a high degree of human impact, largely before the development of aquaculture. Because of the low temperature requirements for rainbow trout, the location of farms is restricted to high-altitude areas in the Andes Mountains, and a government zoning study indicated that only 2% of the country was highly suitable for trout farming (a further 10% is moderately suitable). Regarding the habitat impacts of net pens, Colombia has 47 large reservoirs, lakes, and lagoons, of which only 4 are used for aquaculture, and only Lake Tota and Lake Cocha are used for trout. The habitat impacts of floating net pens in these lakes appear limited (and immediately reversible), yet there are still likely to be some impacts on the ecosystem services provided by the waterbody. Production in the lakes appears to be managed primarily by the regional authorities (Corpoboyacá and Corponariño), and the potential for trout production to expand to other waterbodies in Colombia appears to be well-managed under Fisheries and Aquaculture Management Plans (Plan de Ordenamiento Pesquero y Acuícola—POPA), although specific details are challenging to find. Overall, the score for Criterion 3—Habitat for net pens is 6.9 out of 10.

The majority of trout raceways and ponds in Colombia appear to have been constructed in former agricultural land, with perhaps minor impacts to dry or riparian forests and to scrublands. Inland aquaculture in general (of all species) is perceived as a relatively low driver of habitat change or loss of wetlands in Colombia. The Agricultural Rural Planning Unit (Unidad de Planificación Rural Agropecuaria—UPRA) has developed a detailed map that defines suitable locations for trout aquaculture, but it does not take account of habitat impacts in its defining methodology. There is now a permitting process in place for raceway and pond farms that includes land use and forest permits, and the latter is required for any modification to vegetation during the establishment or modification of a farm. This permitting process, along with apparently comprehensive environmental impact assessment requirements, is considered to apply to new farms, but the effective enforcement of the regulatory system is challenged by the high proportion of farms that currently do not have the necessary permits. Though there are active efforts to "formalize" aquaculture farms by many organizations, the process is costly for farmers, and only 15.4% were considered formalized in 2022. The goal is 50% by 2032. With the majority of ponds constructed in former agricultural land, but a low proportion of formalized farms, the score for Criterion 3—Habitat for ponds is 5.5 out of 10.

Justification of Rating

Factor 3.1. Habitat Conversion and Function

According to the Convention on Biological Diversity,[76] Colombia is listed as one of the world's "megadiverse" countries, hosting close to 10% of the planet's biodiversity (worldwide, it ranks first in bird and orchid species diversity and second in plants, butterflies, freshwater fishes, and amphibians). Colombia has over 720,000 basins and micro-watersheds, and approximately 1,800 waterbodies classified as ponds, lakes, and reservoirs (Cruz-Casallas et al. 2011). These supply the headwaters to several key rivers in South America, including the Amazon and Orinoco Rivers, making Colombia one of the most hydrologically rich countries on earth (MADR 2010)(Cruz-Casallas et al. 2011)(Merino et al. 2013). Many of these watersheds are areas of high biodiversity, which government agencies work to protect through proper agriculture and aquaculture zoning, best aquaculture management strategies, and mitigating the risk from aquaculture activities interfering with ecosystem services or habitat function (AUNAP 2014b).

The first principle of the 2014 National Plan for the Development of Sustainable Aquaculture in Colombia is the "Principle of sustainability and protection of Biodiversity." Thus, the plan will "… promote the use of aquaculture systems that ensure the sustainable use of natural resources and will stimulate processes and mechanisms that contribute to guaranteeing the balance of ecological and biodiversity conservation; for that, it will use the ecosystem approach … ."

The plan also recognizes that aquaculture activities make use of environmental services and natural resources that are also used by many other human activities, and in this context of multisectoral use of the ecosystem, it also recognizes that land use planning is an essential instrument to support sustainability. While the 2014 National Plan document is readily

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76 https://www.cbd.int/countries/profile/?country=co#:~:text=Biodiversity%20Facts&text=Colombia%20is%20listed%20as%20one,butterflies%2C%20freshwater%20fishes%20and%20amphibians.

available, understanding the practical results of the plan over the last 8 years is more challenging to determine.

In 2013, AUNAP conducted an aquaculture zoning study (AUNAP 2013). Figure 21 shows that, considering the temperature and water requirements for the production of coldwater species (i.e., trout) in Colombia in addition to a variety of legal exclusions, only 2% of the country's land area is suitable for trout aquaculture, while 10% is moderately suitable. These areas are associated with the high mountain areas of the Andes Mountain range (Figure 21).

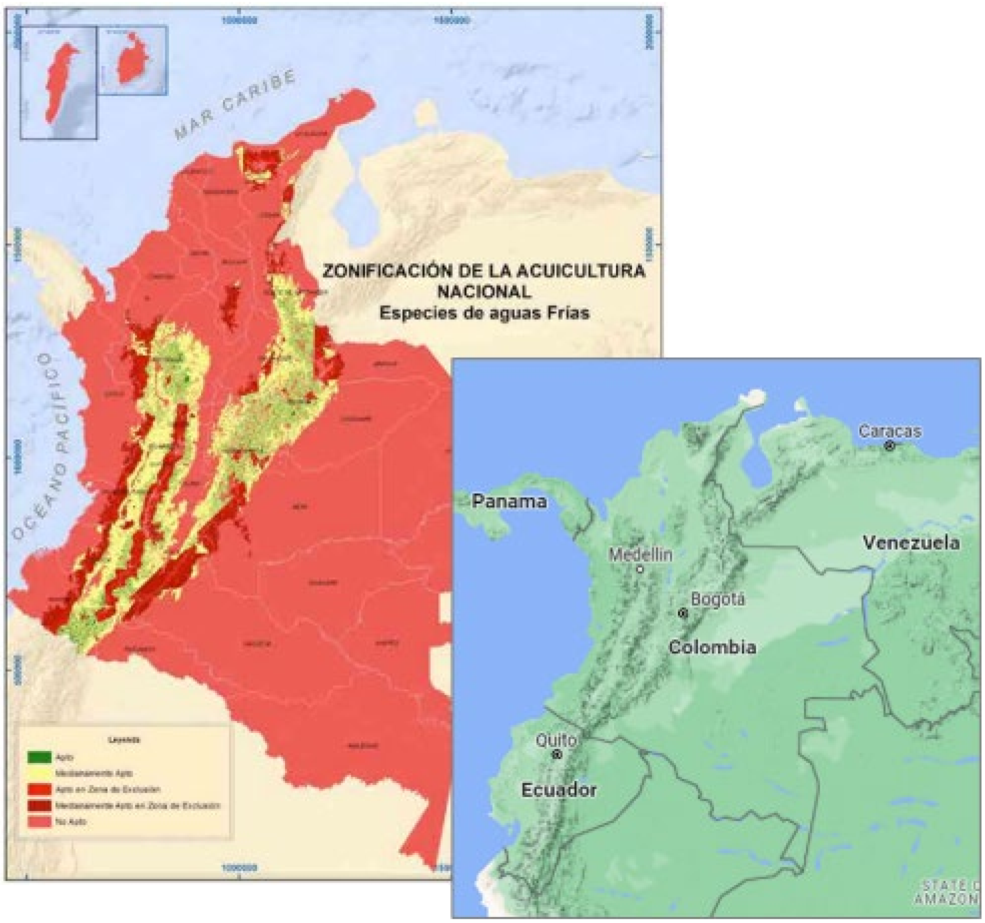

Figure 21: Aquaculture zoning for coldwater species (i.e., trout), associated with high elevations in the Andes Mountain range. In the main (left) image, green areas are suitable, yellow are moderately suitable, bright red areas are suitable but in exclusion zones, dark red are moderately suitable but in exclusion zones, and the large pale red areas are not suitable. The right inset image shows the topography of Colombia and the Andes Mountains. Main image from AUNAP (2013), inset image reproduced from Google Maps.

Seven departments (Cundinamarca, Boyacá, Antioquia, Santander, Cauca, Nariño, and Huila—see Figure 6 for their locations within Colombia) together have more than 91.6% (2,641,663 hectares) of the total area suitable for the development of this activity.

Regarding human impacts in these areas, Figure 22 shows a map of the Human Spatial Footprint Index (El índice de huella espacial humana—IHEH)[77] between 1970 and 2015 (Correa-Ayran et al. 2020). The IHEH index is scored from 0 to 100, indicating in ascending order the degree of human impact (from all human activities). By comparing this map to the areas suitable for trout aquaculture in Figure 21, it is clear that trout aquaculture takes place in areas with high human impact. When the human impact in Colombia is considered at a high level, the Convention on Biological Diversity considers that the main threats to the conservation of biodiversity include, among others, increasing social inequality, internal armed conflict for more than five decades, shifting of the economy toward primary industries, the illegal drug trade, weak access policy and titling, and implementation of extensive livestock and agricultural models.

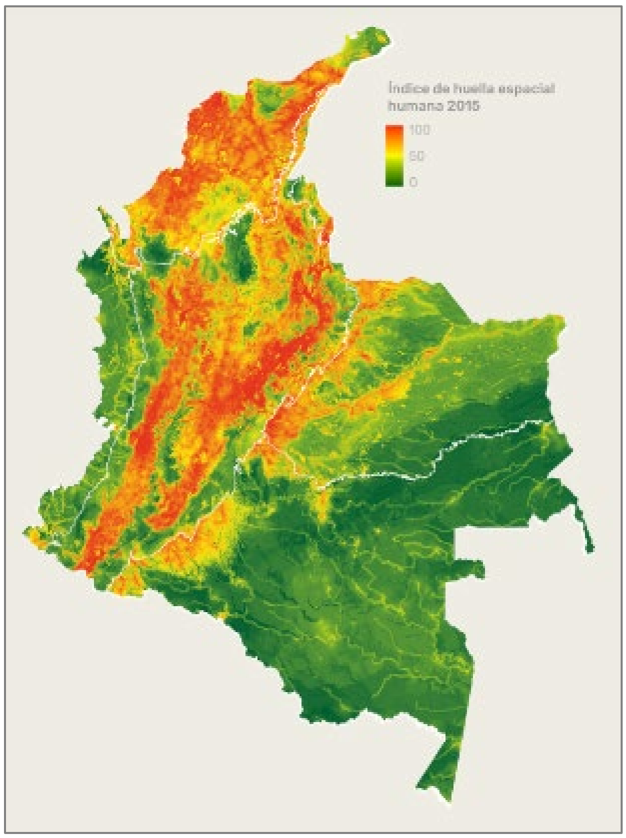

Figure 22: Map of the Human Spatial Footprint Index in Colombia as of 2015. Higher values in the 0–100 range indicate a higher human impact (from all human activities). Image reproduced from humboldt.org.co.

By considering the timeline of change within the 1970 to 2015 period of the IHEH study (Correa-Ayran et al. 2020), Figure 23, box (a) shows that the hotspots of change primarily occurred in the 1970 to 1990 portion of this period. And, by comparing the changes from 1970 to 2015 in

[77] A project from the Alexander von Humboldt Biological Resources Research Institute: El cambio en la huella espacial humana como herramienta para la toma de decisiones en la gestión del territorio | Biodiversidad 2018 (humboldt.org.co)

Figure 23, box (d) to the overall index in 2015 in Figure 22, it can be seen that large changes also occurred before 1970, including in the areas considered by AUNAP (2013) to be suitable for rainbow trout production (Figure 21).

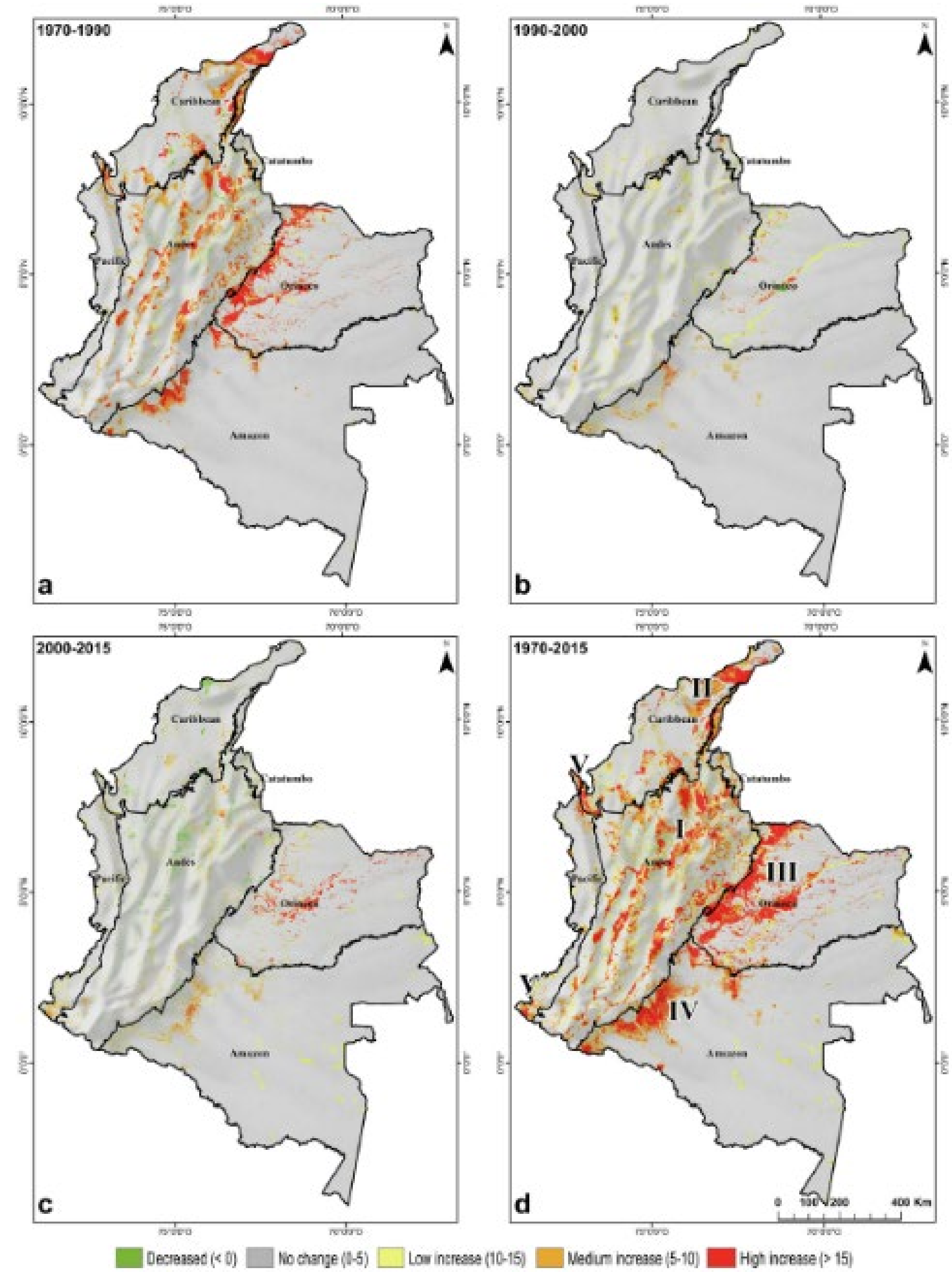

Figure 23: Spatial distribution of hotspots of change in the Human Spatial Footprint Index: a) Period 1970–1990; b) Period 1990–2000; c) Period 2000–2015; and d) Period 1970–2015. Image reproduced from Correa-Ayran et al. (2020).

Considering the small harvest volumes of rainbow trout in the earliest FAO data from 1980 (85 mt), which reached 9,000 mt by the turn of the century (see Figure 7 in the Introduction), it can be seen that trout farming is a recent development in Colombia (as a contrasting example, shrimp farming in Indonesia is reported to have begun in the 15th century; Rimmer et al. 2013). The largest increase in trout production did not take place until the last decade, when production increased from 6,657 mt to 27,851 mt between 2015 to 2020. This in no way implies that trout farming has not had habitat impacts in the context of the IHEH study, but it is perhaps reasonable to assume that rainbow trout aquaculture primarily developed in landscapes and habitats that had already seen significant human impact. The situations for net pens and ponds are discussed separately below.

Net Pens

As noted in the introduction, of the 47 large reservoirs, lakes, and lagoons in Colombia, only 4 are used for aquaculture, and only Lake Tota and Lake Cocha (also known as Laguna or Lago Guamuez) are at high altitude and used for rainbow trout farming (Fedeacua 2016). Although Colombia has 33 constructed (i.e., dammed) reservoirs, both Lake Tota and Lake Cocha are natural lakes and are the two largest freshwater bodies in the country.[78] Lake Cocha (and a large area of the drainage basin around it) was designated as a Ramsar[79] site in 2001 (the total designated area is 39,000 ha, of which the lake covers 4,200 ha).

Although the net pens are easily visible in online satellite imaging (e.g., Google Earth or Microsoft Bing maps[80]), they occupy a small percentage of the total lake areas. For example, in Lake Tota, the total area of net pens was roughly 0.02% of the area of the lake (based on production in 2014; CONPES 2014), and Burbano-Gallardo et al. (2021) estimated that, in Lake Cocha, the net pens occupy 0.49% of the lake's surface area.

The floating net pens are not considered to have any direct habitat impact on the lake. Potential impacts to the lake benthos are addressed in Criterion 2—Effluent. Studies in temperate coastal water bodies have shown that the net pens and their supporting infrastructures (i.e., the floats and weights, and the mooring ropes, buoys, and anchors) contribute much physical structure to nearshore habitats, and impose on the physical environment at the farm location by modifying light penetration, currents, and wave action as well as providing surfaces for the development of rich biotic assemblages that may further increase the complexity of the habitat (e.g., McKindsey 2011). But the applicability of this study to net pens in tropical freshwater lakes is tenuous.

Lake Tota is a breeding ground for several threatened or endangered bird species, including the least bittern (*Ixobrychus exilis bogotensis*), the Colombian ruddy duck (*Oxyura jamaicensis andina*), the Bogotá rail (*Rallus semiplumbeus*), and Apolinar's wren (*Cistothorus apolinari*). The last confirmed sighting of the Colombian grebe (*Podiceps andinus*), now considered to be extinct, was at Lake Tota (WWN 2012, Wikipedia—Lake Tota). Lake Cocha is associated with important bird species such as the grebe (*Podiceps occidentalis*), the golden peck duck (*Anas georgica spicauda*), several species of snipes (*Gallinago gallinago paraguaiae*, *Gallinago nobilis*,

[78] https://www.sula.com.co/blog/top-11-lakes-of-colombia/

[79] Ramsar site number 1047. Laguna de la Cocha | Ramsar Sites Information Service

[80] Google does not have a good quality image of Lake Cocha, but Microsoft Bing maps does.

Gallinago gallinago delicata), and the endemic ducks (*Anas cyanoptera borreroi*, *Oxyura jamaicensis ferruginea*). But it is not clear how aquaculture affects the behavior of these animals, particularly considering other human activities on (and around) the lakes. For example, the last sighting of the Colombian grebe in Lake Tota was in 1977, before the development of aquaculture in the lake (Birdlife International[81]).

Regarding the potential range of ecosystem services provided by these natural lakes, the most likely impact appears to be on access and use of the reservoir for purposes other than trout farming (e.g., tourism, which is important at least to the area around Lake Tota). Overall, the physical presence of floating net pen trout farms is considered to have some impact on the ecosystem services of the lake, but only a minor one. Therefore, the score for Factor 3.1—Habitat Conversion for net pens is 8 out of 10.

<u>Ponds and tanks</u>
The map of aquaculture production units (UPAs) in Colombia (from SEPEC[82]) shows that the locations of rainbow production are clearly restricted regarding altitude yet are widespread within those suitable high-altitude areas of Colombia. Detailed data on farm sizes, their date of construction, or their former habitat types are not available. There is clearly a wide range of farms sizes, and from a visual perspective of farms in the SEPEC map layer, it can be seen that the majority of the listed UPAs appear to be small.

