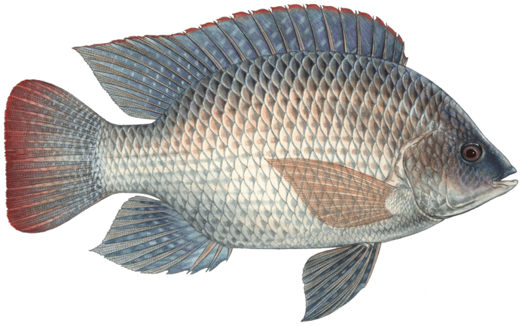
Monterey Bay Aquarium
Seafood Watch

Tilapia

Oreochromis mossambicus x Oreochromis niloticus, Oreochromis niloticus



Colombia

Ponds, Freshwater net pen

Report ID 27818
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Seafood Watch Standard used in this assessment: Aquaculture Standard v4

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.

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[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: Are well managed and caught or farmed in environmentally friendly ways.

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

Avoid/Red: Take a pass on these. These items are overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Tilapia (Nile and Red) produced in net pens and ponds in Colombia

Criterion	Score		
	Net Pens		**Ponds**
C1 Data	5.23		4.77
C2 Effluent	4.00		5.00
C3 Habitat	7.60		5.47
C4 Chemicals	4.00		4.00
C5 Feed	5.08		5.33
C6 Escapes	4.00		5.00
C7 Disease	4.00		4.00
C8X Source	0.00		0.00
C9X Wildlife	–6.00		–6.00
C10X Introduction of secondary species	–4.00		–4.00
Total	23.90		23.56
Final score (0–10)	**3.42**		**3.37**

OVERALL RATING

Final Score	3.42		3.37
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. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects a very significant impact. Two or more Red criteria, or one Critical criterion (highlighted with black background and white text) result in a Red final result.

Summary

The final numerical scores for tilapia produced in net pens and ponds in Colombia are 3.42 out of 10 and 3.37 out of 10, respectively, which are at the low end of the Yellow range. With no Red or critical criteria, the final recommendation is a “Good Alternative.”

Executive Summary

Colombia's total finfish aquaculture production in 2021 was 188,658 metric tons (mt), of which 58% or 109,421 mt was tilapia. This represents less than 1% of global tilapia production (5.61 million mt in 2020). Nearly all of Colombia's tilapia exports are consumed in the United States, where tilapia is the fourth most popular seafood group (behind shrimp, salmon, and canned tuna). The United States imported 192,414 mt of tilapia in 2021, of which 12,874 mt came from Colombia. There is a substantial domestic market for tilapia in Colombia, reflected in a dramatic increase in the annual per-capita consumption of fish from 1.7 kg to 8.8 kg between 1986 and 2020.

Two species of tilapia are produced in Colombia: Nile (or black) tilapia (*Oreochromis niloticus*) and red tilapia, a selectively bred hybrid of several species that is known as *Oreochromis* spp. There are a range of production systems, but two-thirds (66%) of the total tilapia production in Colombia occurs in ponds, with approximately one-quarter (26%) in net pens. The remainder (approximately 8%) is in tank-based recirculation or biofloc systems. Other systems, such as concrete tanks or raceways and small-scale polyculture ponds, are also present but are considered to represent a minor part of the total production.

It is of relevance to note that, of the approximately 36,000 aquaculture farms in Colombia, the majority are small (defined as "limited resource" farms; Acuicultura de recursos limitados). In contrast, production for export continues to be dominated by a small number of large companies. Tilapia production is distributed across large areas of Colombia, but net pen production is focused almost exclusively in the Betania Reservoir in the Department of Huila. Huila is also important for pond production (39% of Colombia's total aquaculture production occurs in this department) and is the focus of this assessment.

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 ponds. It should be noted that Seafood Watch also has separate recommendations for farmed tilapia certified to various assurance schemes. See 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—and 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

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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

(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 specific data, and the specific roles of additional organizations regarding aquaculture (e.g., the Ministry of Environment and Sustainable Development [Ministerio de Ambiente y Desarrollo Sostenible—MADS]) are not easy to determine. In some instances, the only available data points are from a small subset of large farms in the publicly available audit reports for international certifications such as the Aquaculture Stewardship Council. Although there is generally a greater body of information on the concentrated net pen production in the Betania Reservoir, there are few data with which to understand the typical practices of the tens of thousands of small-scale pond farms across Colombia. It is of note that FEDEACUA provided some information through direct communications, and offered to facilitate a visit to tilapia farms in Colombia. Understanding the regulatory and management system, particularly its practical implementation at small farms, remains a challenge. Although many academic studies provided useful information, many research gaps remain. Overall, the final score for Criterion 1—Data is 5.23 out of 10 for net pens, and 4.77 out of 10 for ponds.

Studies of the physical, chemical, and biological characteristics of the Betania Reservoir show that it is clearly eutrophic; although effluent wastes from the tilapia farms contribute, they do not cause it alone. Nevertheless, the industry has a history of operating above the established carrying capacity of 22,000 mt, and at more than 28,000 mt of production in 2021, it continues to do so. Thus, there is clearly a cumulative impact on the waterbody, but there does not appear to be a negative impact beyond it; i.e., the water quality in the Magdalena River downstream of the reservoir is consistently higher than upstream of it. Given the artificial nature of the reservoir, it could be argued that the impacts within it are a low environmental concern, but the decreased water quality is considered sufficient to cause fish mortalities, particularly of farmed fish, which is a higher concern. Overall, the score for Criterion 2—Effluent for net pens is a moderate score of 4 out of 10.

Without sufficient data to understand the effluent impacts (or lack thereof) of pond farms, the risk-based assessment was used. Considering the typical feed and fertilizer use, it is estimated that there is a total nitrogen input of 89.9 kg N/mt of tilapia (a similar value to that stated in an independent certification audit). After the removal of nitrogen in harvested tilapia, the total waste nitrogen produced is 68.4 kg N/mt. Approximately half of this is considered to be discharged from the ponds to the environment (34.9 kg N/mt, and a score of 6 out of 10 for Factor 2.1). Educational information produced by FEDEACUA and the government describes a comprehensive regulatory framework in place for effluent discharge permits, but there continues to be low uptake, with 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. Therefore, with low effective enforcement, the effluent management score (Factor 2.2) is low (3.2 out of 10). The scores combine to give a final score for Criterion 2—Effluent for ponds of 5 out of 10.

The Betania Reservoir continues to be the only waterbody used for large-scale tilapia production in Colombia. The habitat impacts of floating net pens in this artificial environment appear limited; yet, given their number and distribution, they are still likely to have some impacts on the remaining ecosystem services provided by the waterbody. Production in the reservoir appears to be managed according to the legality of producers and the nutrient carrying capacity of the reservoir, but the potential for tilapia 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). As a result, the score for Criterion 3—Habitat for net pens is 7.60 out of 10.

The majority of tilapia ponds in Colombia appear to have been constructed in former agricultural land, with perhaps minor impacts to dry or riparian forests and 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 tilapia aquaculture, but it does not account for habitat impacts in its defining methodology. There is now a permitting process in place for pond farms that includes land-use and forest permits; 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 quite high proportion of farms that currently do not have the necessary permits. Although 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 most ponds constructed in former agricultural land, but a low proportion of formalized farms, the score for Criterion 3—Habitat for ponds is 5.47 out of 10.

The increasing disease challenges introduce the potential for the use of veterinary medicines and treatments. Nine products are specifically listed for use in fish in Colombia: four antimicrobials, one antiparasitic treatment, two vaccines, and two hormones, but there are no readily available data with which to understand their use in Colombian tilapia farms. The only specific data points are from four audit reports for four large farms from the Aquaculture Stewardship Council, showing zero antimicrobial use. Although the use of antimicrobials or other chemicals in tilapia aquaculture in other countries may be common (e.g., China), this cannot be extrapolated to the farming situation in Colombia. The potential use of alternatives, such as vaccines, probiotics, natural remedies, and the management of environmental conditions such as decreasing stocking density of fish and water quality, must also be considered.

Although there is considerable circumstantial information available, the frequency and scale of chemical use in Colombian tilapia farms is essentially unknown regarding the specific data (or lack thereof) from the thousands of farms. Circumstantial information indicates that it cannot be assumed that the production system is dependent on chemical intervention (a score of 2 out of 10), nor can it be robustly assumed that the species or production systems have a demonstrably low need for chemical use (a score of 6 out of 10), despite the assertions of FEDEACUA and the few available data points from large farms. Therefore, the final score for Criterion 4—Chemical Use is an intermediate score of 4 out of 10 for both net pens and ponds.

Specific data on the composition of tilapia feeds are limited, but the available information indicates that fishmeal and fish oil levels are low, and the feeds are dominated by crop ingredients. Feed conversion ratios vary according to the production system and feed/fertilizer regime, but without specific details, a global average value of 1.7 was used. With an apparently high use of by-product sources of fishmeal and fish oil (from tuna fisheries), the available data indicate that the Forage Fish Efficiency Ratio (FFER) is low (0.25), meaning that, from first principles, 0.25 mt of wild fish must be caught to supply the fish oil to grow 1 mt of tilapia. Again, this value is likely to vary across farms and production systems (for example, some farms can be seen to have an FFER of zero). The source fisheries for the marine ingredients are moderately sustainable, and the Wild Fish Use score is 7.15 out of 10. Five feed company websites provide data on feed protein levels and feeding schedules, and the average weighted feed protein content over a production cycle is 27.9%, with minor variations between ponds and net pens (e.g., where tilapia are grown to a large size in net pens to produce fillets). With a whole tilapia protein content of 14% (and the eFCR of 1.7), there is a substantial net loss of protein (69.4% for ponds and a score of 3 out of 10, and 71.5% in net pens and a score of 2 out of 10). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 22.31 kg CO_2-eq kg^{-1} farmed seafood protein (score of 4 out of 10). The three scores combine to give final scores for Criterion 5—Feed of 5.08 out of 10 for net pens and 5.33 out of 10 for ponds. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Tilapia was initially introduced into Colombia for aquaculture purposes, but with active government stocking in the country’s freshwater bodies (in addition to aquaculture escapes), it became established in the 1960s, before the large-scale development of the aquaculture industry. Until recently, tilapia had been legally defined as an introduced, invasive species by the Colombian government, but new regulations in December 2015 declared Nile and red tilapia (and rainbow trout) “domesticated.” Although the new resolution recognizes the threat from additional escapes and prevents further active stocking, tilapia is considered fully established for the purposes of this assessment. Net pen aquaculture systems for tilapia carry a high risk of escape, but best practices for escape management, including the use of all male or sterile fish, are considered widespread. There are no data available on escape events in Colombia or on post-escape recaptures, but potential impacts are reduced when the species has been historically introduced and actively stocked into the environment. The final escape criterion score is based on the interaction of the risk of escape (Factor 6.1; score 2 of 10 for net pens and 4 out of 10 for ponds) and the risk of competitive and genetic interactions with wild species (Factor 6.2; score 6 of 10 for tilapia in Colombia), and results in moderate final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 5 out of 10 for ponds.

Although it is clear that pathogens and parasites have become increasingly problematic in tilapia aquaculture in Colombia as it has intensified and increased in scale, there is little recent information on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and 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. Although there is evidence of large mortality events associated with disease, this appears to be limited to intensive farms (often intensive net pen farms), and considering the dominant sector of small farms in Colombia, it is less likely that there are high disease-related infections or mortalities. 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 tilapia farms, the final score for Criterion 7—Disease for both net pens and ponds is 4 out of 10.