Ricaurte et al. (2017) studied the perceived importance of a suite of potential drivers of land-use change and habitat loss in Colombia, particularly with reference to wetlands. Expert participants allocated perceived importance scores from 1 to 3 for 19 potential drivers of change in categories of agricultural crops, cattle ranching, mining, water infrastructure (which included inland and marine aquaculture), and road infrastructure. Figure 24 shows that inland aquaculture was perceived to be a relatively low driver of wetland land-use change and habitat loss.

[81] http://datazone.birdlife.org/species/factsheet/22696615
[82] Ubicación Geográfica de las Unidades de Producción de Acuicultura - SEPEC (aunap.gov.co)

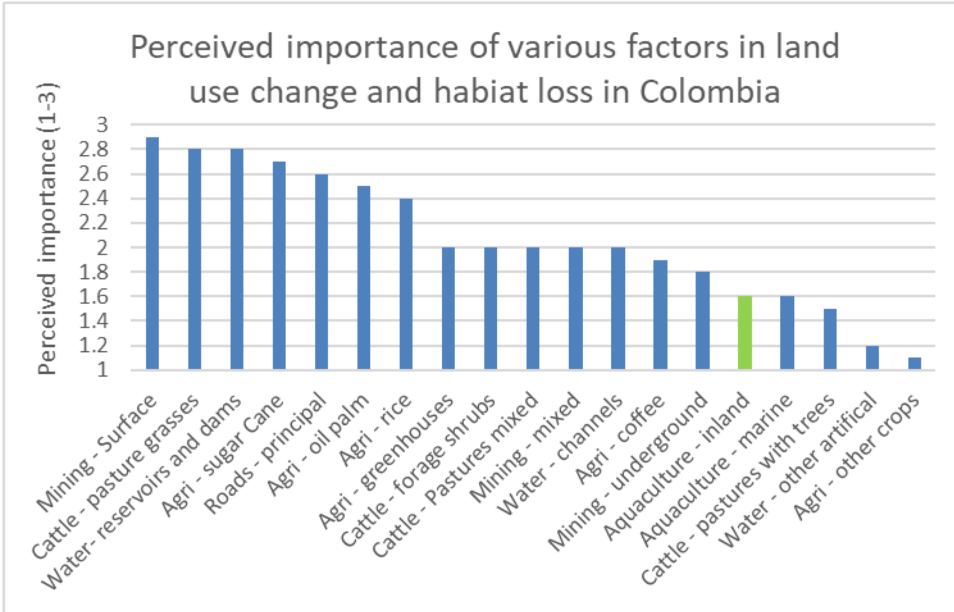

Figure 24: Perceived importance of various drivers of change in land use and habitat loss regarding wetland ecosystem services in Colombia. Inland aquaculture is highlighted in green. Data from Ricuarte et al. (2017).

Given the lack of formal records or data on the specific types of former habitats in which trout ponds have been constructed in Colombia, an approximation of typical former habitats must be made. Given the locational information available from SEPEC, such an approximation can be made using satellite images (specifically, the historic image function of Google Earth Pro) and a suitable sample of the trout UPAs. Farms were selected randomly at a high level from the SEPEC map layer at random throughout Colombia. Where SEPEC identified the UPA as a trout producer, and where the resolution of the Google Earth images allowed sufficient visualization, the former habitats of 50 farms were recorded. The former habitats were categorized as primarily a) agricultural, b) sparse scrub, c) dense scrub or dry forest, and d) wetland or riparian forests. For c) and d), Google Earth Pro was used to identify if the forest was adjacent to a marked river or stream. It was found that there was limited and often insufficient resolution in historical images, and in some cases, farms were categorized as being located in former agricultural land if it could clearly be seen that the farm was located in an agricultural landscape (i.e., based on an assumption that the conversion of the original habitats to agricultural land was likely to have occurred before the development of aquaculture).

Of the 50 farms analyzed (from 5 departments), 42 (84%) were either demonstrably built in former agricultural lands or were clearly located in an extensive agricultural landscape. The remaining eight farms (16%) were also primarily located in agricultural landscapes, were but sufficiently surrounded by trees to suggest that there may have been significant clearance for the farm construction. Given the association of trout farms with rivers or other lotic water sources, it could be assumed that any trees would be of a riparian nature, and therefore of a high habitat value. But the random survey of farms from satellite images shows that the “average” or “typical” rainbow trout farm in Colombia appears to be built in former agricultural land. Given the previously modified nature of this habitat (i.e., at some point historically it was converted from its original natural state to agricultural land), its subsequent conversion from agricultural fields or grazing land to aquaculture ponds is not considered to have resulted in a loss of ecosystem functionality. That is, the ecosystem services provided by the agricultural land have largely been maintained, and the conversion to aquaculture has not caused a loss of functionality of the area. Nevertheless, in many cases, the construction of farms can be seen to have had at least some impact on riparian forests or other forested areas, and the number of farms that it is possible to survey in Google Earth is limited (by time and the availability of sufficient resolution in the older images).

Figure 25 shows a relatively small area (approximately 0.75 square miles) that includes eight separate UAPs from the SEPEC database. But, although this is an example of a concentrated group of farms, it is clear that the farms are somewhat dispersed in a predominantly agricultural landscape.

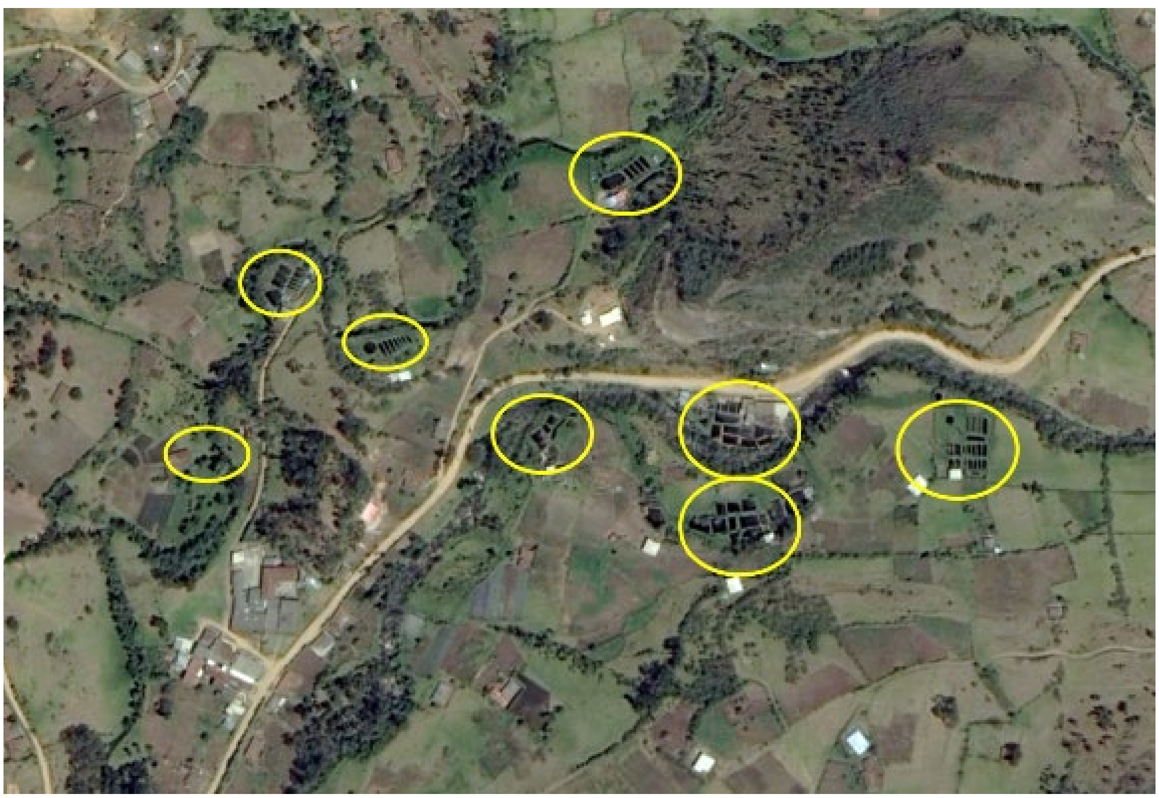

Figure 25: Example of a concentrated grouping of eight trout farms in a small area of Colombia. The farms are located in a primarily agricultural landscape. Each yellow circle shows a separate UAP identified from the SEPEC database. Image reproduced from Google Earth.

For contrast, Figure 26 shows a larger view of the same area of trout farms in Colombia (note the distinctive curve in the road), with an example of continuous shrimp ponds in an aquacultural landscape in southern Vietnam at approximately the same scale. Although Figure 25 and the top image in Figure 26 show an example of a concentrated area of trout farms, it is clear that they are a small component of a broader agricultural landscape.

Figure 26: Example of trout farms within an agricultural landscape in Colombia (top image—the yellow circles highlight the same eight farms shown in Figure 25), compared to continuous shrimp ponds in an aquaculture landscape in Vietnam. The scales show that the images are of (very) roughly the same scale. The eight UPAs in Figure 25 can be seen in the top image. Images reproduced from Google Earth.

Overall, considering the results of Ricaurte et al. (2017), in addition to the ability to study a sample of farms from satellite images and applying some precaution (given the minimal amount of formal data), raceway and pond trout farms are considered to be maintaining the functionality of the ecosystems in which they were constructed, but with moderate impacts. The score for Factor 3.1 for ponds is therefore 7 out of 10.

Factor 3.2. Farm Siting Regulation and Management

Factor 3.2a: Content of habitat management measures

In the 2018–2022 Policy Strategy for the Fishing Sector and Aquaculture, the Ministry of Agriculture and Rural Development (Pinzon 2019) recognized that aquaculture activity in Colombia has developed without adequate planning, and that the regulatory framework of the sector was quite limited regarding aquaculture. The success of the 2018–2022 strategy is unclear in terms of the development of a new regulatory system, but the following is based on the regulatory reviews and supporting documents provided by Fedeacua[83] (accessed in May 2023).

Net pens

Fish production in floating cages in natural or artificial bodies of water can only take place if the body of water has a Fisheries and Aquaculture Management Plan (Plan de Ordenamiento Pesquero y Acuícola—POPA), which must be prepared and regulated by the National Authority of Aquaculture and Fishing—AUNAP and the relevant regional authority (in the Department of Boyacá, this is the Regional Autonomous Corporation of Boyaca, Corpoboyacá, and in Narino is Corponariño). More specifically (according to Ley 25 of 2014), it is the role of AUNAP to identify potential water bodies (for example, according to the zoning studies described in Factor 3.1 and Figure 21 above) and to establish the criteria and general methodological parameters for the preparation, execution, monitoring, and evaluation of the POPA. Subsequently, regarding the development of the POPA (facilitated by a Technical Committee for Fisheries and Aquaculture Management chaired by AUNAP), it is the responsibility of the Regional Autonomous Corporations (i.e., the regional environmental authority) to prioritize the uses of water resources, identify users, and advance studies of water quality, fish carrying capacity studies, and potential zoning and suitable locations for net pens. Unfortunately, no further specifications on the methodological parameters and requirements for POPAs could be readily obtained from AUNAP or the regional authorities.

Fedeacua (2016) noted that, of 47 existing reservoirs and lagoons in Colombia, only 4[84] have POPAs (the two high-altitude cold-water lakes of Tota and Cocha, the warm-water Betania Reservoir in the department of Huila, and the coastal El Guájaro Reservoir in the Atlantico department). Unfortunately, no specific POPA documentation could be readily obtained for any of these lakes. Fedeacua (2016) considered at least 19 additional bodies of water in Colombia to have fish farming potential because of their suitable environmental conditions and because they do not have legal, technical, or socioeconomic restrictions. Fedeacua had initiated the process for consultation and formalization of this activity with the industry, environmental authorities, and the community, but seven years later in 2023, Lakes Tota and Cocha remain the only waterbodies used for net pen rainbow production (pers. comm., Cezar Pinzon, Fedeacua, September 2022).

[83] https://www.fedeacua.org/page/eduaqua

[84] Betania, in the Department of Huila; Tota, Boyacá; La Cocha, Nariño; and El Guájaro, Atlántico.

Each net pen farm occupying a reservoir, or any other body of water, must have a permit from the relevant autonomous corporation (Fedeacua 2018a). Specifically, this is called a Channel Occupation Permit (Permiso de Ocupación de Cauce). Apart from limiting the number of net pens or their size, it is not readily apparent how any habitat impacts would be managed for floating net pens in a lake (including within the POPA process). As noted previously (Factor 3.1), the net pens occupy a small percentage of the total surface area of both lakes, and according to one company in Lake Tota and a representative of Fedeacua, production is limited in both Lake Tota and Lake Cocha according to the number of permitted companies and the number of net pens permitted (see also Factor 3.2 below). Therefore, although the process is unclear, there does appear to be a process in place to limit and/or manage the development of net pen trout farming in other waterbodies in Colombia (through POPA), in addition to apparent controls from the regional authorities in each of the lakes currently used. Thus, regarding the apparent controls on the expansion of production, particularly to other waterbodies, there is considered to be an area-based habitat management system in place that is addressing the future expansion of the industry. The score for Factor 3.2a—Content of habitat management measures is 4 out of 5.

Raceways and ponds

As discussed in Factor 3.2b below, the primary challenge with understanding the regulatory system for raceway and pond farms in Colombia is the current low level of formalization of farms. A formalized fish farmer is one who has the required permits and complies with Colombian regulations on development and environmental matters issued by the Ministry of Environment and Sustainable Development, the relevant Environmental Authority, and AUNAP (Fedeacua 2018a).

Under this formalization process, the respective permits are for water abstraction and discharge, a riverbed occupation permit, and a cultivation permit (Fedeacua 2018a). Of particular relevance to raceways and ponds is the additional requirement for a Land Use permit, and a Forestry Permit when the fish farmer needs to extract, cut, remove, or take advantage of plant species for the construction or modification of a fish farming project. These permits are issued by the relevant regional authority; for example, in Antioquia this is Corporación Autónoma Regional del Centro de Antioquia (Corantioquia). An additional component of formalization is the registration as a livestock-aquaculture establishment (Registro Pecuario de los Establecimientos de Acuicultura—RPEA) with the Colombian Agricultural Institute (Instituto Colombiano Agropecuario—ICA).

The Agricultural Rural Planning Unit (Unidad de Planificación Rural Agropecuaria—UPRA) within the Ministry of Agriculture and Rural Development is responsible for land use management in Colombia. There is also a Directorate of Territorial Environmental Planning and National Environmental System (Dirección de Ordenamiento Ambiental Territorial y Sistema Nacional Ambiental—SINA[85]) within the Ministry of Environment and Sustainable Development

[85] https://www.minambiente.gov.co/ordenamiento-ambiental-territorial-y-sistema-nacional-ambiental-sina/

(Ministerio de Ambiente y Desarrollo Sostenible—MADS[86]), but the specific role of SINA (or MADS) regarding aquaculture is not readily transparent from their publicly available information (website).

In addition to high level protections such as national parks and regional parks, UPRA has developed a zoning map of suitable locations for coldwater aquaculture (i.e., trout) in Colombia (see Figure 21 above). The map was developed under an agreement (219 of 2016) between AUNAP and UPRA within the "Comprehensive Policy for the Development of Sustainable Fisheries" and was a planned activity in the 2014 "National Plan for the Development of Sustainable Aquaculture" in Colombia. The maps are generated from a previous national aquaculture zoning process conducted in 2013 (AUNAP 2013), and define detailed areas according to five suitability categories (high, medium, low, not suitable, and legally excluded) based on biophysical and socioeconomic factors.

But the applicability of the map to this Habitat Criterion is greatly limited by the lack of consideration of environmental or ecosystem impacts within the defining methodology, except for the default legal exclusions from national protected areas. In defining the suitable areas, the biophysical aspects of the methodology are limited to production requirements (e.g., temperature, water availability, soil, and slope), and the socioeconomic aspects are limited to accessibility, electricity, and proximity to markets (AUNAP 2013b). There does not appear to be any consideration of habitat impacts of single or multiple farms in any area.

Regarding environmental impact assessments (EIA), Coze and Nava (2009) considered that EIAs for aquaculture projects have only recently been applied as a decision-making tool in many countries of Latin America. Nevertheless, they also note that EIAs became mandatory for new aquaculture sites in Colombia in 1997 and included measures for preventing and mitigating environmental impacts (Coze and Nava 2009). According to the same authors, Decree 1220 of 2005 specifies that an Environmental Study is the basic instrument for decision-making regarding environmental permitting for projects and activities likely to affect the natural or an artificial environment. This decree has subsequently been updated multiple times, and the current version appears to be 2041 of 2014.[87] This decree states that environmental studies must be prepared based on the terms of reference that are issued by the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS), and though specific terms of reference relating to aquaculture (or other related activities such as agriculture) do not appear to be available from MADS,[88] the preparation methodology for environmental studies (MADS 2020) applies to all activities.

[86] https://www.minambiente.gov.co/

[87] https://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Decretos/1389917#:~:text=Licencia%20ambiental%20global.,de%20explotaci%C3%B3n%20que%20se%20solicite.

[88] The list of projects does not include those relating to aquaculture; https://www.minambiente.gov.co/asuntos-ambientales-sectorial-y-urbana/terminos-de-referencia-para-la-elaboracion-de-estudios-ambientales/

MADS (2020) clearly establishes that a robust EIA process is in place for the preparation of environmental studies in Colombia. The >300-page document details the comprehensive requirements for the study of abiotic, biotic, and socioeconomic environments and the preparation and presentation of the impact studies. Of relevance here is the specific consideration of significant, cumulative, and synergistic environmental impacts. These are defined by MADS (2020) as:[89]

- Significant environmental impact: impact that, given the environmental sensitivity of the geographical area in which it occurs, generates an alteration in environmental conditions, which reduces the integrity of the system and puts its environmental sustainability at risk, and is evidenced in changes in the value of qualitative or quantitative parameters.
- Cumulative environmental impact: environmental impact resulting from successive, incremental, and/or combined effects of projects, works, or activities when added to other existing, planned, and/or reasonably anticipated future impacts.
- Synergistic environmental impact: impact originating from complex interactions between other impacts, whether generated by the same project or by several. A synergistic impact can be evidenced when the combined effect of two impacts is greater than the sum of those generated individually or when they cause the appearance of a third impact.

Overall, there is currently a site-specific permitting process in place for aquaculture that includes land use and forestry permits. As part of that permitting process, there appears to be a robust EIA methodology in place for new projects that considers their own impacts in addition to the cumulative and synergistic impacts relating to other aquaculture operations, or other industries. But it appears that large numbers of trout farms in Colombia are likely to have been constructed before the establishment of these requirements. Based on the available evidence of the current regulatory system, the score for Factor 3.2a for raceways and ponds is 3 out of 5.

<u>Factor 3.2b Enforcement of Habitat Management Measures</u>

As noted above, it is recognized that aquaculture activity in Colombia had previously developed without adequate planning, and that the regulatory framework of the sector was quite limited regarding aquaculture (Pinzon 2019). And regarding enforcement, Hernandez-Rodruquez (2001) previously considered the “complex and unmanageable” status of the laws and regulations in the early 2000s to be hindering their ability to be enforced.

According to Ramirez and Gomez (2014), enforcement of regulations was still relatively weak throughout the first decade of the 2000s, but efforts have been made to improve guidance, regulation, and enforcement regarding aquaculture, particularly through the creation of AUNAP in 2011 (AUNAP 2014a)(AUNAP 2014b)(The Nation 2013). Currently, the Technical Directorate of Inspection and Surveillance (Dirección Técnica de Inspección y Vigilancia—DTIV) within AUNAP is responsible for the control and surveillance of the country’s fishery resources and aquaculture production, and the regional authorities (such as CAM in Huila) are also involved.

[89] As machine translated by Google.

Although no specific information is readily available on the enforcement activities of DTIV, there is secondary evidence of some measures taking place, as discussed below.