Tilapia strains used in aquaculture have been domesticated for decades; for example, Watanabe et al. (2002) describe the process to develop red tilapia stocks in the 1980s, along with the domestication of Nile tilapia. As noted in Criterion 6—Escapes, Resolution 228 of 2015 declared Nile tilapia and red tilapia “domesticated” in Colombia. Also, as a nonnative species, all tilapia grown in Colombia are produced in hatcheries with no use of wild broodstock or seed. Further, if any “wild” tilapia from Colombia were used as broodstock, they would not be included in the scoring of this criterion (i.e., there would not be any sustainability concerns with their capture and use). Therefore, Colombian tilapia culture is considered to be fully independent of wild fisheries for stock, and the score for the exceptional Criterion 8X is a deduction score of 0 out of –10 for both net pens and ponds.

Because of the visually attractive nature of surface-feeding tilapia (particularly red tilapia) to avian predators, interactions are to be expected. ASC audit reports provide some information on the likely species present in Colombia (including birds, otters, and crocodiles), some of which are listed as “Near Threatened” or “Vulnerable” by the International Union for the Conservation of Nature (IUCN). There are regulations in place regarding the use of predator netting, and while examples of their deployment can be found, the extent of their use across the thousands of tilapia farms in Colombia is not known. A risk of entanglement remains. Although there is minor anecdotal evidence of injuries to some animals, including vulnerable species, there are no data available with which to understand if mortalities occur, and if so, at what scale. Therefore, the extent of interactions with wildlife is largely unknown. Overall, some regulations or management measures are in place that aim to limit wildlife mortalities, but enforcement is unknown, and mortality numbers are unknown. Because of the unknown status, the final score for Criterion 9X is a precautionary deduction of –6 out of –10 for both net pens and ponds.

New species of zooplankton in the Betania Reservoir and the spread of pathogens such as tilapia lake virus are examples of unintentional introductions of nonnative species during the movements of live tilapia into and within Colombia. Although tilapia fingerlings were previously known to be shipped into Colombia from hatcheries in Ecuador, the current scale of this practice is unclear. But, the development of hatcheries in the main tilapia producing departments of Colombia is likely to have reduced this practice substantially. The importation of smaller numbers of selectively bred tilapia broodstock from breeding centers in Honduras or elsewhere likely continues, but is now accompanied by quarantine and inspection requirements at the port of entry. Although the sources of live animal movements have some potential for biosecurity (e.g., reduced or zero water exchange, along with quarantine and monitoring), the movements of tilapia into and within Colombia continue to present a risk of unintentionally introducing nonnative species. The final score for Criterion 10X—Escape of Unintentionally Introduced Species is –4 out of –10 for both net pens and ponds.

The final numerical scores for tilapia produced in net pens and ponds in Colombia are 3.42 out of 10 and 3.37 out of 10 respectively, which are at the low end of the Yellow range. With no Red or critical criteria, the final recommendation is a “Good Alternative.”

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Introduction

Scope of the analysis and ensuing recommendation

Species
Nile Tilapia—*Oreochromis niloticus*
Red Tilapia—*Oreochromis* spp.

Geographic coverage
Colombia

Production Methods
Freshwater net pens
Freshwater ponds

Species Overview

Tilapia are freshwater species of fish native to Africa (Fitzsimmons, 2011) and consist of three genera: *Oreochromis* (maternal mouthbrooders), *Sarotherodon* (paternal or biparental mouthbrooders) and *Tilapia* (substrate spawners). Tilapia are omnivorous, capable of spawning year-round, and tolerant of wide environmental fluctuations (McConnel and Lowe-McConnell 1987) (Boyd 2004) (Fitzsimmons 2007), all characteristics that make them suitable for aquaculture. Tilapia was first introduced to Colombia (for aquaculture purposes) in the 1960s (*O. mossambicus* and *O. niloticus*), with other species coming later (Daza and Parra, 2019). Production increased in the 1980s after the introduction of red tilapia, which is a hybrid of multiple species within the genus *Oreochromis*, and is commonly referred to as *Oreochromis* spp. This assessment is based on Nile (or black) tilapia (*Oreochromis niloticus*) and red tilapia (*Oreochromis* spp.), and for the purposes of this assessment, both types are mostly discussed collectively under the general name "tilapia." In Colombia, they are referred to as "mojarra."

Production statistics
According to data from the United Nations Food and Agriculture Organization (FAO), the first recorded aquaculture harvests of tilapia in Colombia occurred in the early 1970s. By the turn of the century, production was approaching 20,000 metric tons (mt), and continued to grow, reaching 49,893 mt in 2010 (Figure 1). Production has approximately doubled again over the last decade to 100,959 mt in 2020 (FishstatJ, 2022). The 2021 total finfish production was 188,658 mt, of which 58% or 109,421 mt was tilapia (data provided by pers. comm., Cesar Pinzon, FEDEACUA, September 2022).

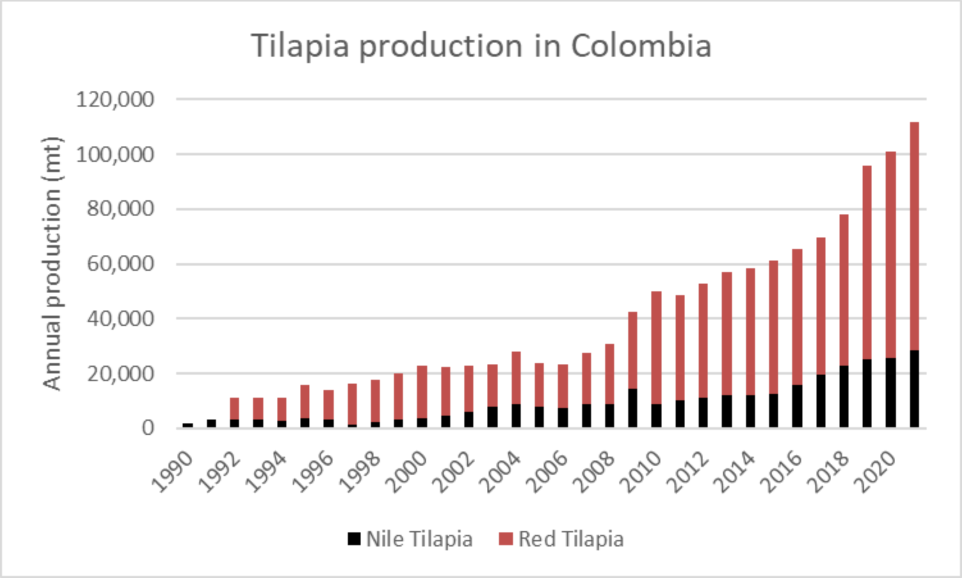

Figure 1: Annual tilapia production in Colombia from 1990 to 2021. Data from 1990 to 2020 from FAO FishstatJ, and for 2021 from FEDEACUA (pers. comm., 2022).

FAO data also show that global production of tilapia reached 5.61 million mt in 2020, with the largest producers at that time being China (1.24 million mt), Indonesia (1.07 million mt), and Egypt (0.84 million mt). Colombia is the thirteenth-largest producer with less than 1% (0.89%) of global production, based on 2020 data.

Of Colombia's total finfish production of 188,658 mt in 2021, 58% was tilapia, with 19% cachama (*Piaractus brachypomus* and *Colossoma Macropomum*), 16% rainbow trout (*Onchorynchus mykiss*) and 7% "other" (data provided by pers. comm., Cesar Pinzon, FEDEACUA, September 2022). The Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural—MADR) reports aquaculture harvests of finfish from 30 departments, but by far the most dominant is the southern central department of Huila, with approximately 39% of finfish production (2021 data) (Figure 2). As discussed below, Huila is the almost exclusive source of tilapia for export from Colombia.

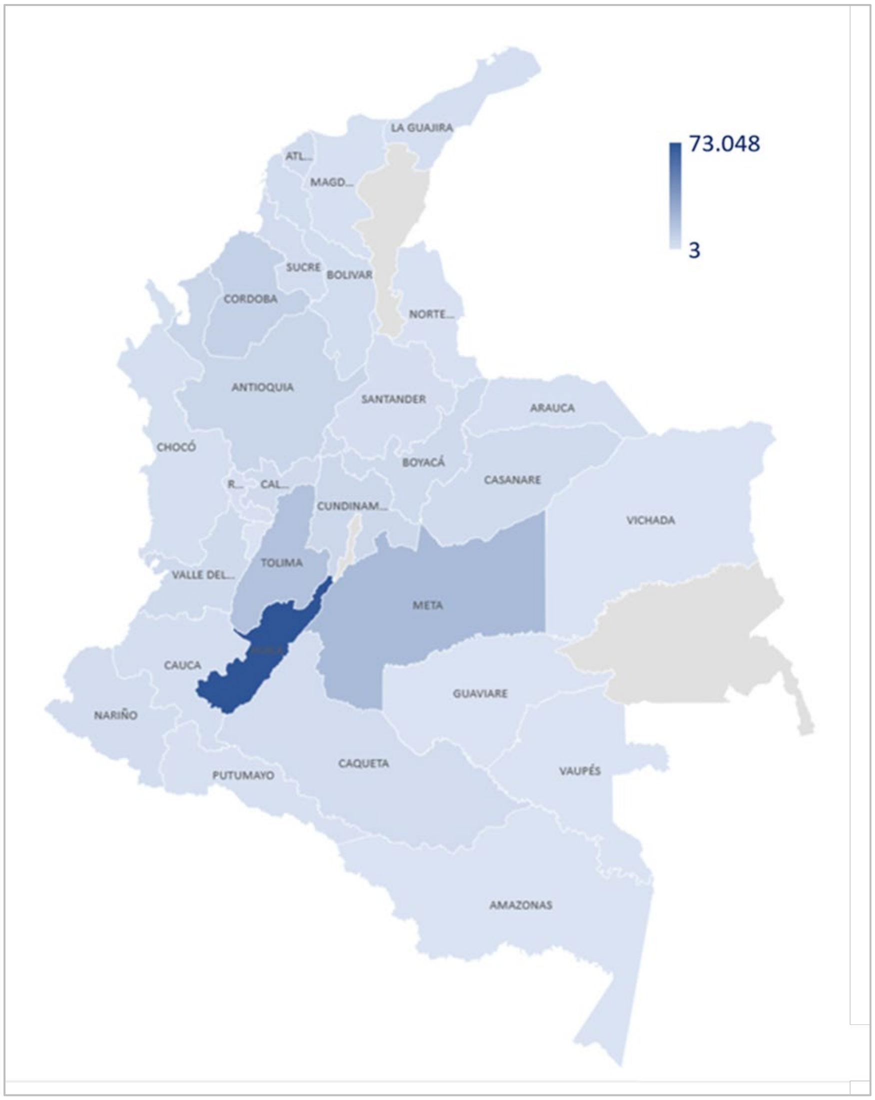

Figure 2: Production of finfish in Colombian departments. The color shade indicates the scale of production in metric tons per the map legend. The total production in Huila was 73,048 mt (in 2021) compared to 20,813 mt in Meta and 17,156 mt in Tolima. Image reproduced from FEDEACUA (pers. comm., 2022).

It must be noted that Colombia does not maintain detailed farm-level production records for its approximately 36,000 aquaculture farms (Unidades de Producción de Acuicultura), and the above production figures are based on estimates made by FEDEACUA according to feed use data from feed companies and farm surveys of feed use and production (Cesar Pinzon, FEDEACUA, September 2022). Both AUNAP and FEDEACUA are working to increase the number of fully registered (or "formalized") farms, but the costs to small farmers are substantial (FEDEACUA, 2018a) (Roca-Lanao et al., 2021) (see Factor 2.2b in Criterion 2—Effluent).

It is of relevance to note that of the approximately 36,000 aquaculture farms in Colombia, the majority are small; for example, a 2011 survey of aquaculture farms in Colombia showed that over 26,000 were designated as "limited resource" farms (Acuicultura de recursos limitados), meaning subsistence farmers, and nearly 3,000 were micro- or small business farms. Only 245 were medium or large farms (AUNAP 2014).

Import and export statistics

Tilapia is the fourth most popular seafood group in the United States[4] (behind shrimp, salmon, and canned tuna), and the U.S. imported 192,414 mt of tilapia in 2021 (NOAA Fisheries, 2022). Colombia was the source of 12,505 mt of U.S. tilapia imports in 2021 (12,874 mt according to NOAA), and Figure 3 shows how this amount has varied since the year 2012 (MADR, 2022). Exports to the United States from Colombia began increasing after the signing of the United States–Colombia Trade Promotion Agreement in 2006 (NMFS 2015). Figure 3 shows that the total export is a relatively minor component of the total tilapia production in Colombia, and there is a substantial domestic market reflected in an increase in the annual per-capita consumption of fish from 1.7 kg to 8.8 kg between 1986 and 2020 (Clavijo-Lopez et al., 2022).

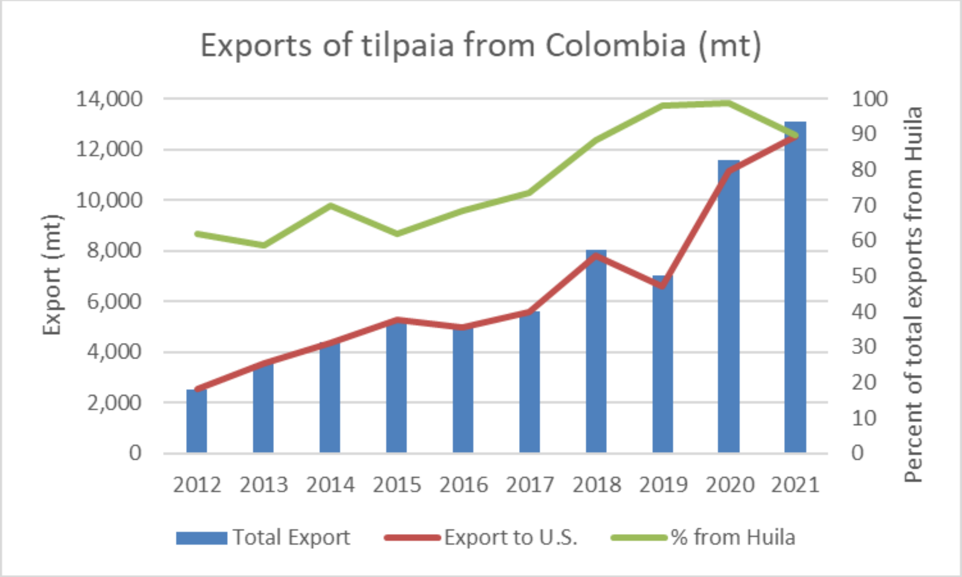

Figure 3: Annual exports of tilapia from Colombia. Blue bars show the total annual tilapia export from Colombia. The red line shows the amount exported to the United States. The green line (on the secondary right y-axis) shows the percentage of exports produced in Huila. Data from MADR.

Nearly all Colombian tilapia exports go to the United States (red line in Figure 3); in 2021, 95.6% of the total Colombia tilapia export was consumed in the United States. Tilapia exports are primarily produced in the Department of Huila (see green line in Figure 3 and secondary y-axis), with an average of 95.4% of tilapia exports between 2019 and 2021. The dominance of the Department of Huila in export markets can also be seen in certifications to the Global Seafood Alliance Best Aquaculture Practices (BAP), of which there were 27 farms certified in 2021 and 25 were in Huila. Nine hatcheries were also certified to BAP, all in Huila. Similarly, all four companies certified to the Aquaculture Stewardship Council (ASC) are in Huila.[5]

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[4] National Fisheries Institute Top 10 list for Seafood Consumption. Accessed August 22, 2022. https://aboutseafood.com/about/top-ten-list-for-seafood-consumption/

[5] www.asc-aqua.org

Colombia's 12,505 mt of export is the third-largest source of tilapia on the United States seafood market, but is dwarfed by imports from China of 129,423 mt in 2021 (NOAA Fisheries, 2022). Nevertheless, as discussed in the "Product Form" section below, it is an important source of fresh tilapia (as opposed to frozen).

Table 1: Scientific and market names

Scientific Name	*Oreochromis* spp.
Common Name	Tilapia
Spanish	Mojarra
French	Tilapia du Nil
Japanese	Chikadai or Izumidai

Product forms

Because of its proximity and short flight time to the United States, Colombia has primarily exported fresh tilapia to the U.S. market; in 2021, 97% of exports to the U.S. were fresh and 3% frozen. In 2021, 62% of Colombia's tilapia imports to the U.S. (by weight) were of fillets, and 38% were whole fish.

Production systems

According to FEDEACUA (pers. comm., 2022), two-thirds (66%) of the total tilapia production in Colombia occurs in ponds, with approximately one-quarter (26%) from net pens and the remainder (approximately 8%) from tank-based recirculation or biofloc systems. These figures match those that can be estimated from data in MADR (2020), Carrera-Quintana et al. (2022), and Camero-Escobar and Calderón-Calderón (2018). Other systems such as concrete tanks or raceways and small-scale polyculture in ponds also are present, but considered to be a minor part of total production (Carrera-Quintana et al., 2022).

There are considerable differences in these proportions of production from different systems for the international export market versus the domestic market; i.e., 70% of production for export is produced in net pens and 30% in ponds (FEDEACUA, pers. comm., 2022). The Betania Reservoir in Huila (created by damming the Magdalena River in the mid-1980s (GEO 2012)) is the primary net pen production site for tilapia, and particularly for exports (Carrera-Quintana et al., 2022) (Camero-Escobar and Calderón-Calderón, 2018) (Pulido et al., 2015). Despite 63 apparently suitable freshwater lakes and reservoirs, and efforts from the industry to expand into others, the Betania Reservoir continues to be the only significant lentic waterbody used for net pen tilapia[6] production in Colombia (SAC, 2021).

Although the net pen production is dominated by a small number of large companies, approximately 80% of tilapia production in Colombia comes from small farms, mainly the many thousands of small pond farms (FEDEACUA, pers. comm., 2022). Of the large companies, 28 are

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[6] A small number have been developed for net pen trout production.

certified under the Best Aquaculture Practices scheme (BAP[7]) (of which 27 form 4 clusters or farm groups) and 4 companies are certified to the Aquaculture Stewardship Council (ASC[8]).

According to Carrera-Quintana et al. (2022), there are four main sectors. The first is traditional subsistence farming, using family labor for personal consumption. The second sector concerns small-scale farms producing approximately 10 to 20 mt for local markets. The third sector consists of small and medium farms producing between 20 mt and 240 mt per year, who usually rent processing plants (from large producers) to supply the domestic markets. Lastly are large farms producing more than 240 mt per year, mainly fresh tilapia for export to North America or for the domestic market.

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[7] https://www.bapcertification.org/

[8] www.asc-aqua.org

Analysis

Scoring guide

- With the exception of the exceptional factors (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.seafoodwatch.org/-/m/sfw/pdf/standard%20revision%20reference/2015%20standard%20revision/mba_seafoodwatch_aquaculture%20criteria_final.pdf?la=en
- The full data values and scoring calculations are available in Appendix 1

Criterion 1: Data Quality and Availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

C1 Data Category	Data Quality	
	Net Pens	Ponds
Production	5.0	5.0
Management	5.0	2.5
Effluent	7.5	5.0
Habitat	7.5	5.0
Chemical Use	2.5	2.5
Feed	5.0	5.0
Escapes	5.0	5.0
Disease	5.0	5.0
Source of stock	10.0	10.0
Wildlife mortalities	2.5	2.5
Introduction of secondary species	2.5	2.5
C1 Data Final Score (0–10)	**5.23**	**4.77**

Brief Summary

Data availability in Colombia has improved, with increasing amounts of information available from a variety of sources–particularly the government—and 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 specific data, and the specific roles of additional organizations regarding aquaculture (e.g., the Ministry of Environment and Sustainable Development [Ministerio de Ambiente y Desarrollo Sostenible—MADS]) are not easy to determine. In some instances, the only available data points are from a small subset of large farms in the publicly available audit reports for international certifications such as the Aquaculture Stewardship Council. Although there is generally a greater body of information on the concentrated net pen production in the

Betania Reservoir, there are few data with which to understand the typical practices of the tens of thousands of small-scale pond farms across Colombia. It is of note that FEDEACUA provided some information through direct communications, and offered to facilitate a visit to tilapia farms in Colombia. Understanding the regulatory and management system, particularly its practical implementation at small farms, remains a challenge. Although many academic studies provided useful information, many research gaps remain. Overall, the final score for Criterion 1—Data is 5.23 out of 10 for net pens and 4.77 out of 10 for ponds.

Justification of Ranking

Industry or Production Statistics

The governmental organization responsible for aquaculture in Colombia 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[9]) provides a layer on Google Maps of the location of aquaculture production units (UPAs[10]) in Colombia. The map provides the specific locations of each unit and the species produced. An example of the UPAs (for all species) in the Department of Huila is shown in Figure 4 and an example of the detail in Figure 5.

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

[10] Aquaculture production units; Unidades de Producción de Acuicultura (UPAs).

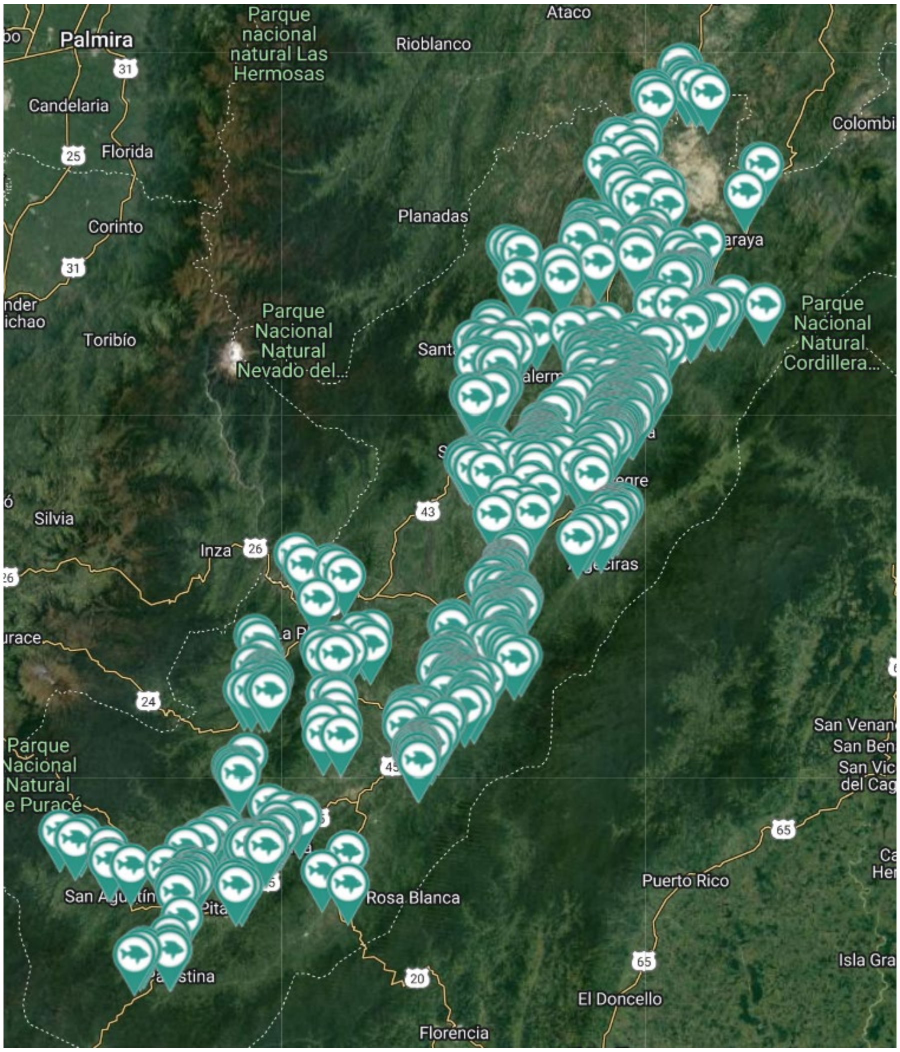

Figure 4: Screenshot of the SEPEC Google Map application showing location information for all UPAs in the Department of Huila only. Note these are for all aquaculture species.