Net pens

The establishment of AUNAP in 2011 was considered to improve the aquaculture enforcement situation in Colombia, and Ramirez and Gomez (2014) subsequently reported robust penalties for infringements of regulations (regarding water quality). There are examples of enforcement of aquaculture regulations in other lakes in Colombia; for example, AUNAP, CAM, and the national police had enforced the regulations of tilapia net pen farms in the Betania Reservoir to close down any illegal projects (i.e., those without the proper environmental use permits), and all the farms in the Betania Reservoir were considered legal as of 2014 (AUNAP 2014a)(AUNAP 2014b)(AUNAP 2014c)(The Nation 2013). Similarly, a recent 2021 example is available (ASOCARS 2021) showing enforcement by the regional environmental authority (CAM) in shutting down 8 illegal operations with 15 net pens. But similar examples from trout farms in Lake Tota or Lake Cocha could not readily be found. The application and enforcement of the POPA process through AUNAP is not transparent, although personal communications with a large farm in Lake Tota indicate that the regional environmental authority (in that case Corpoboyacá) is active in allocating permits and defining limits on production intensity (i.e., the number of net pens permitted). Other enforcement activities associated with the habitat impacts of floating net pens in an artificial reservoir are not expected to be readily apparent, but the general activities to enforce the scale of production in terms of legally permitted operations are considered relevant. Although readily available information or compliance data are limited in this regard, the score for Factor 3.2b—Enforcement of Habitat Management Measures for net pens in the two lakes where trout farming takes place is 3 out of 10.

Raceways and ponds

As discussed in Factor 3.1a above, there is a regulatory process for raceway and pond farms in place in Colombia with registration requirements, in addition to water, land, forest, and cultivation permits applicable. The starkest indicator of poor enforcement in this regard is the highly limited number of “formalized” farms that have these permits and registrations, and therefore the high number of “informal” farms. (Note: this section is largely a repeat of the same content in Factor 2.2b in Criterion 2—Effluent.)

“Formalización” is the term given to the permitting and registration process in Colombia. According to Carrera-Quintana et al. (2022), most of the fish farmers in Colombia operate legally, but according to Fedeacua (2018a), formalization is the first step for all fish farmers to legally carry out their productive activity. According to Fedeacua (2018), a census of aquaculture farms was made in 2014, but as of 2018, only 2% of those surveyed farms at the national level were formalized. This varies by department; for example, in Huila (with the largest aquaculture production in Colombia), it was 8.3% in 2018 (Fedeacua 2018). Fedeacua, AUNAP, and the regional authorities are leading the process to increase the number of formalized farms, and in 2022, Fedeacua (2022) claims significant progress, with 15.4% of the estimated 35,000 farms formalized. The recent progress has been the most substantial, with 10.6% of farms formalized between October 2021 and May 2022, in contrast to the 4.8% of farms that had been formalized at any point since the establishment of AUNAP in 2011 (Fedeacua 2022). According to Fedeacua (2018a), the goal is for 50% of producers to be formalized by 2032, but also notes that the process is costly for small farmers.

Regarding the registration component of the formalization process (i.e., with the RPEA or RGPA), the apparent number of registered farms is also low. For example, while a list of farms in the RPEA does not appear to be readily available, the RGPA lists only 478 farms (accessed July 31, 2023[90]). Nevertheless, the ICA can also be seen to be active in promoting the formalization of farms in various departments (for example, in Cauca in 2019[91] and Cordoba in 2018[92]). Colombia also has a National Authority for Environmental Licenses (Autoridad Nacional de Licencias Ambientales—ANLA[93]), but information relating to aquaculture does not appear to be readily available. The fisheries statistical service (SEPEC) is also actively characterizing farms with annual surveys covering thousands of farms (a total of approximately 8,700 since 2016; Roca-Lanao et al. 2016, 2018, 2019, 2020, 2021), but it is not immediately clear how this relates to the formalization process.

Overall, it appears that the large majority of aquaculture farms in Colombia are still not formalized, and with a goal of 50% formalization by 2032, this appears likely to continue for some time. In terminology, it is clear that the large majority of farms are "informal"; however, although the formalization process is required to operate legally in Colombia, it may not be correct to state that these farms are operating illegally. Nevertheless, substantial efforts are being made by many organizations to increase the number of formalized farms, and it is considered likely that there would be active enforcement of the permitting process for any new farms. Therefore, though the enforcement organizations are identifiable and active, the quite limited number of formalized farms means that the measures appear limited, and there is no indication that cumulative habitat impacts are considered. The score for Factor 3.2b—Enforcement of Habitat Management Measures for raceways and ponds is 2 out of 10.

Conclusions and Final Score

Colombia is listed as one of the world's "megadiverse" countries, but according to the Human Spatial Footprint Index, many areas have had a high degree of human impact, largely before the development of aquaculture. Because of the low temperature requirements for rainbow trout, the location of farms is restricted to high-altitude areas in the Andes Mountains, and a government zoning study indicated that only 2% of the country was highly suitable for trout farming (a further 10% is moderately suitable). Regarding the habitat impacts of net pens, Colombia has 47 large reservoirs, lakes, and lagoons, of which only 4 are used for aquaculture, and only Lake Tota and Lake Cocha are used for trout. The habitat impacts of floating net pens in these lakes appear limited (and immediately reversible), yet there are still likely to be some impacts on the ecosystem services provided by the waterbody. Production in the lakes appears

[90] https://www.aunap.gov.co/rgp/
[91] https://www.ica.gov.co/noticias/producers-aquaculture-competitiveness-valley
[92] https://www.ica.gov.co/noticias/ica-registro-predios-acuicolas-bioseguros-cordoba
[93] https://www.anla.gov.co/

to be managed primarily by the regional authorities (Corpoboyacá and Corponariño), and the potential for trout production to expand to other waterbodies in Colombia appears to be well managed under Fisheries and Aquaculture Management Plans (Plan de Ordenamiento Pesquero y Acuícola—POPA), although specific details are challenging to find. Overall, the score for Criterion 3—Habitat for net pens is 6.9 out of 10.

The majority of trout raceways and ponds in Colombia appear to have been constructed in former agricultural land, with perhaps minor impacts to dry or riparian forests and to scrublands. Inland aquaculture in general (of all species) is perceived as a relatively low driver of habitat change or loss of wetlands in Colombia. The Agricultural Rural Planning Unit (Unidad de Planificación Rural Agropecuaria—UPRA) has developed a detailed map that defines suitable locations for trout aquaculture, but it does not take account of habitat impacts in its defining methodology. There is now a permitting process in place for raceway and pond farms that includes land use and forest permits, the latter of which is required for any modification to vegetation during the establishment or modification of a farm. This permitting process, along with apparently comprehensive environmental impact assessment requirements, is considered to apply to new farms, but the effective enforcement of the regulatory system is challenged by the high proportion of farms that currently do not have the necessary permits. Though there are active efforts to “formalize” aquaculture farms by many organizations, the process is costly for farmers and only 15.4% were considered formalized in 2022. The goal is 50% by 2032. With the majority of ponds constructed in former agricultural land, but a low proportion of formalized farms, the score for Criterion 3—Habitat for ponds is 5.5 out of 10.

Criterion 4: 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

All production systems

C4 Chemical Use parameters		Score
C4 Chemical Use Score (0–10)		**4.0**
Critical?	No	**Yellow**

Brief Summary

While examples of companies with chemical-free rainbow trout production are available in Colombia, there is no central source of data with which to understand chemical use across all the farms in the country. Personal communications with representatives of two grow-out farms (one using net pens and one using raceways) and one fingerling producer helped describe common chemical use characteristics, but it is noted that their practices cannot robustly be extrapolated to other trout farms. Antimicrobial use is the primary concern, and there is no evidence of pesticide use or any other chemicals of concern. Antimicrobial use appears to be largely restricted to the moderately frequent treatment of small fish in the hatchery (up to 3 g), or a common treatment immediately after transfer to the net pens or raceways (between 10 and 30 g). These treatments are mostly associated with the *Flavobacteirum* pathogen, which causes rainbow trout fry/fingerling syndrome. Thus, it is possible that some fish may be treated more than once per production cycle, but because of the small amounts of active chemicals used for such small fish (for example, compared to rainbow trout grown to a large harvest size in marine net pens), the overall concern for potential environmental impacts or contributions to the development of resistance is generally lower. Regarding the scoring, it cannot be confirmed that the frequency of antimicrobial treatments is less than once per cycle (which would score 8 out of 10), but considering the treatment of only small fish, it could be argued that there is a demonstrably low need for chemical use (which would score 6 out of 10). Nevertheless, the somewhat routine use of antimicrobials could also be argued to indicate a dependency on chemical intervention (which would score 2 out of 10), and the regular use of only two different types of antimicrobials, even in small quantities (in addition to an isolated case reporting antimicrobial resistance in *Weissella* bacteria), could represent some concern for the development of resistance (score 4 out of 10). Overall, with the typical use apparently focused on small quantities of antimicrobials to treat small fish, the intermediate score of 4 is considered to be the most appropriate, indicating a moderate concern. It could be argued that the larger companies (on whose personal communication this assessment was based) have more robust management and better control of chemical use, so the score of 4 out of 10 may not be representative of the many smaller companies in Colombia. On the other hand, it could be argued that the big companies are more likely to have disease problems and may be more willing to use expensive antimicrobial treatments than small farms. Therefore, although the generalization is noted here, the final score for Criterion 4—Chemical Use of 4 out of 10 is applied to all farmed trout in Colombia.

Justification of Rating

This Seafood Watch assessment focuses on antimicrobials and pesticides as the dominant veterinary chemicals of concern in aquaculture. Though other types of chemicals may be used (e.g., anesthetics, or in some cases antifoulants), the risk of impact to the ecosystems that receive them is acknowledged to be less than that for antimicrobials and pesticides.

There do not appear to be any readily available data on chemical use in aquaculture in Colombia, and no academic studies could be found that robustly defined their use (or non-use). A previous information request was made to the Instituto Colombiano Agropecuario (ICA), and although a list of registered chemicals for aquaculture was provided (discussed further below), no data were available on the volume or frequency of their use in aquaculture (pers. comm., Anon, Instituto Colombiano Agropecuario, November 1, 2022).

While examples of trout farming companies with public policies of chemical-free production can readily be found in Colombia (e.g., El Divisio[94]), the lack of public data can be confounded by studies that, perhaps incorrectly, imply the use or impacts of chemicals in trout farming in Colombia. For example, in their study of waste generation by the production of rainbow trout in Lake Tota, Torres-Barrera and Grandas-Rincón (2017) reported that the different chemicals and antibiotics used to combat disease outbreaks accumulate at the bottom of the lake, where they can favor anaerobic conditions and be conducive to the emergence of more resistant bacteria. This implies a significant concern, but Torres-Barrera and Grandas-Rincón (2017) provided no specific data from Lake Tota, and instead referenced their statement to Rabassó (2006), which was a highly simplistic study of the general environmental impacts of net pen aquaculture in Spain. Thus, the concern implied in Torres-Barrera and Grandas-Rincón (2017) can in no way be used to indicate any use of such chemicals in trout farms in Lake Tota, or any impact thereof. Indeed, the problem is compounded by secondary referencing in subsequent academic papers; for example, in a study of pollution in Lake Tota and regarding fish farming waste, Jaramillo-García et al. (2020) state: "[I]n order to combat diseases, large quantities of chemicals and antibiotics are produced, generating the development of resistant bacteria.[95]" But this

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[94] http://www.eldiviso.com/

[95] Translated from: "…con el fin de combatir enfermedades, se producen grandes cantidades de químicos y antibióticos generando el desarrollo de bacterias resistentes."

statement is referenced to the same Torres-Barrera and Grandas-Rincón (2017) study and therefore has no relevance to trout farming in Lake Tota.

For this assessment, a representative of two grow-out companies (one using net pens in Lake Tota, and one using raceways in the Risaralda department) and a representative of a hatchery/fingerling producer provided information on their typical antimicrobial treatment practices, and this is elaborated in the antimicrobial section below.

Regulatory measures for veterinary medicines

The regulatory system for veterinary medicines in Colombia is based on Resolution 1056 of 1996 on the technical control of Livestock Inputs, in addition to other specific measures such as Resolution 1326 of 1981 on the use and commercialization of antimicrobial products for veterinary use. These are listed by the ICA.[96] [97] There are various subsequent resolutions and amendments relating to the prohibitions of certain substances (e.g., Resolution 1082 of 1995, which prohibited the use of certain antimicrobials). Fedeacua's "Good Production Practices in Aquaculture" (BPPA[98]) standard also provides a list of common best practices relating to the types and application procedures for chemical use, but it is not clear what the level of uptake is within the many small trout farms in Colombia.

It is also of note that the application for a wastewater discharge permit (see Factor 2.2a in Criterion 2—Effluent) requires the description of potential inputs, including chemicals for fish treatment and/or nonharmful products involved in the cleaning or maintenance of the facilities. But it is of relevance to note that a discharge permit is not required for diffuse discharges, such as net pens located in lakes, lagoons, reservoirs, or other lentic bodies of water (Fedeacua 2018c).

According to the ICA, Colombia has approximately several thousand registered veterinary products (updated list May 17, 2023[99]), of which five are relevant to trout aquaculture. These are four antimicrobials (oxytetracycline, florfenicol, and the sulfadimethoxine-ormetoprim mix), and one antiparasitic treatment (ethylenediamine dihydroiodide). Although two vaccines are registered by the ICA for tilapia (for *Streptococcus*), there are none registered for trout. Antimicrobials and pesticides are discussed below.

Antimicrobials

As discussed above, there does not appear to be any routine collection or publication of antimicrobial use data for aquaculture in Colombia. According to a trout farm manager associated with two large companies, and a representative of a major fingerling producer, trout

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[96] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/normatividad-aplicable

[97] https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios/resoluciones-prohibicion-o-restriccion-de-sustanci

[98] https://www.fedeacua.org/files/bppa.pdf

[99] The most recent list is available here: https://www.ica.gov.co/areas/pecuaria/servicios/regulacion-y-control-de-medicamentos-veterinarios.aspx

commonly face a disease challenge in two key periods. The first is when the fish are less than 3 grams and their immune system is immature, and the second is during the stressful period after fingerlings are transferred from the hatchery/nursery to raceways or net pens at approximately 10–30 g weight (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023)(pers. comm., Eduard Sarmiento, Truchas Suralá June 2023). In both cases, the bacteria *Flavobacterium psychrophilum* is the most common pathogen that requires antimicrobial treatment (see Criterion 7—Disease).

In the hatchery (which operates on a monthly production cycle), the fingerling producer stated that some batches of fry are treated with florfenicol (10 mg per kg fish biomass), but not all batches are treated and not every month, with treatments mainly occurring between January and March when temperatures are higher (pers. comm., Eduard Sarmiento, Truchas Suralá June 2023). The same fingerling producer reported that the only time the facility had records of a repeated treatment on a single batch of fry was during January. The fingerling producer reported that the use of carefully formulated and balanced feeds had helped greatly to reduce antimicrobial use (pers. comm., Eduard Sarmiento, Truchas Suralá June 2023). For the fingerlings after transfer to the raceways or net pens, a representative of two companies (one operating net pens and one operating raceways) reported that a single treatment of antimicrobials (oxytetracyline at a low dose of 10 mg per kg fish biomass[100]) is common for fish up to a maximum weight of 30 g, after which they are never treated again. (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023).

This treatment of only small fish is consistent with the broader perception from academic literature that the most common pathogens in freshwater trout aquaculture affect fish in the hatchery/fry/fingerling phase of production. For example, the most common disease problem in trout in Colombia, *Flavobacterium psychrophilum* (see Criterion 7—Disease), is commonly known as rainbow trout fingerling (or fry) syndrome—RTFS (Rochat et al. 2017). Earlier studies have established that the disease primarily affects small fish; for example, in a review of RTFS, Faruk (2002) noted that the syndrome appears to affect rainbow trout in the weight range of 0.2 to 10.0 g, also noting that mortality generally occurs in fish ranging from 0.5 to 5.0 g in weight.

Because of the smaller quantity of antimicrobials used to treat such small fish, their use in the hatchery phase is typically considered to be a lower concern. For example, the freshwater stage of rainbow trout production destined for grow-out in marine net pens can continue up to approximately 200 g,[101] and using the example of better data availability from Chile, it can be seen that only 10.6% of the total antibiotics used for rainbow trout by weight are administered in the freshwater phase (i.e., the large majority of antimicrobials used to produce rainbow trout in Chile are used in the marine net pen phase as opposed to the freshwater stage). For

[100] An oxytetracycline product available in Colombia recommends an in-feed dose of 50 to 75 mg per kg of feed: https://acuagranja.com.co/producto/oxitetraciclina-hidroclorada/

[101] For example, a large company in Chile states that rainbow trout are transferred from freshwater hatcheries to marine net pens at 180 g: www.australis-seafoods.com/en/nuestros-productos/proceso-productivo/agua-dulce/

reference, the use of antimicrobials in rainbow trout as a whole in Chile (i.e., including the marine net pen grow-out phase) is a high concern (SFW 2022).

According to the information from the two companies noted above, the typical treatment is of florfenicol at a dose of 10 mg per kg of fish for 10 days; i.e., a total dose of 100 mg per kg of fish. Considering a worst-case scenario of such an antimicrobial treatment at the maximum size of 30 g, with substantial mortality before harvest of 40% and a modest harvest weight of 400 g, it can be calculated[102] that the treatment would represent 12.5 g of antimicrobial per mt of trout production (g/mt). For reference, this is in the same range as the calculated use of antimicrobials in the freshwater phase of rainbow trout production in Chile of 19.9 g/mt in 2021, which was calculated using data from Sernapesca (2022), but is much lower than the 165.6 g/mt used in the marine phase of rainbow trout production in Chile in 2021. The purpose of this comparison is simply to illustrate that at a worst-case scenario in Colombia (i.e., the maximum fish size treated, high mortality, and modest harvest weight), the antimicrobial use could (by comparison) be considered to be relatively low. To further this analysis, if Colombian fish were treated at the smallest size after transfer to raceways or net pens (at approximately 10 g), with a lower mortality of 10% and a larger harvest size of 500 g, the antimicrobial treatment would represent 2.2 g of oxytetracycline per mt of trout production. The treatment of small fish of less than 3 g in the hatchery would correspondingly use smaller amounts of antimicrobials. For example, a treatment of one million fish of 1 g or 2 g would use 100 g to 200 g of florfenicol in total over the 10-day treatment; i.e., 10 g to 20 g per day (pers. comm., Eduard Sarmiento, Truchas Suralá June 2023).

To provide one example to counter this assumption that only small fish are treated with antimicrobials, an isolated case of a *Weissella tructae* (formerly *Weissella ceti*) bacterial outbreak at four farms between 2016 and 2019 noted that larger fish between 250 g and harvest size of 400–500 g were affected and treated (Vásquez-Machado et al. 2020). Nonetheless, the discussion above regarding the dominant use of antimicrobials in very small fish is still considered to be representative of the bulk of production in Colombia.

The four antimicrobials approved by the ICA in Colombia are common aquaculture drugs; for example, they are all approved for aquaculture use in the United States by the Food and Drug Administration.[103] A superficial search for antimicrobials for sale in Colombia only shows florfenicol and oxytetracycline listed in major online aquaculture supply companies; for example, Aquagranja[104] and Truchas Sarala[105] between them sell two brands of florfenicol and two of oxytetracycline.

Florfenicol is not used in human medicine, but the World Health Organization's list of Highly and Critically Important Antimicrobials for Human Medicine (WHO 2019) categorizes it as highly

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[102] If treated at 30g, 1 kg represents 33.33 fish. The total antimicrobial used is 100 mg. After 40% mortality 20 fish harvest at 400 g would be 8 kg of fish. This equates to 12.5 g of antimicrobial per mt of trout production.
[103] https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs
[104] Antibioticos (acuagranja.com.co)
[105] https://truchasurala.com/productos/florcap-5/

important due to the potential for human pathogens to acquire resistance genes from florfenicol-treated nonhuman sources (e.g., livestock or fish). Oxytetracycline is also listed as highly important for human medicine (and is used in human medicine). For veterinary applications, the World Organisation for Animal Health (WOAH) has also prepared the List of Antimicrobial Agents of Veterinary Importance, within which both florfenicol and oxytetracycline are listed as “Veterinary Critically Important Antimicrobial Agents” (WOAH 2019). The WOAH (2019) states: “The wide range of applications and the nature of the diseases treated make phenicols [and tetracyclines] extremely important for veterinary medicine. This class is of particular importance in treating some fish diseases, in which there are currently no or very few treatment alternatives.” This emphasizes the need for responsible and prudent use (OIE 2019).