Figure 5: Screenshot of the SEPEC Google Map application showing examples of individual UPA tags.

Although there are clearly thousands of UPAs listed on the SEPEC map, it is not clear if all aquaculture operations are shown; for example, Roca-Lanao et al. (2021) document annual efforts to survey and document thousands of UPAs, which to date have surveyed over 8,000 farms but much less than the estimated total of approximate 36,000. Similarly, the government also operates the "General Registry of Fisheries and Aquaculture" (El Registro General de Pesca Y Acuicultura—RGPA[11]), which provides a list of aquaculture facilities with cultivation permits, but it includes only approximately 480 operations. Therefore, although much detailed information is available, uncertainties remain regarding the number, location, and characteristics of the tilapia farms in Colombia. Nevertheless, since 2019, the annual SEPEC survey reports (e.g., Roca-Lanao et al., 2021) have provided useful information on the production characteristics of the sampled farms.

Regarding production quantities, the primary source of data in Colombia is the Ministry of Agriculture and Rural Development (MARD; Ministerio de Agricultura y Desarrollo Rural), particularly its quarterly bulletins[12] published through the Management and Performance Information System for Chain Organizations (Sistema de Información de Gestión y Desempeño de las Organizaciones de Cadenas—SIOC), which include national and departmental production of each species in addition to various figures on export and certification. Despite this, it must be noted that Colombia does not have a robust reporting system for aquaculture production, and

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[11] RGPA COLOMBIA | Registro Nacional de Barcos Pesqueros

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

according to the industry trade body (Federación Colombiana De Acuicultores—FEDEACUA), the 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, MARD, or FAO are considered to be estimates only. Nevertheless, they give a useful indication of the scale of production and trends. The FAO FishstatJ database does provide annual production data for Nile and red tilapia, but the sources of these figures also seem 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 tilapia farms. Overall, there are robust transparency efforts regarding industry production characteristics, but they continue to be hampered by large numbers of poorly documented farms. The data score for Industry or Production Statistics is 5 out of 10.

Management and Regulations

FEDEACUA has good information documenting and listing the regulatory structures in Colombia; for example, FEDEACUA and AUNAP have produced a series of booklets[13] 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[14] [15]). As is typical of regulatory documentation, understanding the practical implementation of the various resolutions and their supporting legislation is challenging. Similarly, the specific roles (regarding aquaculture) of the Directorate of Territorial Environmental Planning and National Environmental System (Dirección de Ordenamiento Ambiental Territorial y Sistema Nacional Ambiental—SINA[16]) within the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS[17]) is unclear, as is the relevance of the National Authority for Environmental Licenses (Autoridad Nacional de Licencias Ambientales—ANLA[18]) 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.[19] Overall, the data score for Management and Regulations is 5 out of 10.

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

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

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

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

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

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

[19] https://www.fedeacua.org/page/revista

Effluent

For net pens in the Betania Reservoir, estimates of the annual production (from Carrera-Quintana et al., 2022; MARD; and FEDEACUA) can be compared to the carrying capacity established by Lizarazo et al. (2005). The ongoing validity of the carrying capacity was confirmed by the Regional Autonomous Corporation of Alto Magdalena (La Corporación Autónoma Regional del Alto Magdalena—CAM[20]) (pers. comm., J. Ortez Cuellar, CAM, November 10, 2022). A series of academic studies (Carrera and Daza, 2021; Martinez-Silva, 2015; Martinez-Silva et al., 2016; and Martinez-Silva et al., 2018) clearly establish the nutrient status of the reservoir. Water quality monitoring by the Instituto de Hidrología, Meteorología y Estudios Ambientales—IDEAM[21] is useful to identify the impacts of the effluent beyond the reservoir. Overall, the data score for Effluent in net pens is 7.5 out of 10.

For ponds, the IDEAM water quality data are less useful, and CAM reported that there was no specific monitoring of tilapia farms (pers. comm., J. Ortez Cuellar, CAM, November 10, 2022). Therefore, there are no specific data with which to understand effluent impacts (or the lack thereof) of ponds. Thus, feed conversion ratios (e.g., from Tacon et al., 2022), and fertilizer inputs (e.g., from Green, 2022) allow the nutrient inputs to be estimated, and the value can be compared to a similar value in an ASC audit report (ASC 2021d). The educational booklets from FEDEACUA[22] comprehensively describe the regulatory systems in place, and FEDEACUA (2018, 2022) help understand the uptake of permits in the enforcement aspect. Therefore, the Effluent data score for ponds is 5 out of 10.

Habitat

For net pens, the establishment of production solely in the Betania Reservoir is confirmed by Carrera-Quintana et al. (2022), SAC (2021), and GEO (2012), and the net pens can easily be seen on satellite images (e.g., Google Earth). The artificial nature and heavily modified ecosystem services of the reservoir can be established from Fialho et al. (2021) and Valenti (2021). Information on management measures is primarily linked to Fisheries and Aquaculture Management Plans (Plan de Ordenamiento Pesquero y Acuícola—POPA) from AUNAP, but information on permitting is available from FEDEACUA (2018a). Although fully understanding the habitat impacts of the floating net pens in an artificial reservoir remains a challenge, the data score for Habitat for net pens is 7.5 out of 10.

For ponds, the Google Map layer from SEPEC[23] (examples in Figure 4 and 5 above) and the historic image function of Google Earth Pro are both quite useful to understand the location and former habitats of pond farms. But, the useability is challenged by the sheer number of farms and the lack of a database format. Studies such as Ricaurte et al. (2017) provide some useful information on land-use change regarding wetlands. Regulatory oversight from the Agricultural Rural Planning Unit (Unidad de Planificación Rural Agropecuaria—UPRA), particularly the formulation of species-specific zoning maps of suitability for aquaculture

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[20] https://cam.gov.co/

[21] http://www.ideam.gov.co/web/entidad

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

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

development, is available,[24] and educational information for farmers on land and forestry permits are available from FEDEACUA (e.g., FEDEACUA, 2018a). The data score for Habitat for net pens is 5.0 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). The only specific data points are the annual audit reports of four large companies certified to the Aquaculture Stewardship Council (ASC[25]). Information on the regulatory measures is available from the Colombian Agricultural Institute (Instituto Colombiano Agropecuario—ICA[26] [27]). The ICA also has a list of registered veterinary products[28] from which those for fish, and tilapia specifically, can be extracted. This list was also obtained directly from ICA (pers. comm., Anonymous, 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[29]), but there do not appear to be any data of relevance to aquaculture. A request for information did not receive a response. Overall, the data score for Chemical Use is 2.5 out of 10 for net pens and ponds.

Feed

Five feed companies in Colombia (see Criterion 5—Feed for web links) provide varying but generally minor amounts of technical information on their feeds. The protein content is well represented. One company provides an image of a feed bag from which an ingredient list can be seen and translated. Other examples of feed formulations can be found in academic feed experiments, but their applicability to commercial feeds in Colombia is uncertain. Some feed conversion ratio data can be obtained from independent audit reports of a small number of large farms from the Aquaculture Stewardship Council (ASC[30]), but the global average value from Tacon et al. (2022) is considered the most representative. Useful information on fishmeal and fish oil inclusion levels, the use of by-products, and the source fisheries can be obtained from ASC audit reports. By confirming the feed brands used, it can be seen that the feeds used by certified farms are the primary commercial brands from the feed companies; therefore, the information is applicable to larger numbers of farms beyond the few associated with the audit reports. Nevertheless, some uncertainty remains in the applicability of the available information to the many small farms in Colombia. Overall, the data score for Feed is 5 out of 10.

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[24] Available from Metadata Catalog—UPRA "Aptitud para el cultivo comercial de tilapia plateada y el híbrido rojo en estanques de tierra. Febrero 2018"

[25] https://www.asc-aqua.org/find-a-farm/

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

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

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

[29] https://www.agrosavia.co/

[30] www.asc-aqua.org

Escapes

General academic references establish the fundamental risks of escape from aquaculture systems, but there are no specific data on escape events from net pens or pond farms in Colombia. Resolution 2879 of 2017 lays out the requirements that must be met by aquaculture establishments to minimize the risk of escape, but it is not known how extensively this is enforced. IDEAM[31] provides maps of flood risk and of previous flooding events, but given the wide distribution of tilapia farms, the maps' specific relevance to the risk of tilapia escape is uncertain. Regarding the invasiveness of tilapia, the history of the introduction and establishment in Colombia is documented (e.g., Pullin et al., 1997; Caraballo 2009; FAO-INCODER 2011; Carrera-Quintana et al., 2022). Overall, despite a lack of specific escape data, the circumstantial evidence gives a moderate understanding of the ongoing risk. The data score for Escapes is 5 out of 10.

Disease

There is a substantial global literature on diseases in farmed tilapia, and there are some useful studies in Colombia (e.g., the review by Pulido, 2019 or Bacharach et al., 2016); however, practical information on the occurrence and severity of disease outbreaks (e.g., mortality rates) is limited. The ICA (and FDEACUA) provide information on biosecurity best-management practices[32] (including a certification scheme) in Colombia, but there are no data on their rate of implementation. Similarly, information is not available on the uptake of vaccines for important pathogens such as *Streptococcus*. Although the incidence of disease is likely to vary by production system and intensity, there is little information with which to quantify this. Some academic studies in Colombia have shown the potential for pathogens to influence wild populations (e.g., Camus et al., 1998; Iregui 2004). With substantial general (global) information on tilapia diseases, but limited specific and ongoing information from Colombia, the data score for the Disease criterion is 5 out of 10.

Source of Stock

It has been established for many decades that the tilapia used in aquaculture is domesticated and no longer relies on wild caught broodstock or fry to supply the needs of hatcheries, nurseries, and grow-out farms. For example, 20 years ago, Watanabe et al. (2002) describe the domestication of Nile tilapia and the development of the red tilapia strains that occurred in the 1980s. Information on the official designation of tilapia as a "domesticated" species in Colombia is available in the resolution (Resolution 228 of 2015). Thus, the data score for the 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, but the relevance to current practices is clearly unknown. There are no farm-level records of wildlife mortalities for the

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

[32] https://www.fedeacua.org/files/bioseguridad_acuicola.pdf

production system and location of interest. Some information on typical species of relevance is available from ASC audit reports (e.g., ASC, 2021c), from which checks can be made against the IUCN Red List, but these few examples cannot be considered relevant to the thousands of farms in Colombia. Some information and visual examples of the use of predator nets are available, but again cannot be extrapolated to typical practices. The data availability score for Wildlife Mortalities is 2.5 of 10.

Escape of Unintentionally Introduced Species

Examples of nonnative species introductions during live fish movements in Colombia are available in Martinez-Silva (2018) and Aich et al. (2021). Various anecdotal reports provide some information on potential live fish movements into and within Colombia, including the status of domestic hatchery production, but they are far from conclusive (Villaneda, 2007) (Welling, 2015) (Acuicultores, 2016) (Rojas, 2020). Also, SAC (2019) provides some basic information on the quarantine requirements for the import of live fish into Colombia, but official information from the government or their various resolutions is not readily available. The data score for the Escape of Unintentionally Introduced Species is 2.5 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—and 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 specific 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. In some instances, the only available data points are from a small subset of large farms in the publicly available audit reports for international certifications such as the Aquaculture Stewardship Council. Although there is generally a greater body of information on the concentrated net pen production in the Betania Reservoir, there are few data with which to understand typical practices of the tens of thousands of small-scale pond farms across Colombia. It is of note that FEDEACUA provided some information through direct communications, and offered to facilitate a visit to tilapia farms in Colombia. Understanding the regulatory and management system, particularly its practical implementation at small farms, remains a challenge. Although many academic studies provided useful information, many research gaps remain. Overall, the final score for Criterion 1—Data is 5.23 out of 10 for net pens and 4.77 out of 10 for 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 and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.
- Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.
- Principle: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Net Pens

Effluent Evidence-based assessment

C2 Effluent Final Score (0–10)	4	Yellow

Ponds

Effluent Risk-based assessment

C2 Effluent parameters	Value	Score
F2.1a Waste (nitrogen) production per of fish (kg N ton^{-1})	68.4	
F2.1b Waste discharged from farm (%)	51.0	
F2.1b Boundary adjustment (0–1)	0.0	
F2.1 Waste discharge score (0–10)		6
F2.2a Content of regulations (0–5)	4	
F2.2b Enforcement of regulations (0–5)	2	
F2.2 Regulatory or management effectiveness score (0–10)		3.2
C2 Effluent Final Score (0–10)		**5**
Critical?	No	Yellow

Brief Summary

Studies of the physical, chemical, and biological characteristics of the Betania Reservoir show that it is clearly eutrophic; although effluent wastes from the tilapia farms contribute, they do not cause it alone. Nevertheless, the industry has a history of operating above the established carrying capacity of 22,000 mt, and at more than 28,000 mt of production in 2021, it continues to do so. Thus, there is clearly a cumulative impact on the waterbody, but there does not appear to be a negative impact beyond it; i.e., the water quality in the Magdalena River downstream of the reservoir is consistently higher than upstream of it. Given the artificial nature of the reservoir, it could be argued that the impacts within it are a low environmental concern, but the decreased water quality is considered sufficient to cause fish mortalities, particularly of farmed fish, which is a higher concern. Overall, the score for Criterion 2—Effluent for net pens is a moderate score of 4 out of 10.

Without sufficient data to understand the effluent impacts (or lack thereof) of pond farms, the risk-based assessment was used. Considering the typical feed and fertilizer use, it is estimated that there is a total nitrogen input of 89.9 kg N/mt of tilapia (a similar value to that stated in an independent certification audit). After the removal of nitrogen in harvested tilapia, the total waste nitrogen produced is 68.4 kg N per mt. Approximately half of this is considered to be discharged from the ponds to the environment (34.9 kg N/mt, and a score of 6 out of 10 for Factor 2.1). Educational information produced by FEDEACUA and the government describes a comprehensive regulatory framework in place for effluent discharge permits, but there continues to be low uptake, with 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. Therefore, with low effective enforcement, the effluent management score (Factor 2.2) is low (3.2 out of 10). The scores combine to give a final score for Criterion 2—Effluent for ponds of 5 out of 10.

Justification of Ranking

With sufficient data and information to understand the nutrient dynamics of tilapia aquaculture in net pens in Betania Reservoir, the evidence-based assessment has been used. But, with limited information on the impacts (or lack of impacts) from pond effluents, the risk-based assessment has been used. These are assessed separately below.

Effluent: Net Pens

The Betania Reservoir was formed by damming the Magdalena and Yaguara Rivers, and it had an initial depth of 91 meters and an area of approximately 7,400 hectares (Martinez-Silva et al., 2018). According to Carrera-Quintana et al. (2022), 15% of the total Colombian finfish aquaculture production occurs in net pens in the reservoir, and with a 2021 total finfish production of 188,658 mt finfish (pers. comm., Cesar Pinzon, FEDEACUA, September 2022), this percentage equals approximately 28,448 mt.

Figure 6 shows a screenshot from the SEPEC map layer of aquaculture production units (UPAs) in the reservoir, and the intensive nature of the industry there is apparent. The industry grew rapidly (Carrera and Daza, 2021), and its operation results in the loss of soluble nutrients to the water column and an increase in sedimentation of uneaten feed and fecal particles that adds to the sediment transported into the lake from the rivers (Carrera-Quintana et al., 2022). According to FEDEACUA's series of educational booklets for fish farmers,[33] a discharge permit is not required in Huila 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).

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

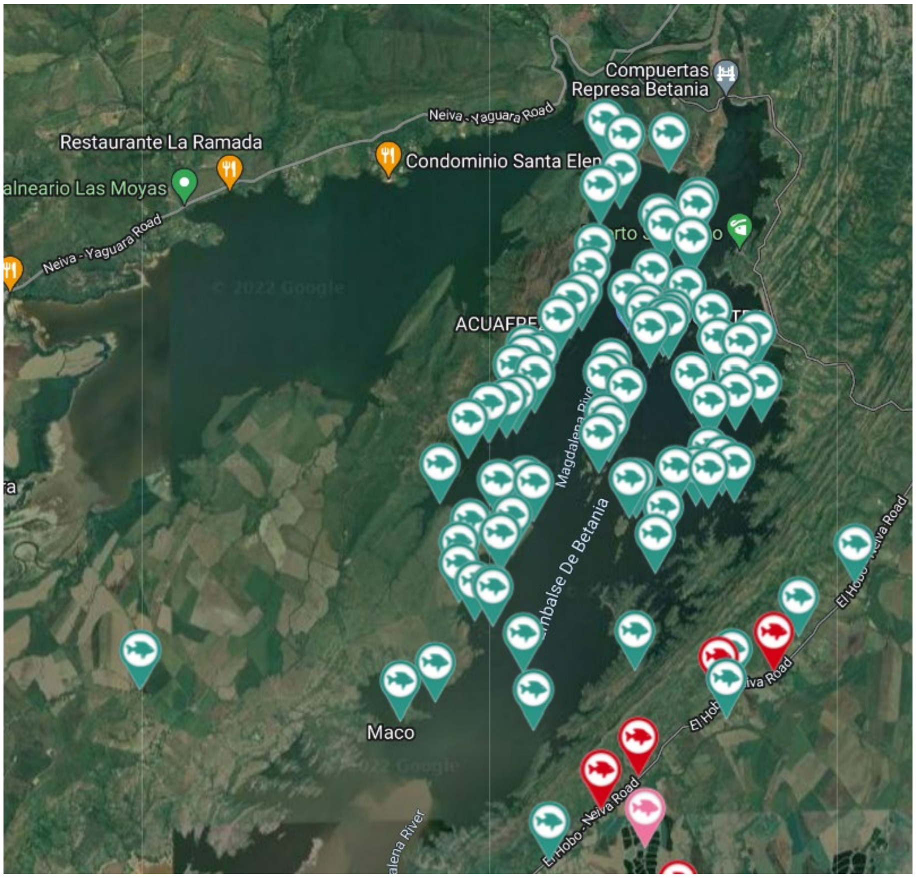

Figure 6: Screenshot from the SEPEC layer in Google Maps showing aquaculture production units (UPAs) in the Betania Reservoir. Note that there are no UPAs in the Yaguara river side of the reservoir (i.e., the northeastern area of the lake above). Grey UPAs are ongrowing (fattening) sites, red UPAs are breeding/nurseries, and pink are both ongrowing and breeding sites. Image reproduced from SEPEC.

The point when the natural purification rate of the water body becomes insufficient to maintain equilibrium (also known as the carrying capacity) is the initiation of the process of eutrophication (Carrera and Daza, 2021). According to the Ministry of Agriculture and Rural Development (MADR), the carrying capacity of the reservoir to support aquaculture activities has previously been established at 22,000 mt of production (Lizarazo et al., 2005). In 2014, the National Aquaculture Plan (Plan Nacional para el Desarrollo de la Acuicultura Sostenible en Colombia) stated that the production volumes had widely exceeded the 22,000 mt maximum culture load capacity. The Regional Autonomous Corporation of Alto Magdalena (CAM) confirmed that 22,000 mt continues to be the working value for the reservoir's capacity (pers. com., J. Ortez Cuellar, CAM, November 2022), but it appears (from the estimated production of 28,448 mt) that the capacity of the lake is still being exceeded. Therefore, it would be expected that there are negative impacts to the water quality of the lake due to tilapia aquaculture.

In a recent study, Carrera and Daza (2021) assessed the physio-chemical characteristics of the water quality in the Betania Reservoir. The results from two areas of the waterbody (i.e., the eastern arm of the reservoir area fed by the Magdalena River that includes tilapia farms, and the northwestern arm, fed by the Yaguara River, without aquaculture) can tentatively be used to indicate the impacts of aquaculture. Carrera and Daza (2021) had nine sampling locations, as shown in Figure 7; the results for four relevant parameters (oxygen saturation,[34] ammonia,[35] nitrite,[36] and transparency[37]) are shown in Figure 8. The results show that the dissolved oxygen concentration is higher in the two sampling locations in the Yaguara arm of the reservoir, whereas ammonia and nitrite are higher at the locations near aquaculture. The transparency results are variable (and likely dominated by natural sedimentation from the rivers supplying the lake; e.g., the sediment plume from the Magdalena River can be seen at the bottom of Figure 6, close to sampling location 5).

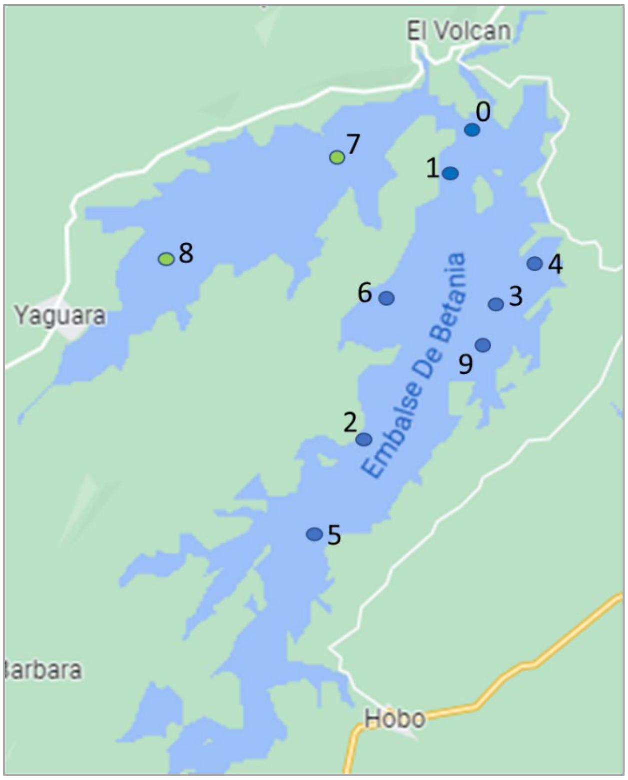

Figure 7: Map of the sampling stations used by Carrera and Daza (2021). Base map reproduced from Google Earth.