Many antimicrobials are not completely metabolized by the treated fish and are subsequently excreted in urine and feces (Sun et al. 2012, and references therein). According to the representative from the hatchery, all effluent water is filtered to remove particulates, and the waste is dried and used as a compost, but there is no special effluent treatment during periods when antimicrobials are being used (pers. comm., Eduard Samiento, Truchas Suralá June 2023). Similarly, the representative from the two grow-out farms (one raceway and one net pens) indicated that they also collect particulate waste (see Criterion 2—Effluent) and process it similarly. Considering the relatively small amount of antimicrobials being used, the concentrations of antimicrobials in solution in the effluent water and thereby in the receiving waters may also be low but are challenging to estimate. Sun et al. (2012) studied the fate of florfenicol in simulated aquatic ecosystems at concentrations of 10, 50, and 150 mg/l, and showed that the half-life of florfenicol in water and sediments ranged from approximately 25 to 53 days and noted that all treatment concentrations inhibited sediment microflora.

Regarding the collected particulate wastes and their processing (drying) and use as a soil conditioner or compost, there is likely to be some breakdown of antimicrobials during this process, but active ingredients or partially active metabolites could enter the soil through land application of these wastes, with some further potential to enter the aquatic environment by runoff, driftage, or leaching (Tasho et al. 2018)(Zhang et al. 2016)(Chen et al. 2019). The extrapolation of these results (for antimicrobials or active metabolites in solution or bound to particulate wastes) to potential impacts in natural environments, particularly the receiving waters of trout farms in Colombia (or nearby agricultural land), is tenuous at best, and there is little readily available evidence to comprehensively understand the environmental impact (if any) of these antimicrobial treatments.

<u>Antimicrobial resistance</u>

The use of antimicrobials in aquaculture links it to global concerns regarding the development of bacterial resistance to one or more antimicrobials and the passage of resistance genes from aquatic to terrestrial pathogens (Santos & Ramos 2018)(Lulijwa et al. 2020). The subject of antimicrobial susceptibility and resistance is extremely complex and the focus of a voluminous and rapidly growing body of literature; thus, understanding the complex potential impacts to food safety, occupational health, and (marine and nonmarine) antimicrobial resistance continues to be challenging to fully comprehend (Lulijwa et al. 2020). The relatively small quantities apparently used for rainbow trout in Colombia reduce this concern; however, there does appear to be a somewhat regular and repeated use of only two types of antimicrobials.

In the apparently isolated case of the *Weissella tructae* outbreak in four farms between 2016 and 2019, Vásquez-Machado et al. (2020) reported that the infection had been temporally controlled by the use of antimicrobials, but the bacteria quickly acquired resistance to these drugs (florfenicol), as proved by subsequent isolates and antibiograms. No further details were provided, and the assessment of antimicrobial resistance did not appear to be part of their study, so the relevance to broader concerns regarding resistance is uncertain.

The Colombian Program for the Integrated Surveillance of Antimicrobial Resistance (Programa Colombiano para la Vigilancia integrada de la Resistencia Antimicrobiana—COIPARS) began in 2007, of which the activities include the monitoring of antimicrobial resistance in indicator bacteria from different origins (livestock, livestock feed, and human origin) and the monitoring of the consumption of antimicrobial agents in humans and animals. Donado-Godoy et al. (2015) describe a pilot program in poultry, but the further development of the program is not readily apparent, nor do there appear to be any readily available data. A request for further information to the oversight entity (Corporación Colombiana De Investigación Agropecuaria—AGROSAVIA[106]) did not receive a response.

In a review of livestock production and the emergence of antibiotic resistance in Colombia, Arenas and Melo (2018) included an unsubstantiated reference to antimicrobial use in tilapia aquaculture in Colombia but did not include any mention of antimicrobial use in trout. Instead, the review indicated that the greater concern for aquaculture is the contamination of water sources by antimicrobial use in other industries and from municipal wastewater (Arenas and Melo, 2018).

Pesticides

Neither of the representatives from the hatchery or grow-out farms mentioned the use of any pesticides in trout production in Colombia, but this cannot be assured for all the farms across the country. The one antiparasitic treatment registered for use in fish in Colombia (as listed by ICA) is ethylenediamine dihydroiodide (trade name Dermo-Gard Aqua). The same superficial search for products for sale in Colombia show it is available (e.g., from Aquagranja[107]), and the associated technical sheet shows that it can be used for any freshwater or marine species, including rainbow trout. The product can be applied either in feed or as a bath treatment. The chemical is recognized by the U.S. Food and Drug Administration as Generally Recognized As Safe (GRAS[108]), but this relates to human safety as a food additive, and there are no readily available data or other information on the potential environmental impacts of using or discharging water that has been treated with this chemical. A brochure for the product states

[106] https://www.agrosavia.co/
[107] https://acuagranja.com.co/producto/dermogard-aqua-antiparasitario-protector-cutaneo-avimex/
[108] https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras

that it has a specific ectoparasiticidal effect (i.e., it kills external parasites) and is specified to control protozoa (including *Trichodina* spp. and *Ichthyophthirius* spp.) and arthropods (including the crustacean parasites *Argulus* spp. and *Caligus* spp.). It could be assumed that this substance may therefore have an impact if discharged in an active form, but no information on the frequency, scale, or manner of its use in Colombia trout farms could readily be found.

The national water study (IDEAM 2018) noted that in Colombia, as in most countries, there is massive and indiscriminate use of pesticides, both in the agricultural area and in the health sector, which has generated a favorable scenario for the appearance of acute and chronic intoxications. Colombia ranks as one of the countries with the highest consumption of pesticides in Latin America (IDEAM 2018), but the data presented imply that these are primarily agricultural pesticides (e.g., the top three pesticides listed are organophosphates, carbamates, and thiocarbamate) and there is no information with which to understand pesticide use in aquaculture (or any associated impacts).

United States Food and Drug Administration import data

According to the Import Refusal Report,[109] the most recent relevant[110] refusals for imported trout from Colombia were two events in 2017 that the FDA categorizes as being: "pursuant to Section 801(a)(3) in that it [i.e., imported trout] appears to contain a new animal drug (or conversion product thereof) that is unsafe within the meaning of Section 512." This is a broad refusal category, but a representative of the company involved in both cases (TroutCo) reported that the refusal was associated with the detection of malachite green that had come from green ink on the product labels (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023). This is certainly feasible and has been demonstrated previously due to the widespread use of malachite green as an industrial dye. For example, the British Food Standards Agency reported that a source of malachite green contamination in fish may come from packaging of fresh fish by retailers using green-colored towels containing this dye (Van der Roest et al. 2007). The same study noted that modern analytical methods were now sensitive enough to detect such contaminations. After removing the problematic ink, TroutCo noted that there has not been another refusal (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023).

Conclusions and Final Score

While examples of companies with chemical-free rainbow trout production are available in Colombia, there is no central source of data with which to understand chemical use across all the farms in the country. Personal communications with representatives of two grow-out farms (one using net pens and one using raceways) and one fingerling producer helped describe common chemical use characteristics, but it is noted that their practices cannot robustly be extrapolated to other trout farms. Antimicrobial use is the primary concern, and there is no evidence of pesticide use or any other chemicals of concern. Antimicrobial use appears to be largely restricted to the moderately frequent treatment of small fish in the hatchery (up to 3 g), or a common treatment immediately after transfer to the net pens or raceways (between 10

[109] Import Refusal Report (fda.gov)—accessed November 6, 2023

[110] There was a refusal in 2018 but it was for contamination and/or unsanitary conditions or packaging.

and 30 g). These treatments are mostly associated with the *Flavobacteirum* pathogen that causes rainbow trout fry/fingerling syndrome. Thus, it is possible that some fish may be treated more than once per production cycle, but because of the small amounts of active chemicals used for such small fish (for example, compared to rainbow trout grown to a large harvest size in marine net pens), the overall concern for potential environmental impacts or contributions to the development of resistance is generally lower. Regarding the scoring, it cannot be confirmed that the frequency of antimicrobial treatments is less than once per cycle (which would score 8 out of 10), but considering the treatment of only small fish, it could be argued that there is a demonstrably low need for chemical use (which would score 6 out of 10). Nevertheless, the somewhat routine use of antimicrobials could also be argued to indicate a dependency on chemical intervention (which would score 2 out of 10), and the regular use of only two different types of antimicrobials, even in small quantities (in addition to an isolated case reporting antimicrobial resistance in *Weissella* bacteria), could represent some concern for the development of resistance (score 4 out of 10). Overall, with the typical use apparently focused on small quantities of antimicrobials to treat small fish, the intermediate score of 4 is considered the most appropriate, indicating a moderate concern. It could be argued that the larger companies (on whose personal communication this assessment was based) have more robust management and better control of chemical use, so the score of 4 out of 10 may not be representative of the many smaller companies in Colombia. On the other hand, it could be argued that the big companies are more likely to have disease problems and may be more willing to use expensive antimicrobial treatments than small farms. Therefore, although the generalization is noted here, the final score for Criterion 4—Chemical Use of 4 out of 10 is applied to all farmed trout in Colombia.

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	**0.23**	
F5.1b Source fishery sustainability score (0–10)		**2.0**
F5.1 Wild fish use score (0–10)		**4.2**
F5.2a Protein INPUT (kg/100 kg fish harvested)	**55.35**	
F5.2b Protein OUT (kg/100 kg fish harvested)	**15.60**	
F5.2 Net Protein Gain or Loss (%)	**–71.64**	**2.0**
F5.3 Species-specific kg CO2-eq kg^{-1} farmed seafood protein	**11.77**	**7.0**
C5 Feed Final Score (0–10)		**4.35**
Critical?	**No**	**Yellow**

Brief Summary

Specific data on the composition of rainbow trout feeds in Colombia are limited (and typically considered proprietary information), but some important details on marine and other aquatic ingredients were provided by two feed companies through third-party communications with Fedeacua. Additional data on feed ingredients, and particularly on protein contents, were available from the websites of four companies representing six brands of feeds. An academic reference feed from a review of rainbow trout nutrition was also used to create a best-fit feed formulation for this assessment. An average feed conversion ratio value of 1.35 was approximated from a variety of sources. Although this value may vary between production systems (i.e., slightly higher in net pens and slightly lower in raceways), there was not sufficient granularity of data to generate separate scores here. With a high proportion of the fishmeal coming from by-product fishmeal sources, and all of the fish oil (from tuna processing wastes from Ecuador and domestic farmed tilapia byproducts), the Feed Fish Efficiency ratio was low. From first principles, 0.23 mt of wild fish would need to be caught to supply the fishmeal to produce 1 mt of rainbow trout in Colombia. The sources and sustainability of the fishmeal from whole fish was not provided, and this reduced the Wild Fish Use score (Factor 5.1) to 4.2 out of 10. With the bulk of production taking place on feeds with 40% protein, the weighted average feed protein content for the whole production cycle was 41.0%. With a lower protein output in farmed trout, there is a substantial net loss of protein of 71.6%, and a score of 2 out of 10 for Factor 5.2. Using economic allocations, the use of by-product aquatic ingredients helped to give a relatively low feed footprint (calculated as the embedded climate change impact in kg CO_2-eq of the feed ingredients) of 11.77 kg CO_2-eq kg^{-1} and a score of 7 out of 10 for Factor 5.3. Factors 5.1, 5.2, and 5.3 combine to give a final Criterion 5—Feed score of 4.35 out of 10.

Justification of Rating

Four feed companies (with six brands in total) can readily be found in internet searches in Colombia: Solla[111]/Agrinal,[112] Contegral[113]/Finca,[114] CIPA,[115] and Italcol.[116] It was also noted that feed may be imported from the Nicovita[117] company in Peru. These companies have variable amounts of data available on their websites, and feed producers typically consider detailed formulation data to be proprietary (Boyd et al. 2021). But with the assistance of Fedeacua, responses to a feed data request were provided by two companies on the condition that the data be aggregated and anonymous. Thus, although full information was not available from all feed companies, the available data, along with various other sources of information (as referenced below), were considered to be sufficient to robustly understand a typical trout feed in Colombia for the purposes of this assessment.

Full feed formulations were not provided, but a list of ingredients was obtained from two companies (using online images of feed bags with sufficient resolution), in addition to specific inclusion levels of aquatic ingredients (i.e., fishmeal and fish oil) provided through Fedeacua. To establish an appropriate "typical" feed formulation for a Colombian trout feed, the generalized feed formulation for rainbow trout in Kamalan et al. (2020)[118] has a close match with 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 3).

Table 3: Best-fit feed formulation based on aquatic ingredient inclusion levels from two feed companies in Colombia, lists of nonmarine ingredients, and the general rainbow trout formulation from Kamalan et al. (2020).

Ingredient	Aggregated or estimated inclusion level (%)
Fishmeal (from whole fish)	3.0

[111] https://www.solla.com/acuicultura/
[112] https://www.sollanutricionanimal.com/marca-agrinal
[113] https://www.contegral.co/
[114] Finca | Alimentos concentrado para animales
[115] Piscicultura - Cipa
[116] Acuicultura Trucha | Italcol
[117] Nicovita Classic Trucha Perú » Nicovita
[118] Kamalan et al. (2020) provided a review of the "Nutrition and Feeding of Rainbow Trout (*Oncorhynchus mykiss*)."

Fishmeal (from by-products)	18.0
Fish oil (from whole fish)	0.0
Fish oil (from by-products)	7.0
Soy meal	15.0
Soy lecithin	1.0
Wheat flour	14.0
Wheat gluten	9.0
Maize gluten	5.0
Rice flour	5.0
Vegetable oil (canola oil)*	10.0
Poultry meal	6.0
Blood meal	4.0
Vitamins and minerals/other	3.0
Total	**100.0**

* The type of vegetable oil was not specified in the available data. As a common ingredient in animal feeds, and included in the formulation of Kamalan et al. (2020), canola (rapeseed) oil was used here. Alternatives will not make a significant difference to the overall score of this assessment.

For further details on any of the calculations and scoring tables used in the assessment below, see the Seafood Watch Aquaculture Standard.

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. Fry et al. (2018) considered a typical range of eFCRs of 1.0 to 2.0 for rainbow trout (in different production systems). No specific data on feed consumption and harvest could be obtained, but various anecdotal figures are available. In communications through Fedeacua, one feed company reported a typical range of 1.2 to 1.4. Separately, a feed company website states a range of 1.25 (for ponds) to 1.35 (in net pens). A significant raceway farm reported an annual average eFCR of 1.28 in 2022 (pers. comm., Oscar Murillo, TroutCo/PezFresco May 2023). In an information/promotion video (from 2018), a representative of the Truchicol company in Lake Tota also noted that an FCR of 1.3 to 1.4 was typical. Therefore, although it is recognized that there may be some variations between production systems, the lack of comprehensive data across larger numbers of farms means an estimate must be made, and with some level of precaution. Thus, a value of 1.35 is used for all production systems.

Factor 5.1. Wild Fish Use

Factor 5.1 combines an estimate of the amount 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)

Partial data on aquatic feed ingredients and their nature (i.e., from whole fish or from by-products of fish already caught or farmed for human consumption) were provided from two feed companies. As noted in Table 3, these data indicate a substantial use of by-product sources of both fishmeal and oil (including all fish oil), which are available from tuna fisheries in Ecuador, and from the substantial in-country production of farmed tilapia. Table 4 shows the specific values used to calculate the Feed Fish Efficiency Ratio (FFER). The default yield values of 22.5% for fishmeal and 5.0% for fish oil were used (from Tacon and Metian 2008).

Table 4: Fishmeal and fish oil inclusion levels from whole fish and by-product sources, eFCR values, and calculated FFER values for rainbow trout in Colombia.

Parameter	Data
Fishmeal inclusion level (total)	21.0%
Fishmeal inclusion level (whole fish)	3.0%
Fishmeal inclusion level (by-product)	18.0%
Fishmeal yield	22.5%
Fish oil inclusion level (total)	7.0%
Fish oil inclusion level from whole fish	0.0%
Fish oil inclusion level from by-product	7.0%
Fish oil yield	5.0%
Economic Feed Conversion Ratio	**1.35**
FFER fishmeal	0.23
FFER fish oil	0.10
Assessed FFER	**0.23**

Because of the substantial use of by-product sources of aquatic ingredients, the FFER values are low: 0.23 for fishmeal and 0.10 for fish oil. From first principles, this indicates that 0.23 mt of wild fish would need to be caught to supply the fishmeal to produce 1 mt of rainbow trout in Colombia.

Factor 5.1b—Sustainability of the Source of Wild Fish

The majority of the fishmeal and all the fish oil are sourced from by-products. According to the information from two feed companies, the by-products are from tuna fisheries in Ecuador and from domestic aquaculture production of tilapia (the 2021 farmed tilapia production in Colombia was 109,421 mt; FAO FishStat data). According to FishSource,[119] the main tuna fisheries in Ecuador are for yellowfin and skipjack, both part of the Eastern Pacific stocks. The FishSource scores for these fisheries (of multiple gear types) are all ≥6, and parts of the yellowfin fishery are certified by the Marine Stewardship Council.[120] These characteristics are equivalent to a score of 6 out of 10 for Factor 5.1b. Also, farmed tilapia, with a Yellow or Good Alternative rating from Seafood Watch,[121] is considered to be equivalent to a score of 6 out of 10 for Factor 5.1b. Unfortunately, no data were provided for the small amount of fishmeal from whole fish, and this must be considered to be an unknown source fishery, which is equivalent to a score of 0 out of 10 for Factor 5.1b. According to the Seafood Watch Aquaculture Standard,

[119] https://www.fishsource.org/
[120] https://fisheries.msc.org/en/fisheries/
[121] https://www.seafoodwatch.org/recommendation/tilapia/nile-tilapia-35511?species=228

the final score for Factor 5.1b is driven largely by the sustainability of whole fish fisheries, which in this case are unknown. Overall, the score for Factor 5.1b—Sustainability of the Source of Wild Fish is 1.94, which is rounded to 2 out of 10.

With a low use of fishmeal and fish oil from whole fish, but uncertainty in their sources, Factors 5.1a and 5.1b combine to give a moderate score of 4.2 out of 10 for Factor 5.1—Wild Fish Use.

Factor 5.2—Net Protein Gain or Loss

The four feed companies mentioned previously (with a total of six brands) all produce a range of feeds of different sizes with different protein contents. Three of the companies representing five of the brands provide protein details on their websites. The feeds are typically referred to as starter (iniciacion), grower or raising (levante), and final feeds (finalizacion), and the protein contents decline as the pellet size increases for larger fish. The companies also provide typical feeding schedules, which show that the majority of the growth occurs on the largest-size feeds (i.e., with lower protein contents). These data can be used to calculate an average feed protein content for the whole production cycle (i.e., weighted according to the amount of growth on each feed). Thus, by considering the protein contents of 16 feeds from five brands and the recommended size ranges of fish for each feed, the average feed protein content used here is 41.0% (the ranges were from 48% to 52% for starter feeds, 40% to 45% for grower feeds, and 40% for all the finishing feeds).

Table 5 shows that, with an eFCR of 1.35, there is a net protein input in feed of 553.5 kg protein per mt of trout production. Regarding the protein outputs in harvested trout, the whole-body protein content of *O. mykiss* is 15.7% (Dumas et al. 2007), so there is a protein output of 157.0 kg per mt of trout production.

Table 5: Values used to calculate net protein gain or loss.

Parameter	Data
Protein content of feed (%)	41.0
Protein content of whole harvested rainbow trout (%)	15.7
Economic Feed Conversion Ratio	1.35
Total protein INPUT per mt of farmed rainbow trout (kg)	553.5
Total protein OUTPUT per mt of farmed rainbow trout (kg)	157.0
Net protein gain or loss (%)	**–71.6**
Seafood Watch Score (0–10)	**2**

These figures indicate that there is a substantial net loss of protein of 71.6% during the production of rainbow trout, which results in a score of 2 out of 10 for Factor 5.2.

Factor 5.3—Feed Footprint

Factor 5.3 approximates the embedded global warming potential (GWP) (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[122] to estimate the GWP of 1 metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. If an ingredient of unknown origin is found in the GFLI database, an average value between the listed global "GLO" value and worst listed value for that ingredient is applied; this approach is intended to incentivize data transparency and provision. In cases where a global value was not available (e.g., fishmeal and fish oil), the most appropriate and/or most geographically relevant ingredient listings were used. The detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

Table 6 shows the ingredient categories selected from the GFLI database according to the above methodology for ingredients of unknown origins. For fishmeal and fish oil, including by-products, the values at processing plants in neighboring Peru were considered the most representative listings available in the GFLI database. 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 6: Estimated embedded global warming potential of 1 mt of rainbow trout feed used in Colombia. GFLI refers to the Global Feed Lifecycle Institute. Note: the fishmeal and fish oil values are averages of all relevant ingredients in the GFLI database.

Ingredient	Ingredient listing in the GFLI Database	Inclusion %	kg CO_2-eq /mt feed
Fishmeal	Fishmeal, at processing/PE	3.0	32.11
Fishmeal by-product	Fishmeal, at processing/PE Economic S	18.0	192.69
Fish oil by-product	Fish oil, at processing/PE Economic S	7.0	451.22
Soybean meal	Soybean meal (solvent), at processing/GLO Soybean meal (solvent), at processing/BR	15.0	501.75
Poultry meal*	Animal meal, poultry, from dry rendering, at plant/RER Economic S	6.0	47.85
Blood meal*	Blood meal, from mixed species, at processing	4.0	25.15
Maize gluten	Maize gluten feed dried, at processing/GLO Maize gluten feed dried, at processing/NL	5.0	52.63
Wheat	Wheat flour, at processing/GLO Wheat flour, at processing/ES	14.0	100.66
Wheat gluten	Wheat gluten feed, at processing/GLO Wheat gluten feed, at processing/BR	9.0	84.59
Rice flour*	Rice feed meal, at processing	5.0	10.77
Vegetable oil (canola)	Crude rapeseed oil (pressing), at processing/RER Crude rapeseed oil (pressing), at processing/CA	10.0	242.80
Soy lecithin	No value in GLFI database	1.0	0.0
Vitamins, minerals*	Total minerals, additives, vitamins, at plant/RER	3.0	26.29
Total		**100.0**	**1,368.53**

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

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

The total estimated embedded GWP of 1 mt of rainbow trout feed in Colombia is 1,368.53 kg CO_2-eq. Considering a whole harvested farmed rainbow trout protein content of 15.6% (from Factor 5.2) and an eFCR of 1.35, it is estimated that the feed-related GWP of 1 kg farmed trout protein is 11.77 kg CO_2-eq. This results in a score of 7 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

Specific data on the composition of rainbow trout feeds in Colombia are limited (and typically considered proprietary information), but some important details on marine and other aquatic ingredients were provided by two feed companies through third-party communications with Fedeacua. Additional data on feed ingredients, particularly on protein contents, were available from the websites of four companies representing six brands of feeds. An academic reference feed from a review of rainbow trout nutrition was also used to create a best-fit feed formulation for this assessment. An average feed conversion ratio value of 1.35 was approximated from a variety of sources. Although this value may vary between production systems (i.e., slightly higher in net pens and slightly lower in raceways), there was not sufficient granularity of data to generate separate scores here. With a high proportion of the fishmeal coming from by-product fishmeal sources, and all of the fish oil (from tuna processing wastes from Ecuador and domestic farmed tilapia by-products), the Feed Fish Efficiency ratio was low. From first principles, 0.23 mt of wild fish would need to be caught to supply the fishmeal to produce 1 mt of rainbow trout in Colombia. The sources and sustainability of the fishmeal from whole fish was not provided, and this reduced the Wild Fish Use score (Factor 5.1) to 4.2 out of 10. With the bulk of production taking place on feeds with 40% protein, the weighted average feed protein content for the whole production cycle was 41.0%. With a lower protein output in farmed trout, there is a substantial net loss of protein of 71.6%, and a score of 2 out of 10 for Factor 5.2. Using economic allocations, the use of by-product aquatic ingredients helped to give a relatively low feed footprint (calculated as the embedded climate change impact in kg CO_2-eq of the feed ingredients) of 11.77 kg CO2-eq kg^{-1} and a score of 7 out of 10 for Factor 5.3. Factors 5.1, 5.2, and 5.3 combine to give a final Criterion 5—Feed score of 4.35 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

C6 Escape parameters	Net pens		Raceways and ponds	
	Value	Score	Value	Score
F6.1 System escape risk (0–10)	2		6	
F6.1 Recapture adjustment (0–10)	0		0	
F6.1 Final escape risk score (0–10)		2		6
F6.2 Invasiveness score (0–10)		6		6
C6 Escape Final Score (0–10)		**4**		**6**
Critical?	No	Yellow	No	Yellow

Brief Summary

No data or records are available on escape events from trout farms in Colombia. Resolution 2879 lists the escape minimization requirements for ponds and net pens, but it is not known how thoroughly these are implemented across the formalized and nonformalized farms in Colombia. It can be seen that the typical net pen structures and typical fish handling practices inevitably have some vulnerability to large-scale or trickle losses. As flow-through systems with high densities of fish, raceways and ponds also have a risk of escape, but the likely use of multiple screens and the potential for direct on-farm recapture substantially reduce the risk. Flooding is inevitably a concern in riparian locations, but the areas suitable for trout farming in Colombia are outside the country's major flooding regions. Although no specific data are available, in the event of an escape in the lakes, an active angling presence in addition to arrangements with local fishers indicate that a significant recapture is likely, but no data on recaptures are available for either net pens or raceways/ponds. The escape risk remains high, and the escape risk score (Factor 6.1) is 2 out of 10 for net pens. The potential for recaptures in the rivers is less clear, but the escape risk score is 6 out of 10 for the more contained raceways and ponds. Rainbow trout is considered to have been widely established in the wild in Colombia because of its introduction and active stocking before the development of aquaculture in net pens and raceways/ponds. Nevertheless, as a highly invasive species that has successfully established across large areas of South America with documented impacts to native species, rainbow trout escapes from farms inevitably continue to be a concern. The apparent decline of rainbow trout populations in the wild after the cessation of active stocking, combined with the sterile all-female nature of the farm stocks, reduces this concern but does not negate it entirely. Therefore, any escapes must be considered to have a risk of competition, predation, disturbance, or other impacts to wild species, habitats, or ecosystems. The score for Factor 6.2—Competitive and Genetic Interactions is 6 out of 10. Factors 6.1 and 6.2 combine to give final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 6 out of 10 for raceways and ponds.

Justification of Rating

Factor 6.1—Escape Risk

All aquaculture operations carry the risk of escape (Diana 2009), but the degree of risk depends on the type of production system and the effectiveness of management, including the proper training of employees and emergency plans in the case of escape (Halwart et al. 2007)(Jensen et al. 2010). No reports, records, or data relating to the escape of trout in Colombia (or their recapture) could be found, so the escape risk must be evaluated according to the fundamental characteristics of the production systems. Resolution 2879[123] of 2017 (AUNAP) lays out the requirements that must be met by Colombian aquaculture establishments to "minimize the risk of escape of exotic, domesticated and/or transplanted species to natural or artificial bodies of water," and these requirements are listed below for each production system.

<u>Net pens</u>

Net-pen production systems are commonly associated with a high risk of escape, given their open nature (Naylor et al. 2005)(Halwart et al. 2007). According to Resolution 2879, the escape minimization requirements for net pens include the following:

- The maximum mesh size is half the maximum height of the smallest fish at all culture phases (fingerlings, juveniles, and adults).
- Install a secondary perimeter and bottom mesh with a mesh eye equal to or less than the maximum height of the smallest fish.
- Extend nets a minimum of 40 cm above the water surface (i.e., jump nets).
- Prevent the entry of birds and other organisms that can capture specimens and potentially release them.
- Have a suitable walkway or floating platform that allows handling activities to be carried out safely and effectively.
- Maintain the flotation systems in optimum condition to avoid sinking and thus avoid the escape of the specimens.
- All rainbow trout to be monosex (single sex).

The escape containment plan provided by one company in Lake Tota also details the operational aspects of escape prevention, including regular review of the net pen flotation and anchoring system, weekly review of all nets, detailed fish inventory (counting), avoidance of equipment that could damage nets, replacement of deteriorating nets, and checks of all

[123] Resolution 2879 of 2017: https://www.redjurista.com/Documents/resolucion_2879_de_2017_aunap.aspx#/

equipment during and after bad weather (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023). It is expected that other farms in Lake Tota, and perhaps Lake Cocha, have similar policies, but it cannot be assumed that they are actively implemented across all farms.

These requirements (if enacted) can help reduce escapes but cannot eliminate them. Images and promotional videos of net pen trout farms in Colombia typically depict simple net pen frame structures of wood and metal, with plastic floats and single nets to contain the fish (example in Figure 27). Although the severe weather and large predators such as seals that can cause massive escapes in marine net pen farms are not present in Lakes Tota or Cocha, the human errors that also commonly lead to large escapes are still present.

Figure 27: Screenshot from a YouTube video (2018) of trout farming in Lake Tota, showing the typical structure of net pens. (https://www.youtube.com/watch?v=Z7bh-9kb7Os)

In addition, the ease with which small numbers of fish can escape during routine operations (commonly referred to as trickle losses or leakage) can be seen in Figure 28, where a single fish has avoided the harvest container and dropped into either another pen or potentially into the lake. Another similar example can be seen in the same video.

Figure 28: Example of a potential single escape. Trout are being harvested from the net pen in the left of this image, in which the net has been raised to crowd the fish. The fish in the lower right has avoided the blue harvest container and dropped into either another pen or potentially into the lake. A similar example of a dropped fish (potentially dead, or in thermal shock) can be seen in the same video at 19:00 minutes. Image reproduced from YouTube. (https://www.youtube.com/watch?v=Z7bh-9kb7Os)

Without further information on escape prevention practices in commercial production, the simple net pen structures are considered to be vulnerable to large escape events or frequent trickle losses, and the score for Factor 6.1 is 2 out of 10.

Ponds and raceways

When operated as linear systems with a high throughput of water and a high density of fish, ponds and raceways have an inherent risk of escape; nevertheless, the constrained physical structures of the farms also provide multiple opportunities to place escape prevention measures. Thus, the inherent risk is reduced to the extent that Fornshell and Hinshaw (2008) consider (in the absence of extreme external forces such as flooding, discussed below) ponds and raceways to actually have a low inherent risk of escape. For example, in a raceway farm in Colombia, Varadhan (2016) noted there is redundancy in screens during the flow of water and effluent from the production raceways through settling ponds and before discharging to the nearby streams. Each screen or body of water (e.g., a settling pond) provides an opportunity to remove fish if they were to escape the primary raceway. But it must be noted that the correct sizing and maintenance of these screens and barriers devices is critical to their efficacy.

Resolution 2879 lists escape minimization requirements for ponds and net pens, and includes the following:[124]

For Ponds:

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124 based on a machine translation by Google

- Install structures for the retention of specimens before discharging all drainage water to any aquatic environment.
- All facilities (for reproduction, egg incubation, larviculture, fingerling, pre-fattening, and fattening) to be located in areas that are not at risk of flooding or natural avalanches.
- The use of protection systems (typically nets) in breeding and fingerling ponds to prevent the entry of birds or other organisms that can capture fish and potentially release them into the natural environment.
- Maintain at least 30 cm (approximately 12") between the water surface and the level of the pond bank to prevent water from overflowing as a result of rain, runoff, or excess water entering the ponds.
- Have a dry place away from the water catchment source or other natural or artificial body of water for the disposal of the mud extracted from the ponds, in order to prevent the loss of eggs, larvae, fingerlings, or other specimens.
- Install filters at the outlets of the drainage tubes or in the overflows of all facilities before discharging water into any aquatic environment.
- Ensure that the drains of the ponds have sufficient capacity to evacuate excess water from rain, runoff, or floods.

Regarding flooding, because of the need for proximity to a water supply and therefore likely riparian locations, there is considered to be an inherent risk of flooding in raceway and pond farms, and therefore an associated risk of escape. The requirements from Resolution 2789, if enacted thoroughly, would substantially reduce the risk of escape from this cause. Nevertheless, it must be noted that, according to IDEAM,[125] Colombia is a country with high vulnerability to flooding, both in floodplains and flat areas, and with sudden increases associated with areas with medium to high slopes. IDEAM provides a suite of maps of varying scales that indicate different aspects of flood risks, and information on historic flooding events. Two examples are shown in Figure 29, with the preliminary flood risk map (left) and an example of a flood event map (right) from 2010–11. According to Ricuarte et al. 2017, Colombia experienced extremely damaging floods in Colombia during that period.

[125] http://www.ideam.gov.co/web/siac/inundaciones

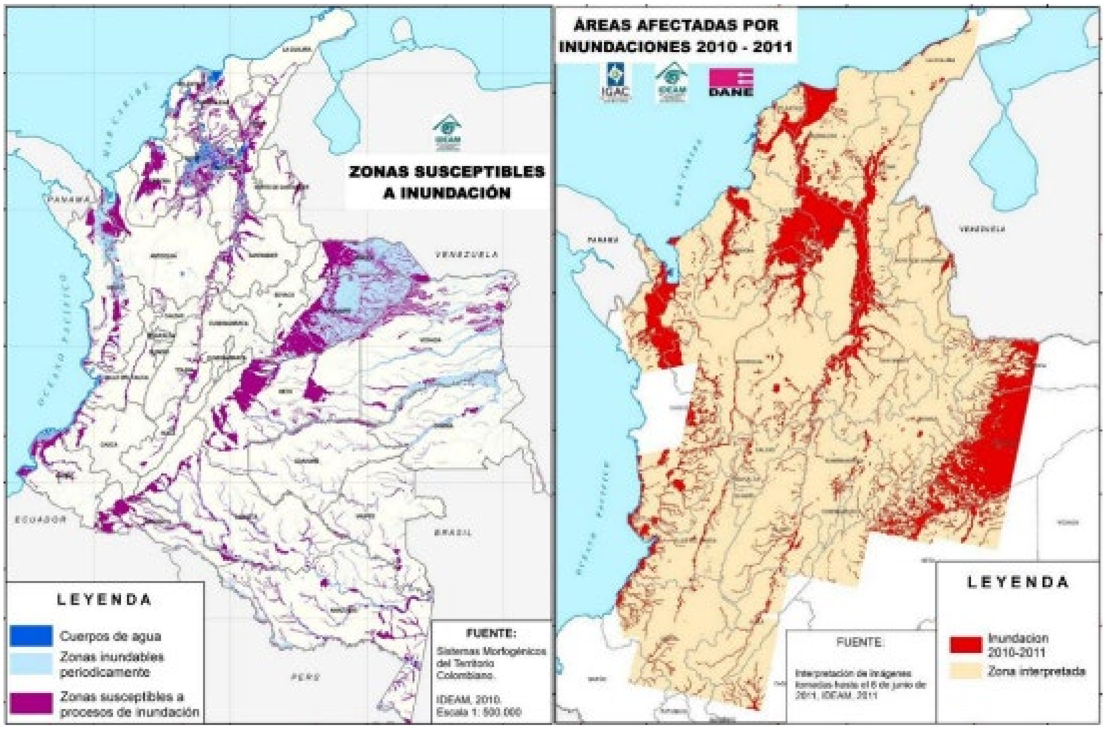

Figure 29: Two examples of flood maps from IDEAM. The left image shows the areas susceptible to flooding (dark blue is existing bodies of water, light blue is areas at risk of periodic flooding, and purple shows areas at risk of general flooding). The right image (note the different area of Colombia covered compared to the left image) shows areas that were flooded during 2010–11 (in red). Images reproduced from IDEAM.

By comparing the flood-prone areas to those areas of Colombia considered suitable (and moderately suitable) for trout farming (see Figure 21 in Criterion 3—Habitat), it is clear that there is little visible overlap at this scale, so farms are most likely to be located outside these main flooding areas. It is still possible that individual farms in any riparian location can experience flooding, but overall, escapes due to flooding are considered here to be a lower concern in Colombia.

Overall, as flow-through systems, raceways and ponds have a risk of escape, but the likely use of multiple screens and the potential for direct on-farm recapture substantially reduce the risk. Flooding is inevitably a concern in riparian locations, but trout farms in Colombia are outside the country's major flooding regions. The score for Factor 6.1 is therefore 6 out of 10.

<u>Recaptures</u>

Resolution 2879 does not include any specific requirements on recaptures in the event of an escape, and no formal requirements or evidence of recaptures were readily available. According to the environmental management plan of a net pen farm in Like Tota, there is a network of local fishers who can be hired immediately for the fishing and capture of escaped individuals, with the intent to quickly avoid, as far as possible, their dispersal (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023). It is likely that other farms in Lakes Tota and Cocha have similar intentions, but information requests to other companies were not returned. Given the somewhat contained nature of the lakes, the evidence of substantial angling activity, and the potential for targeted recapture efforts by local fishers, it is clear that (in the event of a large escape) there could be significant recaptures of the stock, but there are no specific data with which to estimate this. No information could be found for potential recaptures from raceway or pond farms.

It is clear from general internet searches that recreational angling is popular in Colombia's lakes and rivers; however, 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 (i.e., from deliberate stocking), in addition to any recent escapes from fish farms. With no data available with which to estimate the efficacy of recapture activities, no recapture adjustment can be applied to the Escape Risk score for any production system, and the scores for Factor 6.1 remain 2 out of 10 for net pens and 6 out of 10 for raceways and ponds.

Factor 6.2—Competitive and Genetic Interactions

A useful review of trout and char in South America by Arismendi et al. (2019) shows that rainbow trout has been extensively introduced throughout South America over the past 175 years through various government initiatives, mainly to enhance recreational fishing opportunities. Considering the broader scale of these various initiatives, Salgado et al. (2022) note that there are currently more than 50 alien species introduced in the Magdalena River in Colombia, including fish, macrophytes, mollusks, and mammals.

Rainbow trout were first introduced into Colombia's Andean streams, rivers, and lakes in the first half of the 1900s, primarily to populate the region's watersheds with a species of higher economic value than native species (Arismendi et al. 2019)(Esquivel et al. 2014)(Cruz-Casallas 2011)(CONPES 2014). Although some accounts, such as Carrera-Quintana et al. (2022) and Arismendi et al. (2019), also associate the initial introductions of trout with aquaculture, there appears to be some confusion here. For example, Carrera-Quintana et al. (2022) note that trout aquaculture began in the late 1930s when "rainbow trout was introduced to populate cold water lagoons of the Andean region with a fish species of greater economic value than the native species." Arismendi et al. (2019) also mention aquaculture in the context of the initial introductions of trout to Colombia, but they note that, between the 1940s and 1960s, stocking efforts continued to maintain populations that would provide protein sources for local communities, recreational fisheries, and a *promissory* aquaculture industry (i.e., a nascent, potential, or promising *future* aquaculture industry).