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[34] Expected to decrease with intensive aquaculture due to consumption by the fish.

[35] Expected to increase with intensive aquaculture as a result of excretion from fish.

[36] Expected to increase with intensive aquaculture as ammonia is broken down.

[37] Expected to decrease with intensive aquaculture as particulate wastes increase and plankton production increases.

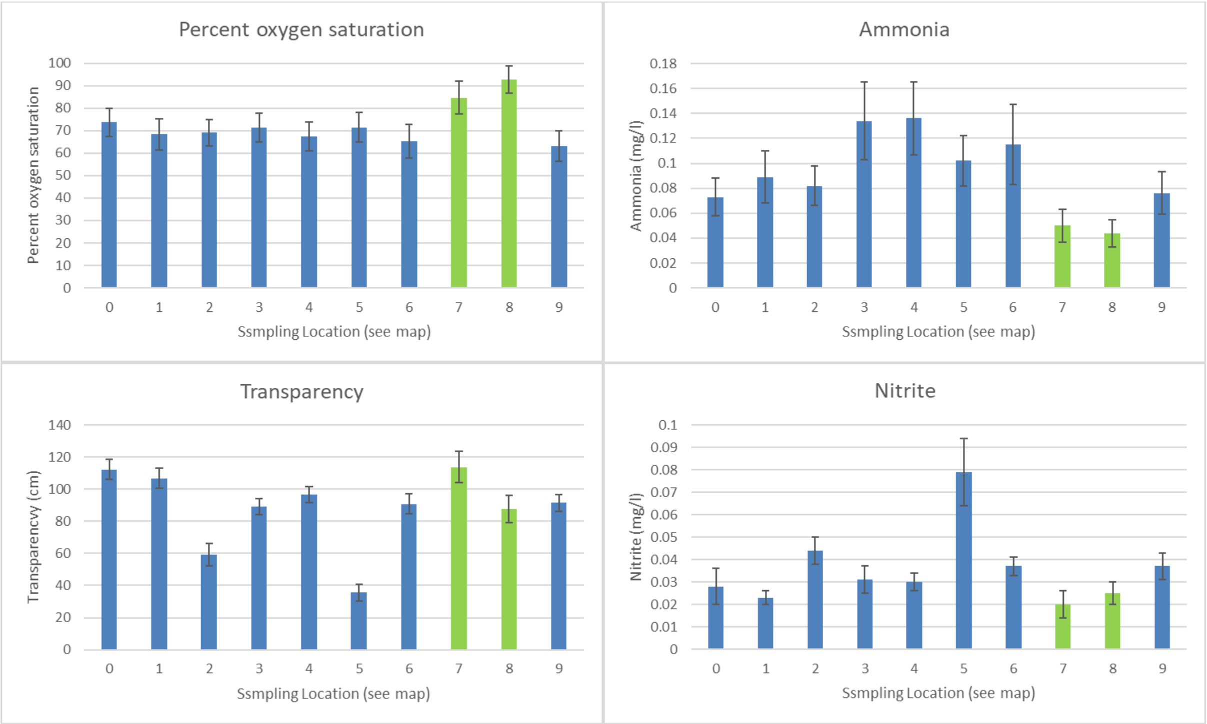

Figure 8: Water quality monitoring results for four parameters measured at nine locations in the Betania Reservoir. Green bars show the sampling locations in the northeastern Yaguara arm of the reservoir (see Figure 7). Data reproduced from Carrera and Daza (2021).

Three aspects of this recent study are important to emphasize. First, the differences between the two arms of the reservoir may be due to natural differences other than the presence of tilapia farms in the Magdalena River side of the reservoir. Second, although it is to be expected that the presence of intensive tilapia farms would affect the water quality of the reservoir, the differences seen in Figure 8 cannot be assumed to be acceptable versus unacceptable regarding the water quality of the lake. Third, there are other sources of nutrients in the lake, such as the river input and agricultural runoff. Although these recent results from Carrera and Daza (2021) do not demonstrate an unambiguous case of eutrophication, they support the findings of earlier studies (discussed below) that were much clearer in their conclusions on the eutrophic status of the reservoir.

Martinez-Silva (2015), Martinez-Silva et al. (2016), and Martinez-Silva et al. (2018) showed that the most abundant species of phytoplankton and zooplankton found in the reservoir were indicative of eutrophic conditions. According to Martinez-Silva et al. (2016), water quality has incrementally decreased over time, and Martinez-Silva et al. (2018) stated that the lake had been in a eutrophic condition for “some years.” These studies describe an enormous discharge of wastes into the reservoir and a high concentration of organic matter, which lead to changes in planktonic communities (including toxin-producing species), low oxygen availability, and mortalities of wild and farmed fish. Overproduction and poor water quality in the lake were two of several potential factors indicated in large fish mortality events in March and April 2015[38] (Pulido et al., 2015).

But, it is important to note that the tilapia farms are not the sole source of nutrient wastes, and Martinez-Silva et al. (2018) conclude that the eutrophic state is caused mainly by the nutrient inputs of the crops and livestock surrounding the reservoir and the fish farming activities that take place in its interior. Nevertheless, Carrera and Daza (2021) note that the rapid growth of aquaculture caused accelerated eutrophication in certain areas of the dam, and the most worrying thing (in their opinion) is that the environmental authorities lack the appropriate control tools. According to the local environmental authority (CAM, 2017), the overproduction and significant environmental impacts were a thing of the past, and efforts are being made to balance the tonnage of production with the carrying capacity of the lake. From the estimated >28,000 mt of production in 2021 compared to the 22,000 mt carrying capacity, it appears this has not yet been achieved.

Given the apparently clear status of eutrophication of the Betania Reservoir and the significant role that net pen tilapia farms play, it must also be considered if this reduction in water quality causes impacts beyond the waterbody; i.e., downstream in the Magdalena River. According to Salgado et al. (2022), water pollution is an emerging threat of significant concern in the Magdalena River, though little evidence is available to quantify this. Salgado et al. (2022) consider the Magdalena River basin to be a woefully understudied ecosystem compared to other similarly sized rivers worldwide, but state that the pollution is a straightforward consequence of a direct discharge of domestic and industrial sewage, and runoff of nutrients and chemicals from agriculture, mining, and oil activities in the Magdalena. Despite the lack of readily available and detailed monitoring data with which to confirm it, Salgado et al. (2022) consider the nitrogen and phosphorus biogeochemical cycles to be completely disrupted, with widespread, uncontrolled application of nitrogen and phosphorous fertilizers as well as pesticides in agriculture.

Regarding the nutrient discharges from the Betania Reservoir, it is important to note that in the upper basin of the Magdalena River, the city of Neiva is responsible for the first significant river pollution discharge (Salgado et al., 2022). Neiva is to the north (i.e., downstream) of the Betania Reservoir, and therefore the discharge from the reservoir is apparently not a significant source of pollution in this context (i.e., according to the study of Salgado et al., 2022).

The Institute of Hydrology, Meteorology and Environmental Studies (Instituto de Hidrología, Meteorología y Estudios Ambientales—IDEAM[39]) is responsible for water quality monitoring in Colombia, and the National Reference Network for Water Quality is made up of 160 monitoring points, from which approximately 40 water quality variables are analyzed. In the Magdalena River, there are 18 points on the main channel and 22 in tributaries; however, the sampling

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[38] Several other potential causes were also noted, including rancid diets, viral agents, high ambient temperatures and low dissolved oxygen, and other opportunistic pathogens

[39] http://www.ideam.gov.co/web/entidad

frequency appears to be low, with two sampling occasions per site per year.[40] IDEAM provides a variety of maps and data outputs from this monitoring.[41] Although data from individual parameters are available, the Water Quality Index (Índice de calidad del agua—ICA) provides an aggregated value (from 0 to 1) based on six basic physicochemical variables.[42] The sampling locations include one approximately 6 miles upstream of the Betania Reservoir (Paso de Colegio, Gigante, –75.57°, 2.46°) and one approximately 3 miles downstream of the dam (La Esperanza, Palermo, –75.4°, 2.73°). The IDEAM results for the Water Quality Index for these two locations are shown in Figure 9, and show that in the years sampled, the water quality was almost always higher downstream of the dam (except for 2019, when it was marginally worse; 0.01 index points). The results show that the water quality upstream of the reservoir has mostly been in the "Regular" category, while downstream has been in the higher "Acceptable" category, but in the last three data years from 2018 to 2020, both have been in the "Acceptable" category.

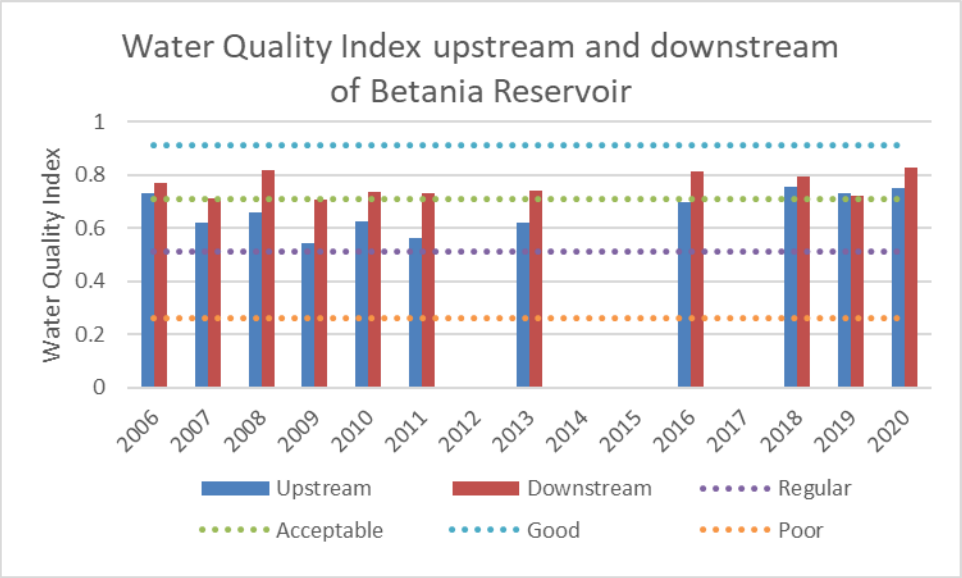

Figure 9: Comparison of the Water Quality Index at a location upstream of the Betania Reservoir, and downstream. Dotted lines represent categorical thresholds: Poor is from 0.26 to 0.50, Regular is from 0.51 to 0.70, Acceptable is from 0.71 to 0.90, and Good is from 0.91 to 1.0 (below 0.25 is Very Poor).

Considering this portion of the Magdalena River compared to the rest of its journey northward, Figure 10 shows that the upper region around Betania Reservoir (to the left of the graph) has Acceptable water quality, but it deteriorates with greater human influence downstream, particularly with the inflow of the Bogotá River carrying the waste of the nation's capital city (labelled Aporte rio Bogotá in Figure 10).