Therefore, it appears that the raising of trout fingerlings (from imported trout eggs) for stocking into lakes for recreational fisheries was termed "aquaculture" (e.g., by Carrera-Quintana et al. 2022) as opposed to the ongrowing of fish to harvest for human consumption. This can be confirmed regarding specific known introductions; for example, the introduction of rainbow trout into Lake Tota in 1939[126] (Torres-Barrera and Grandas-Rincón 2017) was decades before the initial pilot study of trout farming in the lake in the 1980s (CAR 1984). Nevertheless, it is

[126] Alexiades et al. (2022) considered that the year of first introduction to Lake Tota was 1926, referencing MacCrimmon (1971).

also clear that introductions were also made into new regions specifically for aquaculture. For example, Gómez-Hoyos et al. (2018) note that rainbow trout were introduced into aquaculture ponds in the Quindío department of Colombia in 1953; however, they were also introduced into the department's rivers at the same time. Therefore, even if trout escaped from the aquaculture ponds into natural waterbodies, they would likely only supplement those that had been deliberately stocked there.

Therefore, regarding the initial introduction and establishment of rainbow trout in Colombia, it is concluded here that the establishment of rainbow trout in the wild in Colombia was primarily the result of deliberate stocking for recreational fisheries. It is also of interest to note that in the case of Lake Tota, two other species were introduced to the lake in the 1950s from elsewhere in Colombia as food/prey for the trout: the captain fish (el capitán, *Eremophilus mutisii*) and the guapucha (*Grundulus bogotensis*). Both became established in the lake.

Rainbow trout is listed as an invasive species in the Global Invasive Species Database (GISD 2023), and included in its "100 of the world's worst invasive alien species"[127] (along with the brown trout, *Salmo trutta*). Therefore, it is perhaps not surprising that, since their introduction, rainbow trout (followed by brown trout) have been the most successful salmonids introduced to the continent, often becoming the most abundant fishes in their basins (Arismendi et al. 2019). Figure 30 shows their approximate distribution in South America.

[127] http://www.iucngisd.org/gisd/100_worst.php

Figure 30: Distribution of rainbow trout in South America based on sampling and detection reports. Image reproduced from Arismendi et al. (2019).

Although Arismendi et al. (2019) noted the cultural and economic benefits of trout to South America (including aquaculture), there is little doubt about the ecological impacts. There is a substantial body of literature on the subject, but the review by Arismendi et al. (2019) notes that the most common impact of trout and char species in freshwater is the reduction of the relative abundances of native fish, primarily because of predation, plus competition for food and other resources. There are at least five endemic fishes of South America that are apparently extinct following the introduction of trout and char, and rainbow trout has been directly associated with the extinction of at least three native South American fishes and is contributing to the decline of tens to hundreds of other native species across the continent (Arismendi et al. 2019). Specifically, in Colombia, rainbow trout has been a factor in the extinction of the grease catfish (pez graso, or *Rhizosomichthys totae*), a species endemic to Lake Tota (Arismendi et al. 2019). It must be noted that several other nonnative species have also been introduced to Lake Tota, and Mesa-Salazar and Mojica (2016)[128] particularly note the catfish *Eremophilus mutisii* as a factor in the decline of pez graso (they also note the pollution by agrochemicals from nearby agricultural activities that is causing a continuing decline in the

[128] This reference is an IUCN red-list species assessment https://www.iucnredlist.org/species/19661/61472482

quality of the habitat; see Criterion 2—Effluent). Regarding the timing of this extinction in relation to the development of net pen aquaculture in Lake Tota in the 1980s, the species was last reported alive in 1942. Beyond fish, Gómez-Hoyos et al. (2018) also considered rainbow trout to be a factor in the apparent extinction of the Quimbaya toad (*Atelopus quimbaya*) after the introduction into the Quindío department in 1953 (the last observations of the Quimbaya toad were between 1994 and 1999).

The species itself therefore justifies a high level of concern regarding potential impacts from ongoing or future escapes; however, two additional factors must be considered. The first is the population declines of rainbow trout in the wild following the cessation of stocking in Colombia, and the second is the reproductive characteristics of the fish currently used in aquaculture. The restocking programs (of several exotic species) in Colombia were terminated after 2008 because of Resolution 0848, which declared rainbow trout to be an exotic and invasive species, along with tilapia (*O. niloticus*; *O. mossambicus*), common carp (*C. carpio*), largemouth bass (*M. salmoides*), and snakeskin gourami (*T. pectoralis*) (Merino et al. 2013). As a result of this termination of stocking, CONPES (2014) reported a marked decrease in the population sizes of trout in the lake, which in turn has translated into low catches of trout by artisanal fishers and recreational anglers. For example, CONPES (2014) notes that sport fishing contests in the lake have been affected by the decrease in the number and size of fish since stocking was prohibited. Thus, it appears that the previous stocking of trout in the lake had increased their number and size beyond the natural carrying capacity of the lake, perhaps because of natural limitations in suitable food or habitats (e.g., for reproduction, fry survival, or for juveniles/adults).

In December 2015, another resolution (2287) was passed declaring tilapia and trout as domesticated species, which allows the producers to import live fish, although previously only eggs were allowed to be imported. But the intentional release of all species listed is prohibited, and special regulations govern their continued, controlled use for aquaculture activities only (IABIN 2007-2008)(AUNAP Resolucion 2287)(29 Diciembre 2015).

The second factor to consider in determining the appropriate level of concern regarding potential impacts of escaping fish is that the trout produced in farms in Colombia have been manipulated such that they are all female and sterile. Although this process is not 100% effective (99% according to Troutlodge[129]), this greatly reduces the likelihood of reproduction and continuation of rainbow trout populations in the wild.

The escape of trout from farms still represents the introduction of a highly invasive and predatory species into the wild, but when the decline of wild trout populations after the cessation of stocking is considered along with the sterility of the aquaculture stocks, the concern for the propagation and/or extension of the range of rainbow trout in the wild is reduced. Finally, because of the latitude of Colombia and the limited high-altitude areas

[129] Troutlodge is the largest supplier of trout eggs in Colombia and supplies as standard, sterile all female eggs - https://www.troutlodge.com/en/trout-genetics/trout-eggs/

suitable for rainbow trout, only approximately 2% of the total area of Colombia was considered to be suitable for trout aquaculture, and 10% moderately suitable (see Criterion 3—Habitat). Therefore, although Alexiades et al. (2022) noted that the initial introductions of rainbow trout had resulted in established populations in at least eight departments of Colombia, there is inevitably a limited potential range for trout, and no potential for anadromous populations to become established due to a lack of suitable connections to marine environments (i.e., the temperature of rivers increases too much as they descend to low altitudes).

Overall, rainbow trout is considered to have been widely established in the wild in Colombia as a result of active stocking before the development of aquaculture. Nevertheless, as a highly invasive species that has successfully established across large areas of South America with documented impacts to native species, rainbow trout escapes from farms inevitably continue to be a concern. The apparent decline of the species in the wild after the cessation of active stocking, plus the sterile all-female nature of the farm stocks, reduces this concern but does not negate it. Therefore, although the species can be considered to have been fully ecologically established in the production region before aquaculture (score of 8 out of 10 for Factor 6.2) and has a limited suitable geographic range in Colombia (for example, compared to Chile), any escapes must be considered to have a risk of competition, predation, disturbance, or other impacts to wild species, habitats, or ecosystems. Therefore, the score for Factor 6.2 is reduced to 6 out of 10.

Conclusions and Final Score

No data or records are available on escape events from trout farms in Colombia. Resolution 2879 lists the escape minimization requirements for ponds and net pens, but it is not known how thoroughly these are implemented across the formalized and nonformalized farms in Colombia. It can be seen that the typical net pen structures and typical fish handling practices inevitably have some vulnerability to large-scale or trickle losses. As flow-through systems with high densities of fish, raceways and ponds also have a risk of escape, but the likely use of multiple screens and the potential for direct on-farm recapture substantially reduce the risk. Flooding is inevitably a concern in riparian locations, but the areas suitable for trout farming in Colombia are outside the country’s major flooding regions. In the event of an escape in the lakes, an active angling presence in addition to arrangements with local fishers indicate that a significant recapture is likely, but no data on recaptures are available for either net pens or raceways/ponds. The escape risk remains high, and the escape risk score (Factor 6.1) is 2 out of 10 for net pens and 6 out of 10 for the more contained raceways and ponds. Rainbow trout is considered to have been widely established in the wild in Colombia because of its introduction and active stocking before the development of aquaculture in net pens and raceways/ponds. Nevertheless, as a highly invasive species that has successfully established across large areas of South America with documented impacts to native species, rainbow trout escapes from farms inevitably continue to be a concern. The apparent decline of rainbow trout populations in the wild after the cessation of active stocking, combined with the sterile all-female nature of the farm stocks, reduces this concern but does not negate it entirely. Therefore, any escapes must be considered to have a risk of competition, predation, disturbance, or other impacts to wild species, habitats, or ecosystems. The score for Factor 6.2—Competitive and Genetic

Interactions is 6 out of 10. Factors 6.1 and 6.2 combine to give final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 6 out of 10 for raceways and ponds.

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 (net pens and raceways/ponds)

C7 Disease parameters		Score
Evidence or risk-based assessment	Risk	
C7 Disease Final Score (0–10)		**4**
Critical	No	Yellow

Brief Summary

It is clear that pathogens and parasites have become increasingly problematic in trout aquaculture in Colombia as it has intensified and increased in scale, and there is evidence of large mortality events associated with disease. But there is no readily available routine monitoring information or data on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and raceway/pond farms are considered to be "open" to the environment in terms of the potential for amplification of pathogens within them and the subsequent release of those pathogens into waters shared with wild fish. Although some biosecurity measures and best practices have been established (by the government's Institute of Agriculture), their level of implementation among farms is uncertain. The limited amount of data means that the risk-based assessment has been used (the Data Criterion score for the disease section is <7.5 out of 10), and with open systems but no evidence of infections or mortalities in wild fish as a result of pathogen discharges from trout farms, the final score for Criterion 7—Disease for both net pens and raceways/ponds is 4 out of 10.

Justification of Rating

In a 2017 article, Beleño (2017) considered that one of the most important competitive advantages for aquaculture in Colombia is that it is one of only a few countries that are free of diseases. The justification for this claim (apparently attributed to the-then director of Fedeacua) is unclear; however, Álvarez-León (2007, referencing Conroy 1974, 1975) noted that, at least in the 1970s, Colombia was free of many known salmonid diseases, such as whirling disease (caused by *Myxosoma cerebralis*), infectious pancreatic necrosis (IPN), infectious hematopoietic necrosis (IHN), viral hemorrhagic septicemia (VHS), furunculosis (caused by *Aeromonas salmonicida*), ulcer disease (caused by *Haemophilus piscium*), and bacterial kidney disease

(BKD, caused by *Corynebacterium* spp.). Currently, the ICA considers that major salmonid diseases listed by the World Organization for Animal Health are still not present in Colombia[130] [epizootic hematopoietic necrosis, *Gyrodactylus salaris*, infectious salmon anemia virus (ISA), salmonid alphavirus (SAV), IHN, and VHS].

Nevertheless, a limited number of academic studies and anecdotal reports indicate that trout farms in Colombia are currently affected by at least some of the same pathogens that affect the species in farms worldwide. For example, the bacterium *Flavobacterium psychrophilum* (which is the causative agent of cold-water bacterial disease and rainbow trout fingerling syndrome) is considered one of the most significant bacterial pathogens in freshwater salmonid aquaculture worldwide (Rochat et al. 2017), and Arcos (2006) noted that Lake Cocha is no exception to this problem. Previous personal communications indicate that *Flavobacteria* had been the only pathogen concern for the trout industry so far in Colombia, because tight restrictions on ova imports have prevented introduction of common trout diseases, such as infectious pancreatic necrosis (IPN) (pers. comm., A. Dueñas, October 2016)(AUNAP 2015). As a recent anecdotal example of a *Flavobacteria* outbreak, the Colombian ICA responded to a notification of fish mortality in 2018 in the department of Nariño, for which the bacteria *Flavobacterium psychrophilum* was determined to be the cause (ICA 2018). Regarding other pathogens (and in contrast to the personal communications just noted), anecdotal evidence shows that the ICA had also been active in responding to a 2020 fish mortality event at farms in Lake Cocha for which IPN was determined to be the cause (ICA 2021b).

As an example of potentially emerging disease concern, Vásquez-Machado et al. (2020) reported high mortalities of 50–70% in four Colombian trout farms (referred to as concrete ponds) from 2016 to 2019. The bacterial pathogen *Weissella tructae* (formerly *Weissella ceti*) was determined to be the cause and was considered to be a secondary infection associated with the stress of high summer water temperatures. Vásquez-Machado et al. (2020) noted that *W. ceti* could be part of the normal flora of rainbow trout and become pathogenic under certain conditions (e.g., high temperature). Similarly, Cifuentes-Niño (2017) noted that pathogens such as *Flavobacterium psychrophilum* and *Aeromonas salmonicida* are present in most of the farms monitored in Colombia (in a study in the department of Antioquia), but noted that the prevalence was low and “endemic” in nature. This is consistent with broader research that shows that bacteria such as *Flavobacterium psychrophilum* are ubiquitous in the aquatic environment, particularly in freshwater [e.g., Barnes and Brown (2011)].

Nevertheless, human activity, including aquaculture, may have a role in their dissemination (Nicholas et al. 2008) (see Criterion 10X—Introduction of Secondary Species). There is a substantial global literature on the diseases of farmed trout,[131] but in general, bacterial and viral pathogens affecting trout in a farm environment are typically considered to be secondary or opportunistic pathogens that cause outbreaks in the presence of other factors, such as

[130] Aquaculture (ica.gov.co)
[131] For a simple summary, see Chimbor-Mejia (2023) - https://aquahoy.com/principales-enfermedades-en-la-trucha-arco-iris/

variations in the physical-chemical environmental conditions of the water (e.g., from the increase in dissolved solids and the decrease in oxygen in rainy seasons, or from the runoff of sediment, organic waste, and agricultural chemicals) (Sánchez-Fajardo and Cuello 2015)(Álvarez-León, 2007). Nevertheless, without robust and readily available data or studies, it is challenging to understand the prevalence of pathogens and clinical outbreaks on trout farms in Colombia.

Unfortunately, there do not appear to be any readily available data on disease occurrences and/or mortality rates in Colombia trout aquaculture (either in total, or disease-specific), either in the lakes or in raceways and ponds. This could be because disease problems are rare, or simply that there are no formal recording or reporting procedures. According to a government publication in 2010, the tools and specialized centers for the diagnosis of pathogens were lacking at that time in Colombia (MADR 2010). Also, record keeping of pathogen monitoring, detections, disease outbreaks, and treatments applied were lacking or unavailable to external investigators, because the government did not mandate disease reporting (pers. comm., M. Mendoza March 2015)(MADR 2011). Although it is possible this may have improved in the interim (for example, the ICA now provides a leaflet on how to take samples for diseased fish for veterinary analysis[132]), there is currently still no baseline dataset of disease outbreaks or monitoring.

Regarding pathogens in wild fish, specifically the potential impacts of pathogens from fish farms on wild fish populations, it is well established that aquaculture operations may increase the likelihood of pathogen presence and/or parasite amplification in nearby environments [e.g., Naylor et al. (2000), Johansen (2011), Camus (1998)]. But it is challenging to determine if any pathogens discharged from net pen or ponds farms in Colombia would affect fish in the wild (i.e., outside the farm environment, where the conditions such as unnatural stocking densities and reduced water quality are considered to increase the susceptibility of farmed trout to pathogens). In Colombia, the 2007 review by Álvarez-León (2007) noted that there had been significant efforts to characterize the pathologies of fish both in the wild and in farms; however, the review, and particularly the studies referenced (e.g., Conroy 1974, 1975), are now too old to be considered relevant to the current situation in Colombia, and therefore to have any indication of the risk of affecting wild fish by discharge from today's trout farms. It is also noted that some of the pathogens listed above are salmonid-specific, which (without native wild salmonids in Colombia) reduces the level of concern for impacts to native wild fish; nevertheless, the level of concern remains unknown.

Regarding biosecurity management, the ICA has a certification process for "Biosafe Aquaculture Establishments" (Establecimiento de Acuicultura Bioseguro), established under Resolution 20186 of 206, and provides an informational booklet describing the biosecurity measures.[133] These measures include common biosecurity best practices such as control and cleanliness of

[132] https://www.ica.gov.co/areas/pecuaria/servicios/enfermedades-animales/acuicolas-1/plegable-final-diagnostico.aspx
[133] Available from FEDEACU - https://www.fedeacua.org/page/eduaqua

equipment and personnel, use of tested and quarantined sources of fry, veterinary oversight, barriers to wildlife entry, water treatment, notifications of disease outbreaks, and record keeping. A biosecurity management plan provided for one company in Lake Tota included similar requirements (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023). Because the ICA considers[134] that (across the large range of farm types in Colombia) many of the diseases in aquatic animals are generated by ignorance and poor management practices of farmed animals, these educational developments from the ICA (which are also promoted by Fedeacua) are welcome, but again, information on the uptake of these practices and the level of certification to the program is not readily available. It is considered likely that the uptake among small farms is much less than that of the large producers.

Conclusions and Final Score

It is clear that pathogens and parasites have become increasingly problematic in trout aquaculture in Colombia as it has intensified and increased in scale, and there is evidence of large mortality events associated with disease. But there is no readily available routine monitoring information or data on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and raceway/pond farms are considered to be "open" to the environment in terms of the potential for amplification of pathogens within them and the subsequent release of those pathogens into waters shared with wild fish. Although some biosecurity measures and best practices have been established (by the government's Institute of Agriculture), their level of implementation among farms is uncertain. The limited amount of data means that the risk-based assessment has been used (the Data Criterion score for the disease section is <7.5 out of 10), and with open systems but no evidence of infections or mortalities in wild fish as a result of pathogen discharges from trout farms, the final score for Criterion 7—Disease for both net pens and raceways/ponds is 4 out of 10.

[134] https://www.ica.gov.co/getdoc/b082c759-18c7-47da-bed6-0ebe76b48fe0/acuicolas-(1).aspx\

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 (0–10)		**0**
Critical?	No	**Green**

Brief Summary

Rainbow trout has been selectively bred for beneficial traits such as growth rate and disease resistance for decades throughout the world. Two international companies supply all the eggs currently used in Colombia (Troutlodge from the United States and Troutex from Denmark). These suppliers specialize in the domestication and selective breeding of trout from captive breeding stocks. The production of rainbow trout in Colombia 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.

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). As noted in Criterion 6—Escapes, Resolution 228 of 2015 declared rainbow trout to be "domesticated" in Colombia, and as a nonnative species, all trout grown in Colombia is produced in hatcheries with no use of wild broodstock or seed. Further, if any "wild" trout from Colombia were used as broodstock, it would not be included in the scoring of this criterion (i.e., there would not be any sustainability concerns with its capture and use). According to the ICA, Colombia has import arrangements for rainbow trout eggs with the United States, Chile, Denmark, and Spain (see Criterion 10X for more details). Two companies currently supply all the rainbow trout eggs to Colombia: the U.S.-based company Troutlodge[135] (which has previously been the primary source of rainbow trout eggs in Colombia, and likely still is) and the Denmark-based company Troutex[136] (pers. comm., E. Sarmiento, Trucha Suralá June 2023)(Esquivel et al. 2014)(Beleño 2017). Both companies specialize in the domestication and selective breeding of trout from captive breeding stocks, and the production of rainbow trout in Colombia is considered fully independent of wild stocks for broodstock, eggs, or fingerlings.

Conclusions and Final Score

Rainbow trout has been selectively bred for beneficial traits such as growth rate and disease resistance for decades throughout the world. Two international companies supply all the eggs currently used in Colombia (Troutlodge from the United States and Troutex from Denmark). These suppliers specialize in the domestication and selective breeding of trout from captive breeding stocks. The production of rainbow trout in Colombia 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.

[135] https://www.troutlodge.com/en/trout-genetics/trout-eggs/

[136] https://troutex.dk/

Criterion 9X: Wildlife and Predator Mortalities

Impact, unit of sustainability and principle

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

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

Criterion 9X Summary

C9X Wildlife Mortality parameters		Score
Single species wildlife mortality score		–5
System score if multiple species assessed together		n/a
C9X Wildlife Mortality Final Score		**–5**
Critical?	No	**Yellow**

Brief Summary

Because of the visually attractive nature of farmed fish to avian or other predators, some wildlife interactions with trout farms in Colombia are to be expected. A now-dated study from 2003 indicated that lethal control (shooting) was used, but expert opinion now considers this to have ceased. One company provided details on predator exclusion and deterrence methods, but there is no robust information available on current activities or mortality data across the broader industry. The presence of occasional reports and anecdotal evidence in the media of injuries to some animals, including vulnerable species, suggests that if there were a substantial mortality concern, then it would be similarly reported. As noted in Criterion 3—Habitat, trout farms in Colombia have developed in landscapes that had already been substantially affected by humans, and similar predatory species have been (and may continue to be) exploited for human consumption by rural communities. Thus, the extent of current interactions with wildlife in trout farms is challenging to determine, but given Colombia's biodiversity and large numbers of vulnerable species, there is inevitably some concern and a need for precaution. There are regulations in place and examples of farm management plans regarding the use of predator netting, and it is likely that farmers would use nets or other exclusions whenever there is a significant risk of loss to the stock. A small risk of entanglement remains. Overall, expert opinion considers that lethal control is no longer used, and there is some evidence of regulations or management measures in place for nonharmful exclusion; however, their enforcement or enactment across the industry are uncertain, and mortality numbers are unknown. The potential for accidental mortalities such as entanglements remains. With considerable uncertainty, the risk-based assessment must be used, and the final score for Criterion 9X is a precautionary deduction of –5 out of –10.

Justification of Rating

As noted in Criterion 3—Habitat, Colombia is one of the world's "megadiverse" countries, hosting close to 10% of the planet's biodiversity and ranking first in bird and orchid species diversity and second in plants, butterflies, freshwater fishes, and amphibians. It was also noted in Criterion 3 that trout farming primarily occurs in landscapes that have seen considerable human impact before the development of aquaculture (e.g., as indicated by the Human Spatial Footprint Index). Nevertheless, it can be robustly assumed that the fish in trout farms attract various predators, as they do in similar systems elsewhere [e.g., Fornshell and Hinshaw (2008)]. For example, according to a now-dated study, high densities of fish in aquaculture facilities in Colombia attract a number of predatory bird species, including kingfishers, egrets, herons, and osprey (Bechard and Marquez-Reves 2003).

There do not appear to be any readily available data on predator mortalities in Colombia (i.e., of species or numbers), and except for the interactions noted in Bechard and Marquez-Reves (2003), no recent academic studies could be found. Bechard and Marquez-Reves (2003) found that as many as 50% of fish farmers in Colombia use shooting as a method of reducing bird depredation, but again, the now-dated research cannot be relied upon to reflect current practices. An academic industry expert considers that there is no longer any lethal control used in Colombian trout farms (although some farms may use pellet guns as audible bird scarers) and that occasional entanglements in predator netting are the main wildlife interaction (pers. comm., E. Legarda, University of Colombia September 2023). Anecdotal reports in Colombia note an instance of an injured golden eagle in 2016 and a crocodile in a net pen (tilapia) farm in 2020 (ASC 2022d), and an osprey entangled in a predator net of a pond farm (farmed species not specified), also in 2016.[137]

At the country level, a 2014 study titled "The State of the Birds in Colombia" (Fundación ProAve, 2014) noted that decades of deteriorating ecosystem conditions have led to 122 of the country's 1,903 bird species now facing extinction (Fundacion ProAves 2014). Clearly this cannot be related in any specific way to aquaculture interactions, again noting that rainbow trout aquaculture primarily developed in landscapes and habitats that had already seen significant human impact. Nevertheless, because of the lack of data on actual aquaculture interactions with birds or other wildlife, there is inevitably some general level of concern in Colombia, given the typical attraction of farmed fish to predatory birds or other animals.

As noted in Criterion 6—Escapes, Resolution 2879 requires the use of protection systems (typically nets) in breeding and fingerling ponds, and for all net pens, to prevent the entry of

[137] Wild animals were rescued (cam.gov.co)

birds or other organisms that can capture fish. The requirements in Resolution 2789 do not specifically apply to grow-out raceways or ponds, but according to the wildlife management plan of a farm in Lake Tota, Resolution 1517 of 2012 and Decree 2424 of 2009 require the installation of anti-bird mesh on stocked net pens, at all stages of cultivation (pers. comm., Oscar Murillo, TroutCo/PezFresco, June 2023. Although examples of predator nets can be found (Figures 31 and 32), the enforcement of these regulations is uncertain, particularly regarding the low numbers of "formalized" farms in Colombia (see Factor 2.2b in Criterion 2—Effluent). In contrast to these examples of the use of nets, many more examples can be found where trout farms of all types do not have predator nets (e.g., Figures 1, 2, 3, 4, 5, 20, 27, and 28 in this report). According to Fedeacua's manual of best practices, the use of predator nets is based on a risk assessment; i.e., predator nets are only used if there is a significant risk of predator interactions, and it is considered likely that the regulatory procedures follow the same approach. But because of the difficulty of obtaining and translating the correct regulatory documents in Colombia, this has not been confirmed. Although predator nets reduce the interactions with predators, they create a small additional risk of entanglement injuries and/or mortalities.

According to a Flora and Fauna Conservation management plan for a trout farm in Lake Tota, the primary concern is "flying predators" (i.e., birds), for which the only actions listed are netting and to scare them away by physical presence on the farms (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023).

Figure 31: Example of bird netting above a fish farm in Colombia (farmed species not specified). Image source: SEPEC (http://sepec.aunap.gov.co/BancoImagenes/Consulta).

Figure 32: Example of bird netting over a net pen trout farm in Lake Cocha. Image reproduced from the ICA (https://www.ica.gov.co/noticias/ica-fortalece-produccion-acuicola-en-narino).

In a 2009 study of the wildlife of Lake Tota that included observations and interviews with local residents, there was no mention of any interaction between the wildlife observed and the net pen trout farms in the lake (they observed 6 species of fish, 10 species of reptiles, 83 of birds, and 23 of mammals) (Niño and Zambrano 2009). But the study did note that some of these animals were exploited for human consumption or medicinal purposes at an artisanal level, mainly birds and their eggs, and mostly of waterfowl, with the use of guns, catapults, nets, and baited hooks (the latter used to catch herons). All (100%) of the local inhabitants interviewed by Niño and Zambrano (2009) confirmed the use of ducks, 71% used tinguas (rails), 50% used herons, and 42% used partridge. Considering the 2009 date of that study, it is not known if these practices continue. If they do, it would not diminish any interactions with net pens but would put them in some local context. Similar studies for Lake Cocha, or of relevance to raceway or pond trout farms, were not readily available.

As another example of the underlying but nonspecific concern, the Ramsar documents for Lake Cocha and the larger surrounding area note a diverse range of associated flora and fauna, including mammals such as the endangered tapir (*Tapirus pinchaque*), near-threatened Northern pudu (*Pudu mephistotels*), and the endangered spectacled bear (*Tremarctos ornatus*), in addition to important bird species such as grebe (*Podiceps occidentalis*), golden peck duck (*Anas georgica spicauda*), several species of snipes (*Gallinago gallinago paraguaiae*, *Gallinago nobilis*, *Gallinago gallinago delicata*), and the endemic ducks (*Anas cyanoptera borreroi*, *Oxyura jamaicensis ferruginea*). But there is no mention of their interactions with the net pens in the lake.

Conclusions and Final Score

Because of the visually attractive nature of farmed fish to avian or other predators, some wildlife interactions with trout farms in Colombia are to be expected. A now-dated study from 2003 indicated that lethal control (shooting) was used, but expert opinion now considers this to have ceased. One company provided details on predator exclusion and deterrence methods, but there is no robust information available on current activities or mortality data across the broader industry. The presence of occasional reports and anecdotal evidence in the media of injuries to some animals, including vulnerable species, suggests that if there were a substantial mortality concern, then it would be similarly reported. As noted in Criterion 3—Habitat, trout farms in Colombia have developed in landscapes that had already been substantially affected by humans, and similar predatory species have been (and may continue to be) exploited for human consumption by rural communities. Thus, the extent of current interactions with wildlife in trout farms are challenging to determine, but given Colombia's biodiversity and large numbers of vulnerable species, there is inevitably some concern and a need for precaution. There are regulations in place and examples of farm management plans regarding the use of predator netting, and it is likely that farmers would use nets or other exclusions whenever there is a significant risk of loss to the stock. A small risk of entanglement remains. Overall, expert opinion indicates that lethal control is no longer used, and there is some evidence of regulations or management measures in place for nonharmful exclusion; however, their enforcement or enactment across the industry are uncertain, and mortality numbers are unknown. The potential for accidental mortalities such as entanglements remains. With considerable uncertainty, the risk-based assessment must be used, and the final score for Criterion 9X is a precautionary deduction of –5 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 transwaterbody movements (%)	75	2
Biosecurity score of the source of animal movements (0–10)		5
Biosecurity score of the farm destination of animal movements (0–10)		2
Species-specific 10X score		–4.0
C10X Introduction of Secondary Species Final Score		**–4.0**
Critical?	No	Yellow

Brief Summary

Throughout its development, the Colombian rainbow trout industry has relied on imported trout eggs, and according to the Colombian Institute of Agriculture, the majority of production still relies on imported sources. Troutlodge in the United States and Troutex in Denmark are considered to be the dominant suppliers of eggs, but the ICA has also defined import arrangements for trout eggs with Chile and Spain (there are also reports of trout eggs being smuggled into Colombia from Ecuador, but information on the scale or frequency is not readily available). There are substantial movements of trout within Colombia from fingerling producers to grow-out farms, and these are likely to occur between waterbodies. It is estimated that 75% of trout production in Colombia is dependent on live animal movements between waterbodies (i.e., there is a risk that an organism not already present in the receiving waterbody could be introduced from the source). The importation of eggs from the authorized sources has significant biosecurity requirements, particularly the certification of pathogen- and/or disease-free status for 13 pathogens/diseases, and requirements to disinfect eggs within 48 hours of shipment. Although robust biosecurity measures for live fish movements are known to be in place in some fingerling producers (e.g., those certified as biosecure facilities by the ICA), the extent of this program is currently unclear. Overall, the movement of fingerlings within Colombia originating from tank/raceway nurseries is considered to represent a risk of unintentionally introducing organisms to new waterbodies. The final score for Criterion 10X—Introduction of Secondary Species is –4 out of –10.

Justification of Rating

This criterion provides a measure of the risk that alien species *other than the farmed species* are introduced to an ecologically distinct waterbody (i.e., one in which they are not native or present) during importations or other movements of live fish. For example, regarding one of the main pathogens affecting farmed trout (*F. psychrophilum*), Nicolas et al. (2008) considered its distribution at that time to be worldwide but noted that it was unclear what the initial geographic range of the pathogen was before the development of the fish-farming industry and the international trade of fish and fish eggs. Martinez-Silva (2018) compared zooplankton samples from 1999, 2007, and 2017 in the Betania Reservoir in Colombia, and noted several new species in the later samples. Though this may be an artifact of the sampling efforts in the earlier period, Martinez-Silva et al. (2018) primarily attributed the new zooplankton species to fish farming activities in which the fingerlings (in this case tilapia) are transported from other regions of the country in water tanks, bringing microorganisms not found previously in the reservoir. Similarly, the spread of emerging viruses in aquaculture, and their sudden arrival in new locations, is often associated with live animal movements (Aich et al. 2021). For example, a particular concern in Colombia is the *Weissella* bacterial pathogen (*Weissella tructae*), which is considered by Vásquez-Machado et al. (2020) to be an emerging disease in the country.

Factor 10Xa—International or Trans-Waterbody Live Animal Shipments

Throughout its development, the Colombian rainbow trout industry has relied on international sources of trout eggs (Alvis 2006)(Esquivel et al. 2014). Currently, the U.S.-based company Troutlodge[138] and the Denmark-based Troutex are the dominant suppliers. Troutlodge (for example) has two distributors within Colombia (Truchas Suralá[139] and Acuagranja[140]), but other companies in Colombia also claim to be major suppliers of eggs (e.g., Truchas el Paraiso[141]). Truchas el Paraiso state (on their website) that all their eggs are produced from their own breeding program in Colombia.

Troutlodge in the United States was previously noted to be the primary egg supplier in Colombia (Esquivel et al. 2014)(Beleño 2017[142]), and may well still be, but the ICA provided a link to the Health Information System for Import and Export of Agricultural and Livestock Products (Sistema de información sanitaria para importación y exportación de productos agrícolas y pecuarios—SISPAP),[143] which shows that the ICA has established procedures to import embryonated trout eggs from four countries: Chile, Denmark, Spain, and the United States (screenshot in Figure 33) (pers. comm., Juan Diego Morales Patiño, ICA May 2023). Troutlodge and Troutex are considered to be the only major suppliers at present (pers. comm., Eduard Samiento, Truchas Suralá June 2023), but if eggs were imported from other countries

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[138] https://www.troutlodge.com/en/

[139] Inicio - Truchas Suralá (truchasurala.com)

[140] https://acuagranja.com.co/

[141] Truchas el paraíso—Truchas el paraíso (truchaselparaiso.com)

[142] This media article stated Troutlodge was the only company authorized by the ICA, but this no longer appears valid.

[143] https://www.ica.gov.co/servicios_linea/sispap_principal.aspx

authorized by the ICA, they must meet the same biosecurity requirements, which are discussed in Factor 10Xb.

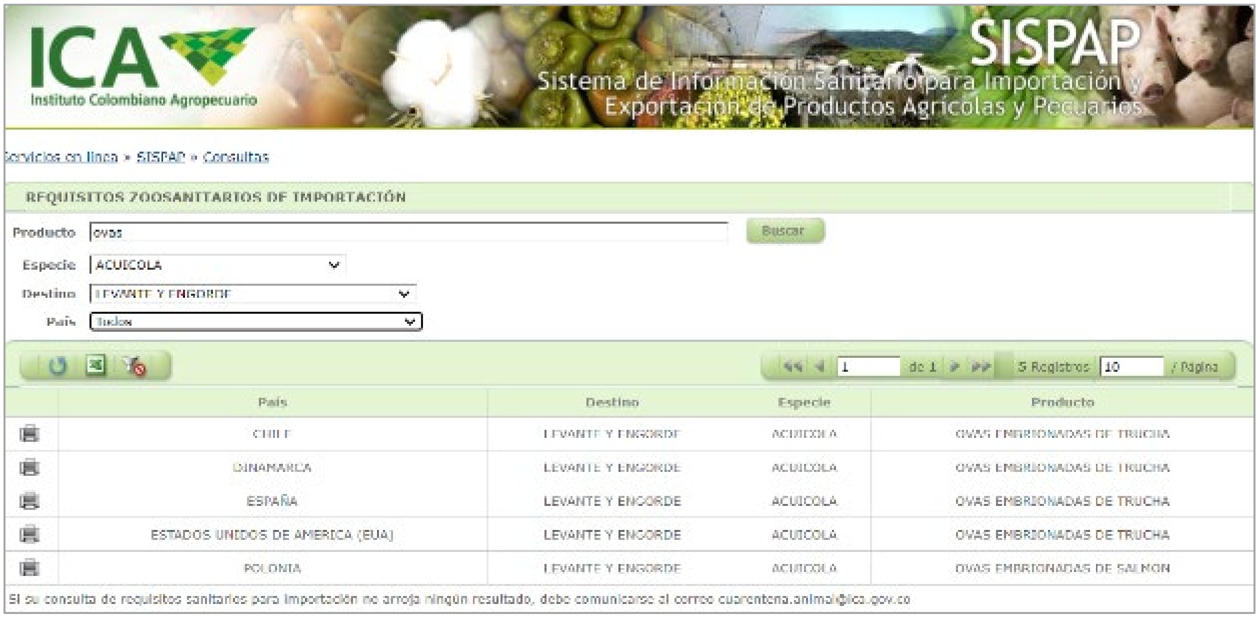

Figure 33: Screenshot from the SISPAP database showing the countries approved for the import of embryonated trout eggs (ovas embionadas de trucha) for raising and fattening (levante y engorda) in aquaculture (acuicola). The thumbnails on the left of each row link to documents listing the biosecurity requirements for each associated shipment. Note that the record for Poland is for salmon eggs. Screenshot from ICA.[144]

The ICA[145] notes that there have also been incidents of smuggling rainbow trout eggs into Colombia from sources in Ecuador, and highlights the disease risk that this represents. It is also likely that companies are operating within Colombia producing uncertified eggs (pers. comm., E. Legarda, University of Colombia September 2023), but further information on the frequency or scale of these movements could not be found.

According to the ICA,[146] the “vast majority” of trout production in Colombia is produced from imported genetic material, which is assumed to mean imported eggs, and most likely dominated by Troutlodge and Troutex. Therefore, based on the “vast majority” statement from the ICA and the concern regarding illegal movements from Ecuador, >90% of trout eggs in Colombia are considered to be imported on a precautionary basis.

Regarding movements of live trout within Colombia, major fingerling producers (including the three companies identified above, which supply both eggs and fingerlings) state that they supply them throughout Colombia. For example, Truchas Suralá has four fingerling production sites—two each in the departments of Cundinamarca and Boyacá—implying that distributions

[144] https://afrodita.ica.gov.co/IA_VW_CONS_REQ_IMPOR/ShowIA_VW_CONS_REQ_IMPORTable.aspx
[145] https://www.ica.gov.co/noticias/ica-notificacion-mortalidad-trucha-arcoiris.aspx
[146] https://www.ica.gov.co/getdoc/b082c759-18c7-47da-bed6-0ebe76b48fe0/acuicolas-(1).aspx/

of fingerlings “throughout Colombia” would involve movements over considerable distances, and inevitably different waterbodies or watersheds. Acuagranja appears to have a single fingerling facility. It is expected that the fingerling facilities would be located in areas of trout farming, and some companies would have their own fingerling facilities, so a substantial percentage of movements would be to local farms in the same watersheds. On a precautionary basis, it is estimated that the majority of fingerling movements would occur between different waterbodies, and a (somewhat arbitrary) figure of 75% is used here on a precautionary basis. As discussed in Factor 10Xb, the movements of eggs are considered to have a higher potential for biosecurity, so the scoring for this criterion is based on the movements of fingerlings within Colombia (i.e., the scoring is based on the movements with the greater concern for unintentionally introducing a secondary species). Therefore, three-quarters of production (75%) is considered to be reliant on trans-waterbody animal movements within Colombia, and the score for Factor 10Xa is 2 out of 10.

Factor 10Xb—Biosecurity of Source/Destination

For the import of eggs, the ICA provided details of the sanitary requirements for the import of embryonated trout eggs via the SISPAP database (pers. comm., Juan Diego Morales Patiño, ICA May 2023). A translation of the requirements is provided in Appendix 3. The salient points are that all shipments require proof of bacteriological and parasitological tests conducted by an authorized laboratory showing that they are free of the following diseases and/or their causative agents: viral hemorrhagic septicemia (HSV),* infectious hematopoietic necrosis (IHN),* epizootic hematopoietic necrosis (EHN),* infectious salmon anemia (ISA),* infectious pancreatic necrosis (IPN),* herpes virus of salmon masou,* piscirickettsiosis (PRS),* renibacteriosis (bacterial kidney disease—BKD), *Aeromonas salmonicida* (furunculosis), *Yersinia ruckeri* (red mouth enteric disease), *Gyrodactylus salaris* (gyrodactylosis), *Ceratomyxa shasta*, and *Myxobolus cerebralis* (whirling disease).* Those diseases or pathogens marked with an asterisk (*) must not have been detected in the previous 2 years in the source facility. In addition, there are disinfection requirements for the eggs (using iodine) after spawning, and within 48 hours of shipments. The website of Troutex notes that, in addition to the pathogens listed above, their eggs are also certified free of spring viremia of carp (SVC), *Oncorhynchus masou* virus disease (OMV), and streptococcosis (*Lactococcus garvieae*).

Overall, with high biosecurity for egg shipments (noting the exception of the unknown scale of the smuggled eggs), the greater risk of unintentionally introducing “hitchhiker” species during live animal movements is considered to be the movements of fingerlings within Colombia.