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[40] http://www.ideam.gov.co/web/agua/mapas

[41] E.g., http://sirh.ideam.gov.co/Sirh/faces/observatorioSuperficiales.jspx and http://www.ideam.gov.co/web/ecosistemas/agua

[42] Dissolved oxygen, total suspended solids, chemical oxygen demand, electrical conductivity, hydrogen potential, and total nitrogen/total phosphorus ratio.

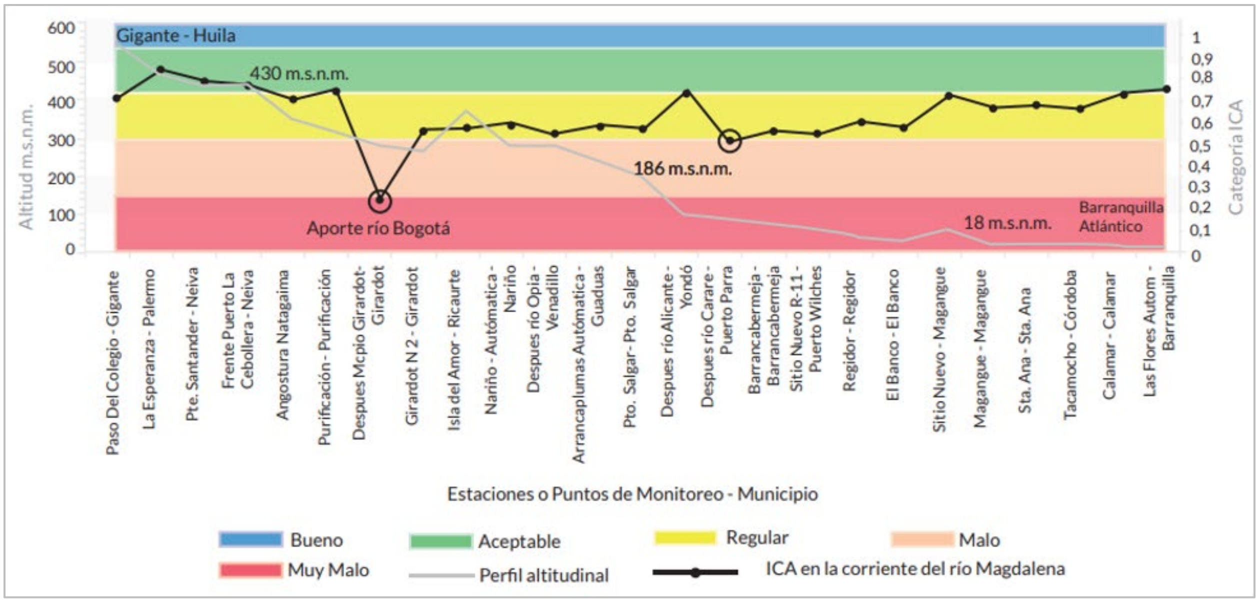

Figure 10: Water Quality Index results (black line, ICA: right vertical axis) for the Magdalena River. The Betania Reservoir is between Paso Del Colegio and Las Esperanza at the left end of the graph. Note the inflow of the Bogotá River (Aporte rio Bogotá). The altitude of the river is shown by the grey line (left vertical axis). Color bands represent categories of water quality. Graph reproduced from IDEAM.

Conclusions and Final Score: Net Pens

Studies of the physical, chemical, and biological characteristics of the Betania Reservoir show that it is clearly eutrophic; although effluent wastes from the tilapia farms contribute, they do not cause it alone. Nevertheless, the industry has a history of operating above the established carrying capacity of 22,000 mt, and at more than 28,000 mt of production in 2021, it continues to do so. Thus, there is clearly a cumulative impact on the waterbody, but there does not appear to be a negative impact beyond it; i.e., the water quality in the Magdalena River downstream of the reservoir is consistently higher than upstream of it. Given the artificial nature of the reservoir, it could be argued that the impacts within it are a low environmental concern, but the decreased water quality is considered sufficient to cause fish mortalities, particularly of farmed fish, which is a higher concern. Overall, the score for Criterion 2—Effluent for net pens is a moderate score of 4 out of 10.

Effluent: Ponds

With the dispersion of pond farms over a large area in Colombia (compared to the concentrated net pen production in Betania Reservoir), the IDEAM water quality monitoring is of limited use in understanding the effluent impacts from thousands of small tilapia farms. For example, using the example of the Department of Huila, which has the largest aquaculture production in the country, Figure 11 shows the average of all sampling locations each year. The best water quality in most years is just into the “Acceptable” category, but there is considerable variation, and the potential for localized impacts is not addressed. Without data that more closely reflect the impacts (or lack of impacts) of pond-based tilapia farms, the evidence-based assessment (Factors 2.1 and 2.2) must be used.

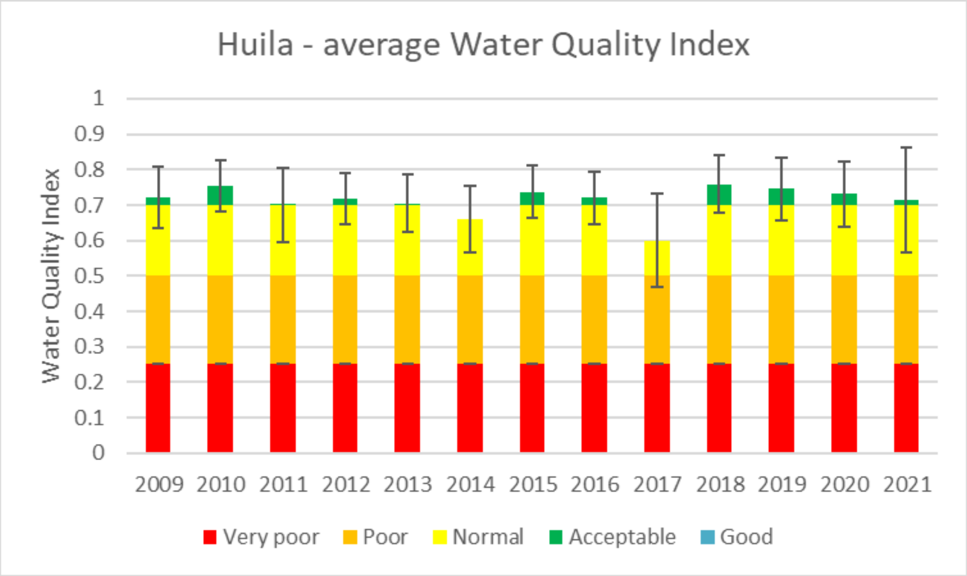

Figure 11: Average water quality index of all sampling locations in the Department of Huila. Error bars show standard deviation. Data from IDEAM.

Factor 2.1—Waste Discharged per ton of Fish

Factor 2.1a: Biological waste production per ton of fish

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 harvested fish). It is noted that phosphorous may be a more important limiting nutrient in freshwater systems.

As discussed in Criterion 5—Feed, the global average economic feed conversion ratio (eFCR) of 1.7 from Tacon et al. (2022) is the most applicable here, and the weighted average feed protein content for ponds is 27.0%. Also included here are nutrient inputs in the form of fertilizer, which is used to enhance the natural productivity of ponds. Green (2022) notes that tilapia can consume natural food organisms throughout its life cycle, but it is common to use targeted fertilization to sustain early growth of stocked juveniles until the transition to compound or complete formulated feed is required for continued rapid growth. Specific information on fertilizer use in tilapia farms in Colombia is limited. Technical information from one of the feed companies (Solla) describes the typical pond preparation process, where phosphate (16:20:0—N:P:K) or urea (46:0:0) fertilizer is added to the pond substrate before filling. The quantity of fertilizer is not mentioned. Echeverry-Castañeda and Herrán-Ruiz (2019) describe the use of organic (cattle, poultry, or pig manure) and inorganic (urea, superphosphate) fertilizers, but again, the quantities are not mentioned. In a review of fertilizer use in aquaculture, Green (2022) notes that there is little published research on optimizing chemical fertilizer applications in fertilizer-feed production systems.

Green (2022) provides examples showing a range of fertilizer uses, with weekly applications for the first 80 days of production of approximately 28 kg/ha, which when combined with typical yields in Colombia, provide an estimated average of 17.5 kg N/mt of production. Therefore, the total nitrogen input (feed multiplied by the eFCR plus the fertilizer) is calculated to be 90.8 kg N per mt of production. This estimate is quite similar to the total nitrogen input values of 89.9 kg N/mt for a large pond farm in an ASC audit report (ASC, 2021b). For nitrogen outputs, the protein content of a whole harvested farmed tilapia is 14% (Boyd 2007), and this equals 22.4 kg N per mt (because protein is 16% nitrogen). The nitrogen waste produced by the fish is therefore 68.4 kg N/mt.

Factor 2.1b: Production System Discharge

The amount of this waste that is discharged is affected by a variety of natural processes in the ponds, in addition to any water treatment, and particularly the water exchange rate. The national water study of 2018 (IDEAM, 2018) 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) range from 5% to 50% per day. But, the same study noted some discussion on the water use parameters and noted that, according to the experience of FEDEACUA and AUNAP, the water exchanges in species such as tilapia are quite scarce, with an estimate of 5% or less.

In their detailed analysis of the water footprint of three aquaculture species in Colombia, Rincon et al. (2017) show that tilapia had a low direct water footprint (i.e., the amount of water consumed directly in the production of the product) compared to cachama (*Colossoma macropomum*) and rainbow trout (*Oncorhynchus mykiss*). Figure 12 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 an indicator of the water exchange; with the more common use of high-exchange and flow-through production systems (e.g., raceways), 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).

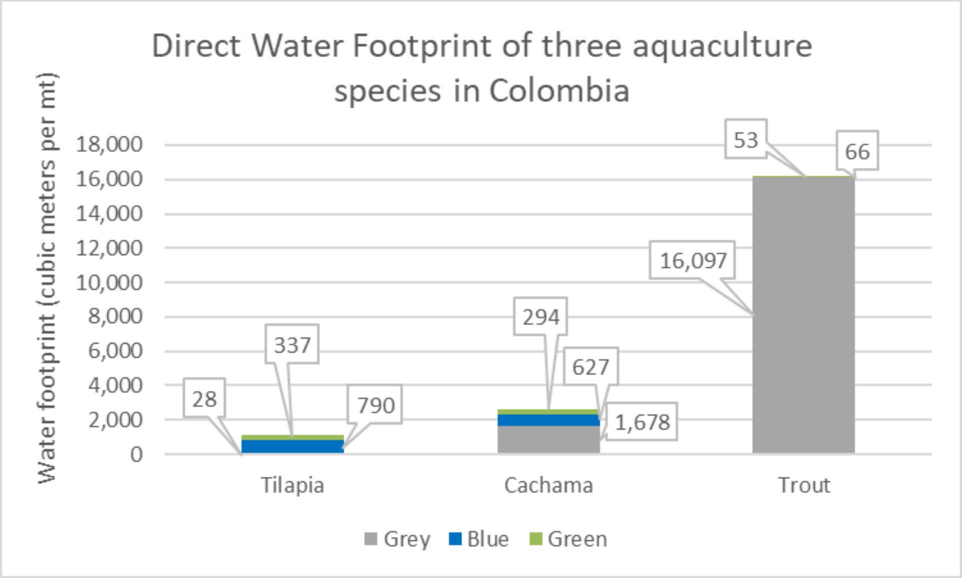

Figure 12: Comparison of the direct water footprint of three aquaculture species in Colombia. Grey bars represent the volume of water required to dilute the effluent loads, which is an indicator of water exchanges. Blue bars represent the volume of fresh water collected from surface or underground sources that evaporates in the production or is incorporated in the product, and green bars represent the volume of water from precipitation that 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)

Although these numbers do not relate directly to a daily percentage water exchange value needed here, the study by Rincon et al. (2017) supports the conclusion that the water exchange in tilapia ponds in Colombia is low. It is also acknowledged that some pond farms use reservoirs and treatment ponds and operate with minimal water discharges to the environment beyond the farm (ASC, 2021d). Considering the >3% or <3% scoring threshold in the Seafood Watch standard, and the “5% or less” estimate in the 2018 National Water Study, the typical daily exchange rate used in this assessment is >3%.