Regarding the movements of fingerlings, as noted in Criterion 7—Disease, the ICA has a certification process for “Biosafe Aquaculture Establishments" (Establecimiento de Acuicultura Bioseguro), established under Resolution 20186 of 206. It is not known how many fingerling producers are certified, but it was reported that all the major grow-out trout producers in Colombia are requesting this certification from their fingerling suppliers (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023). For example, the company Truchas Suralá notes[147] that

[147] https://truchasurala.com/productos/alevinos/

each batch of fingerlings has a health certificate, and that the facility is certified by the ICA under its biosecurity program. A representative of Truchas Suralá described their biosecurity and/or documentary practices regarding each movement of live fish (pers. comm., Eduard Sarmiento, Truchas Suralá June 2023):

- Certificate of Origin of the eggs that gave rise to the fingerlings.
- Sanitary certificate of origin of the eggs.
- Pathogen testing results by the ICA taken at two stages: the first for small fish at 1 g, and the second screening at 15–20 days before transport (testing for ICA-specified important pathogens: flaviobacteria, IPN virus, *Weisella*, *Edwardsiella*[148]).
- A movement permit from AUNAP.

In personal communication with a representative from a grow-out farm receiving fingerlings from Truchas Suralá, examples of all these documents for recent shipments were provided (pers. comm., Oscar Murillo, TroutCo/PezFresco June 2023).

Regarding specific biosecurity practices, it is also relevant to note that the water used in all live fish movements is first-use (i.e., it has not been used elsewhere in the facility) and filtered and disinfected before use in transport tanks, which also have been disinfected and not used for any other movements of live fish. But beyond these examples, it is a challenge to understand typical practices across the trout industry in Colombia. For example, the pathogen screening noted above is a requirement of the ICA certification, yet no information could be found on the number or proportion of fingerling producers in Colombia that have this certification. Although all facilities are likely to have some biosecurity procedures in place, their efficacy in preventing the entry of microorganisms such as pathogens or planktonic organisms into live fish shipments is unclear. Therefore, the score for Factor 10Xb is based initially on the fundamentals of the production system, which in the case of trout nurseries is typically flow-through tanks or raceways (as observed in various pictures[149] of fingerling facilities operated by the companies mentioned above). The initial score is therefore 4 out of 10. The presence of best practices for biosecurity management can increase the score to 6 out of 10, but given the uncertainty in their application in Colombia, an intermediate score of 5 out of 10 for Factor 10Xb is allocated.

The destination for live movements of fingerlings is the grow-out facilities in raceways, ponds, or net pens. These typically have lower biosecurity than fingerling facilities (as a result of being more "open" with higher flow rates, perhaps less water treatment, or simply the open mesh of the net pens). Therefore, the score for Factor 10Xb is based on the production system of the source of fingerling movements and the partial evidence of best practices for biosecurity, and is 5 out of 10.

Conclusions and Final Score

Throughout its development, the Colombian rainbow trout industry has relied on imported trout eggs, and according to the Colombian Institute of Agriculture, the majority of production

[148] *Edwardsiella tarda*, a bacterium that causes Edwardsiella septicemia

[149] For example: [Fincas - Truchas Suralá (truchasurala.com)]

still relies on imported sources. Troutlodge in the United States and Troutex in Denmark are considered the dominant suppliers of eggs, but the ICA has also defined import arrangements for trout eggs with Chile and Spain (there are also reports of trout eggs being smuggled into Colombia from Ecuador, but information on the scale or frequency is not readily available). There are substantial movements of trout within Colombia from fingerling producers to grow-out farms, and these are likely to occur between waterbodies. It is estimated that 75% of trout production in Colombia is dependent on live animal movements between waterbodies (i.e., there is a risk that an organism not already present in the receiving waterbody could be introduced from the source). The importation of eggs from the authorized sources has significant biosecurity requirements, particularly the certification of pathogen- and/or disease-free status for 13 pathogens/diseases, and requirements to disinfect eggs within 48 hours of shipment. Although robust biosecurity measures for live fish movements are known to be in place in some fingerling producers (e.g., those certified as biosecure facilities by the ICA), the extent of this program is currently unclear. Overall, the movement of fingerlings within Colombia originating from tank/raceway nurseries is considered to represent a risk of unintentionally introducing organisms to new waterbodies. The final score for Criterion 10X—Introduction of Secondary Species is –4 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 the following for the provision of data and information and/or technical review of the draft (in no particular order): Cesar Pinzón and Andrea Carolina Piza Jerez of Fedeacua, Oscar Murillo of TroutCo and Pescados Frescos, Eduardo Samineto of Truchas Suralá, Edgar Legarda of Universidad Nacional de Colombia, Juan Diego Morales Patiño of the Instituto Colombiano Agropecuario, in addition to other anonymous providers or reviewers.

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Appendix 1: Data Points and all Scoring Calculations

Criterion 1: Data	**Net Pens**	**Raceway/Pond**
Data Category	**Data Quality**	**Data Quality**
Production	5.0	5.0
Management	5.0	5.0
Effluent	7.5	5.0
Habitat	7.5	5.0
Chemical Use	5.0	5.0
Feed	5.0	5.0
Escapes	5.0	5.0
Disease	2.5	2.5
Source of stock	10.0	10.0
Wildlife mortalities	2.5	2.5
Escape of secondary species	5.0	5.0
C1 Data Final Score (0–10)	**5.46**	**5.00**
	Yellow	Yellow

Criterion 2: Effluent—Net Pens	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0–10)	**4**
Critical?	NO

Criterion 2: Effluent—Raceways/Ponds Risk-based assessment	
2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	41.000
eFCR	1.350
Fertilizer N input (kg N/ton fish)	0.000
Protein content of harvested fish (%)	15.700
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	88.560
N output in each ton of fish harvested (kg)	25.120
Waste N produced per ton of fish (kg)	63.440

2.1b Production System discharge	**Data and Scores**
Basic production system score	1.000

Adjustment 1 (if applicable)	–0.200
Adjustment 2 (if applicable)	0.000
Adjustment 3 (if applicable)	0.000
Boundary adjustment (if applicable)	0.000
Discharge (Factor 2.1b) score (0–1)	0.800
Waste discharged per ton of production (kg N ton^{-1})	50.752
Waste discharge score (0–10)	4.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	2.400
C2 Effluent Final Score (0–10)—Raceways/Ponds	**4**
Critical?	No

Criterion 3: Habitat—Net Pens	
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	4
3.2b Enforcement of habitat management measures	3
3.2 Habitat management effectiveness	4.800
C3 Habitat Final Score (0–10)	**6.933**
Critical?	No

Criterion 3: Habitat—Raceways/Ponds	
F3.1 Habitat conversion and function	**Data and Scores**
F3.1 Score (0–10)	7
F3.2 Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	3
3.2b Enforcement of habitat management measures	2
3.2 Habitat management effectiveness	2.400
C3 Habitat Final Score (0–10)	**5.467**
Critical?	No

Criterion 4: Chemical Use—All production systems	
Single species assessment	Data and Scores
Chemical use initial score (0–10)	4.0

Trend adjustment	0.0
C4 Chemical Use Final Score (0–10)	**4.0**
Critical?	No

Criterion 5: Feed—All production systems	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	3.000
Fishmeal from by-products, weighted inclusion %	18.000
By-product fishmeal inclusion (@ 5%)	0.900
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	0.000
Fish oil from by-products, weighted inclusion %	7.000
By-product fish oil inclusion (@ 5%)	0.350
Fish oil yield value, weighted %	5.000
eFCR	1.350
FFER Fishmeal value	**0.234**
FFER Fish oil value	**0.095**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	1.940
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	**4.200**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	41.000
Protein INPUT kg/100 kg harvest	55.350
Whole body harvested fish protein content	15.700
Net protein gain or loss	–71.635
Species-specific Factor 5.2 score	**2**
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)	**11.768**
Contribution (%) from fishmeal from whole fish	2.347
Contribution (%) from fish oil from whole fish	0.000

Contribution (%) from fishmeal from by-products	14.079
Contribution (%) from fish oil from by-products	3.748
Contribution (%) from crop ingredients	72.571
Contribution (%) from land animal ingredients	5.334
Contribution (%) from other ingredients	1.921
Factor 5.3 score	**7**
C5 Final Feed Criterion Score—All production systems	**4.4**
Critical?	**No**

Criterion 6: Escapes—Net Pens	**Data and Scores**
F6.1 System escape risk	2
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	2.000
F6.2 Invasiveness score	6
C6 Escape Final Score (0–10)	**4.0**
Critical?	No

Criterion 6: Escapes—Raceways/Ponds	**Data and Scores**
F6.1 System escape risk	6
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	6.000
F6.2 Invasiveness score	6
C6 Escape Final Score (0–10)	**6.0**
Critical?	No

Criterion 7: Disease—All production systems	**Data and Scores**
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0–10)	**4**
Critical?	No

Criterion 8X Source of Stock—All production systems	**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—All production systems	**Data and Scores**
Single species wildlife mortality score	–5
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**–5**
Critical?	No

Criterion 10X: Introduction of Secondary Species—All production systems	**Data and Scores**
Production reliant on trans-waterbody movements (%)	75
Factor 10Xa score	2
Biosecurity of the source of movements (0–10)	5
Biosecurity of the farm destination of movements (0–10)	2
Species-specific score 10X score	–4.000
Multispecies assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**–4.000**
Critical?	n/a

Appendix 2: Example of Water Quality Testing Results from a Raceway Farm

Universidad Tecnológica de Pereira

VICERRECTORÍA DE INVESTIGACIONES
INNOVACION Y EXTENSION
LABORATORIO DE ANALISIS DE AGUAS Y ALIMENTOS
INFORME DE ENSAYOS No 621/22

Código	123-LAA-F40
Versión	1
Fecha	2019-02-11
Página	1 de 3

Fecha Edición			Cotización Aprobada No.
AÑO	MES	DÍA	543/22
2022	04	22	

INFORMACIÓN DEL CLIENTE			
Razón Social:	**PESCADOS FRESCOS DE COLOMBIA S.A.S**	Nit o C.C :	800072656-1
Solicitante:	Walter Javier López	Cargo:	Asistente de Compras & Suministros
Dirección:	Carrera 16 Bis No. 9-120	Teléfono/Fax:	(6) 334 3433
Municipio/Departamento:	Pereira – Risaralda	Correo electrónico:	compraspezfresco@gmail.com

INFORMACIÓN DE LA MUESTRA					
Fecha de recepción: 2022-04-07					
Tipo de muestra	Descripción:	Fecha de toma de muestra	Hora de la toma	Tomadas por	Código interno
Agua Cruda	Afluente agua entrada T° de recepción: 19,3 °C	2022-04-07	N.R	N.R	390-1
OBSERVACIONES:					

RESULTADOS						
Fecha del ensayo	Ensayo	Método	Unidades	Código interno: 390-1		Rango permitido:
				Resultado	Uexp	
2022-04-07	Determinación de pH	SM: 4500–H^+ B. Método Electrométrico	UNIDADES	7,46 (22,1°C)	± 0,01	N.E
	Determinación de DBO_5	SM: 5210 B. Test 5 días DBO	mg O_2/L	2,0	N.E	N.E
	Determinación de DQO	SM: 5220 C. Método Titulométrico, Reflujo cerrado DQO	mg O_2/ L	46	N.E	N.E
2022-04-08	Determinación de Sólidos Suspendidos Totales	SM: 2540 D. Método Gravimétrico. Secados a 103 – 105°C	mg/ L	5	N.E	N.E
	Determinación de Fosforo Total	SM: 4500–P D. Método Cloruro Estañoso	mg P / L	0,13	N.E	N.E
2022-04-07	Determinación de Nitrógeno Total	SM: 4500–N_{Org} C. Método Semi-Micro–Kjeldahl	mg N-NH_3 / L	1,10	N.E	N.E

Dirección: Cra 27 No 10-02 Los Álamos – Pereira-Risaralda-Colombia- Laboratorio de Análisis de Aguas y Alimentos Edificio 8 Piso 1 y 2.
Teléfonos: Telefax: (57) (6) 321 5750 / 313 7437 / e-mail: labaguas@utp.edu.co

NIT: 891.480.035 - 9 / Código Postal: 660003 / Conmutador:(57) (6) 313 7300 / Fax: 321 3206 / Dirección: Cra 27 N° 10 - 02 Los Álamos - Pereira - Risaralda - Colombia / www.utp.edu.co
Reacreditada como Institución de Alta Calidad por el Ministerio de Educación Nacional 2013 - 2021

VICERRECTORÍA DE INVESTIGACIONES
INNOVACION Y EXTENSION
LABORATORIO DE ANALISIS DE AGUAS Y ALIMENTOS
INFORME DE ENSAYOS No 621/22

INFORMACIÓN DE LA MUESTRA					
Fecha de recepción: 2022-04-07					
Tipo de muestra	Descripción:	Fecha de toma de muestra	Hora de la toma	Tomadas por	Código interno
Agua Residual	Efluente agua salida T° de recepción: 19,3 °C	2022-04-07	N.R	N.R	390-2
OBSERVACIONES:					

RESULTADOS

Fecha del ensayo	Ensayo	Método	Unidades	Código interno: 390-2		Rango permitido:
				Resultado	Uexp	
2022-04-07	Determinación de pH	SM: 4500–H^+ B. Método Electrométrico	UNIDADES	7,10 (21,9°C)	N.R	N.E
	Determinación de DBO_5	SM: 5210 B. Test 5 días DBO	mg O_2/L	15	N.E	N.E
	Determinación de DQO	SM: 5220 C. Método Titulométrico, Reflujo cerrado DQO	mg O_2/ L	33	N.E	N.E
2022-04-08	Determinación de Sólidos Suspendidos Totales	SM: 2540 D. Método Gravimétrico. Secados a 103 – 105°C	mg/ L	12	N.E	N.E
2022-04-07	Determinación de Grasas y/o aceites	SM: 5520 D. Método Extracción Soxhlet	mg/ L	17,78	N.E	N.E
2022-04-08	Determinación de Fosforo Total	SM: 4500–P D. Método Cloruro Estañoso	mg P / L	0,05	N.E	N.E
2022-04-07	Determinación de Nitrógeno Total	SM: 4500–N_{Org} C. Método Semi–Micro–Kjeldahl	mg N-NH_3 / L	0,96	N.E	N.E

Elaboró: Betty P.

ARIEL FELIPE ARCILA Z.
Profesional I
Matrícula PQI-0181
Reviso

CARLOS HUMBERTO MONTOYA N.
Director de Laboratorio
Matrícula PQI-0177
Autorizó

Dirección: Cra 27 No 10-02 Los Álamos – Pereira-Risaralda-Colombia- Laboratorio de Análisis de Aguas y Alimentos Edificio 8 Piso 1 y 2.
Teléfonos: Telefax: (57) (6) 321 5750 / 313 7437 / **e-mail:** labaguas@utp.edu.co

OBSERVACIONES:

- El Laboratorio de Análisis de Aguas y Alimentos-UTP está autorizado por el Ministerio de la Protección Social para realizar análisis organolépticos, físicos, quimicos y microbiológicos al agua potable.
- **Los métodos utilizados en la ejecución de los ensayos para los análisis de aguas, han sido tomados del Standard Methods for The Examination of Water and Wastewater 23 RD Edition 2017".**
- Los resultados contenidos en el presente informe se refieren al momento y condiciones en que se realizaron los ensayos. El laboratorio no se responsabiliza de los perjuicios que puedan derivarse del uso inadecuado de la información aquí contenida y de las muestras analizadas.
- Los ensayos fueron realizados en las instalaciones del laboratorio de Análisis de Aguas y Alimentos, bajo sus condiciones ambientales.
- Los resultados de este informe hacen referencia única y exclusivamente a las muestras analizadas.
- Los ensayos microbiológicos son realizados por un profesional en el área.
- El informe de ensayos no podrá ser reproducido totalmente excepto cuando se haya obtenido permiso por escrito del laboratorio.
- Cuando es responsabilidad del laboratorio realizar la toma de muestra (s), se sigue el instructivo de toma de muestras. Cuando el cliente es el que toma la (s) muestra (s), el laboratorio no se hace responsable de la información suministrada; por lo tanto, los resultados se aplican a la (s) muestra (s) conforme se recibieron.
- Luego de la entrega del Informe de Ensayos, existe un espacio de tiempo máximo de 15 días hábiles para la atención de reclamos.
- **ABREVIATURAS:** N.R: No reporta - N.E: No establecido - Rango Permitido: Valor permitido dependiendo del tipo de muestra y de acuerdo a las especificaciones de la normatividad para cada matriz - Uexp: Incertidumbre expandida.

-- *FIN DEL INFORME* --

Appendix 3: Biosecurity Requirements for the Import of Trout Eggs to Colombia

Translated from documents provided in the SISPAP database of the ICA.

COLOMBIAN AGRICULTURAL INSTITUTE

ICA

QUARANTINE TECHNICAL DIRECTORATE

ZOOSANITARY REQUIREMENTS FOR IMPORTATION OF:	
Product:	EMBRYONATED TROUT EGGS
Use	RAISE AND FATTEN
Country of origin	UNITED STATES OF AMERICA (USA)
consultation date	05/25/2023 6:57:53

REQUIREMENTS

Each shipment of embryonated salmonid eggs must be accompanied by a certificate issued by the competent authority which must include:

1. Name of the exporter and full address 2. Date of issue 3. Name and location of the farm of origin 4. Date of spawning, 5. Identification of the breeding stock 6. And that it is stated that:

a) The eggs are free of the following diseases and their causative agents: Viral Hemorrhagic Septicemia (HSV), Infectious Hematopoietic Necrosis (IHN), Epizootic Hematopoietic Necrosis (EHN), Infectious Salmon Anemia (ISA), Infectious Pancreatic Necrosis (IPN) , Herpesvirus of salmon masou. For which they must attach the respective laboratory results, carried out by an official control laboratory or authorized by the Official Veterinary Service.

b) The eggs are free of the following diseases: Piscirickettsiosis (PRS), Renibacteriosis (bacterial kidney disease-BKD).

c) The area of origin is recognized by the Official Authority, in accordance with the recommendations of the OIE International Aquatic Animal Health Code, as free of these diseases.

d) In the farm of origin as well as in the breeding farm, in the last two years no causative agent of these diseases has been present. Likewise, that each reproductive (analyzed father to father) that gives rise to the eggs, has been analyzed for these diseases, not detecting any positive results.

e) The eggs are free of the following agents: Aeromonas salmonicida (furunculosis); Yersinia ruckeri (red mouth enteric disease), Gyrodactylus salaris (Gyrodactylosis), Ceratomyxa shasta and Myxobolus cerebralis (tournament disease), for which they must attach the results of bacteriological and parasitological tests carried out by an official control laboratory or authorized by the Official service f) The tournament disease has not been detected in the squad in the last two years.

g) The eggs come from the aforementioned breeders and were disinfected for 10 minutes with an iodine solution of at least 100 ppm. Immediately after spawning and 48 hours before shipment (in a maximum quantity of 2,000 eggs per litre)

h) The boxes or packages in which the eggs are transported are for first use and have been disinfected before leaving the hatchery.

Note:

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This merchandise will be used only in the establishment authorized in this document. Any abnormality or mortality that occurs during the quarantine in the crop must be reported to the ICA.

ADDITIONAL PROVISIONS: The
arrival of the merchandise must be notified 24 hours in advance to the ICA Port Health Office through which the product enters.

In those cases in which it is considered necessary, the ICA will take samples per shipment, for the corresponding laboratory analysis.

THE CERTIFICATES WILL COME IN THEIR ORIGINAL LANGUAGE AND IN SPANISH (In case translation is needed, it will be done by an officially accredited entity).

FAILURE TO COMPLY WITH ANY OF THESE REQUIREMENTS WILL PREVENT THE ENTRY OF THE PRODUCT TO THE COUNTRY.

MAVS 10/20/2008