Regarding water treatment before discharge, it is likely that some large farms have reservoirs and treatment ponds that can be used before discharge (e.g., ASC, 2021d), but it is also likely that the large majority of small farms in Colombia do not have sufficient pond area to achieve this. Therefore, no adjustments are made for the routine use of settling ponds. Similarly, there is no information with which to understand typical practices to dispose of settled particulate wastes in the form of pond sludge. According to Daza and Parra (2019), some fish farms have begun to use part of their effluents to irrigate pastures or crops (e.g., for cattle or rice crops), but they also note that there are few investigations and data with which to assess the scale of this practice. Therefore, the basic adjustment of 0.51 for ponds exchanging an average of >3% per day is used here (which means that 51% of the waste produced by the fish is considered to be discharged). With the biological waste production of 68.4 kg N/mt from Factor 2.1a above, this means that 34 kg N/mt is considered to be discharged from the ponds. This equals a score of 6 out of 10 for Factor 2.1.

Factor 2.2—Management of Farm-Level and Cumulative Impacts

Factor 2.2a: Content of effluent management measures

In their efforts to educate farmers and increase the level of formalization in Colombia, FEDEACUA has produced a series of booklets[43] 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.[44] The broader formalization process also requires a livestock registration for each aquaculture production unit with the Colombian Agricultural Institute (ICA) (specifically, 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[45]) 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 from FEDEACUA (2018c) that the process for obtaining a discharge permit is comprehensive. 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 8 of FEDEACUA, 2018c). Permits are considered and granted by the regional environmental authorities; for example, in Huila, this is the Regional Autonomous Corporation of Alto Magdalena—CAM. 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.

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

[44] 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).

[45] https://rgpacolombia.gov.co

Colombia also has a Directorate of Territorial Environmental Planning and National Environmental System (Dirección de Ordenamiento Ambiental Territorial y Sistema Nacional Ambiental—SINA[46]) within the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS[47]), but the specific role of SINA (or MADS) regarding aquaculture is not readily transparent from their publicly available information (website).

As discussed previously (examples in Figures 11, 10, and 9), IDEAM, in cooperation with the regional environmental authorities (e.g., CAM in Huila), 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). This is considered to provide feedback to discharge permits regarding the consideration of cumulative impacts from other aquaculture producers, but also other industries and municipal wastes. But, this process is not readily transparent. Overall, although the uptake of this system by the thousands of tilapia 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 well-intended and comprehensive. With some uncertainties regarding the incorporation of cumulative impacts from other industries, the score for Factor 2.2a: Content of effluent management measures is 4 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 highly 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 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[48]), but information relating to aquaculture does not appear to be readily available.

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 (e.g., the series of educational booklets[49] and other promotional activities) are a big

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

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

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

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

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, although a list of farms in the RPEA does not appear to be readily available, the RGPA lists only 478 farms (accessed October 12, 2022).[50] Nevertheless, the ICA can also be seen to be active in promoting the formalization of farms in various departments (e.g., in Cauca in 2019[51] and Cordoba in 2018[52]). The fisheries statistical service (SEPEC[53]) 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.

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 (e.g., CAM in Huila). 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 number 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. Using the terminology, it is clear that the large majority of farms are "informal"; however, even though the formalization process is required for legal operation 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

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[50] https://rgpacolombia.gov.co/

[51] https://www.ica.gov.co/noticias/producers-aquaculture-competitiveness-valley

[52] https://www.ica.gov.co/noticias/ica-registro-predios-acuicolas-bioseguros-cordoba

[53] "Information System of the Colombian Fishing Statistical Service" (Sistema de Información del Servicio Estadístico Pesquero Colombiano—SEPEC).

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 is 2 out of 5 for ponds. Factors 2.2a and 2.2b combine to give a low final score for Factor 2.2—Management of Farm-Level and Cumulative Impacts of 3.2 out of 10.

Conclusions and Final Score: Ponds

Without sufficient data to understand the effluent impacts (or lack thereof) of pond farms, the risk-based assessment was used. Considering the typical feed and fertilizer use, it is estimated that there is a total nitrogen input of 89.9 kg N/mt of tilapia (a highly similar value to that stated in an independent certification audit). After the removal of nitrogen in harvested tilapia, the total waste nitrogen produced is 68.4 kg N per mt. Approximately half of this is considered to be discharged from the ponds to the environment (34.9 kg N/mt, and a score of 6 out of 10 for Factor 2.1). Educational information produced by FEDEACUA and the government describes a comprehensive regulatory framework in place for effluent discharge permits, but there continues to be a low uptake, with 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 progress is slow. Thus, with low effective enforcement, the effluent management score (Factor 2.2) is 3.2 out of 10 for ponds. The scores combine to give a final score for Criterion 2—Effluent of 5 out of 10 for ponds.

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)		9		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)		**7.60**		**5.47**
Critical?	No	Green	No	Yellow

Brief Summary

The Betania Reservoir continues to be the only waterbody used for large-scale tilapia production in Colombia. The habitat impacts of floating net pens in this artificial environment appear limited; yet, given their number and distribution, they are still likely to have some impacts on the remaining ecosystem services provided by the waterbody. Production in the reservoir appears to be managed according to the legality of producers and the nutrient carrying capacity of the reservoir, but the potential for tilapia 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). As a result, the score for Criterion 3—Habitat for net pens is 7.6 out of 10.

The majority of tilapia ponds in Colombia appear to have been constructed in former agricultural land, with perhaps minor impacts to dry or riparian forests and 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 tilapia aquaculture, but it does not account for habitat impacts in its defining methodology. There is now a permitting process in place for pond farms that includes land-use and forest permits; 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 quite high proportion of farms that currently do not have the necessary permits. Although 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 quite low proportion of formalized farms, the score for Criterion 3—Habitat for ponds is 5.5 out of 10.

Justification of Ranking

Factor 3.1—Habitat Conversion and Function

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. Although the 2014 National Plan document is readily available, understanding the practical results of the plan over the last 8 years is more challenging to determine. The situations for net pens and ponds are discussed separately below.

Net Pens

The Betania Reservoir is almost exclusively the location of net pen tilapia production in Colombia (Carrera-Quintana et al. 2022) (SAC, 2021). The dam was constructed on the Magdalena River for hydroelectricity production in 1987 (GEO 2012). According to Salgado et al. (2022), large dam projects pose one of the main threats to aquatic biodiversity in tropical rivers, with far-reaching effects on their ecological integrity and biodiversity. MADS (2012) notes that Colombia has 33 dams and reservoirs that cover 56,042 hectares, equivalent to 6% of the lentic bodies of the country. MADS (2012) also notes that the transformations caused by damming and the subsequent flow regulation of rivers and flood plains have impacts on the life cycles of aquatic species, whose populations may go through dangerous fluctuations that jeopardize their survival: specifically, the loss of populations of migratory species, the reduction of fish resources in important stretches of the rivers, and negative effects on ecological systems located in lowlands and flood plains.

For example, the populations of native migratory species such as bocachico (*Prochilodus magdalenae*), which is endemic to the Magdalena-Cauca basin and of economic importance for the artisanal fishery (Landinz-Garcia et al., 2020), have been seriously affected by the physical migratory obstructions of dams (such as Betania) on the Magdalena River (Fontalvo et al., 2018). Given the profound change caused by damming the river for hydropower and the subsequent “artificial” nature of the waterbody, the additional habitat impacts of floating net pens on its surface appear minor. For example, Fialho et al. (2021) and Valenti (2021) consider such reservoirs to be highly modified artificial environments, so the impacts produced by aquaculture are not directly on the natural environment. Nevertheless, the addition of large numbers of net pens (e.g., in the Betania Reservoir; Figure 13) must still be considered in relation to the modified ecosystem services subsequently provided by the reservoir.

Figure 13: Large numbers of net pens in the central area of the Betania Reservoir. Image reproduced from Google Earth.

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 (McKindsey, 2011). But, the applicability of this study to net pens in tropical freshwater reservoirs is tenuous. Given the extensive coverage of net pens across large areas of the reservoir (Figure 13), the most likely impact appears to be on access and use of the reservoir for purposes other than tilapia farming (e.g., tourism). Therefore, considering the artificial nature of the reservoir, the physical presence of large numbers of floating net pen tilapia farms is reasoned to have some impact on the ecosystem services of the lake, but only a minimal one. Thus, the score for Factor 3.1—Habitat Conversion and Function for net pens is 9 out of 10.

Ponds

The map of aquaculture production units (UPAs) in Colombia (from SEPEC[54]) shows that tilapia production is widespread in the west and north of the country. As noted in the Introduction, the Department of Huila in central Colombia dominates the country's aquaculture production by quantity. Detailed data on farm sizes, their date of construction, or their former habitat types are not available. There is clearly a wide range of farm sizes; for example, Figure 14 shows a large tilapia farm in northern Huila, and Figure 15 shows an agricultural farm with two small tilapia ponds. From a visual perspective of farms in the SEPEC map layer, it can be seen that the majority of the listed UPAs are small or very small, with only one or two small ponds visible.

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

Figure 14: An example of a large tilapia farm in Northern Huila, with many large ponds. The yellow line shows a scale of 1 mile. Image reproduced from Google Earth.

Figure 15: Example of a small UPA with two small ponds. The yellow line shows a scale of 0.1 mile. Image reproduced from Google Earth.

Given the lack of formal records or data on the specific types of former habitats in which tilapia 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 tilapia UPAs. Farms were selected randomly at a high level from the SEPEC map layer throughout Colombia (i.e., randomly selecting from the markers shown in Figure 4 for Huila). Where SEPEC identified the UPA as a tilapia producer, and where the resolution of the Google Earth images allowed sufficient visualization,[55] the former habitats of 50 farms were recorded.[56] 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. An example is shown in Figure 16, where it can be seen that some small areas of forest, including riparian forest, have been altered, but the main area of the ponds was previously agricultural land. The results of the sample showed that 68% of farms were in former agricultural land, with 20% in dry scrub, 8% in forests, and 4% in wetlands or riparian forest.

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[55] In some instances, the necessary resolution was limited to more recent satellite images, so the sample is likely biased toward farms that have been built since 2000, compared to before that time.

[56] Note that the SEPEC map layer does not identify farms by name or attribute any identification to them, other than the species produced.

Figure 16: Example of a tilapia UPA with ponds constructed in former agricultural land. Image A is from 2009 and Image B is from 2020. The riparian forest has largely been maintained. Images reproduced from Google Earth.

For reference, the large farm in Figure 15 can be seen to have been constructed sometime after 2014 (with expansion continuing to 2020), primarily in former agricultural fields and grazing land, but also some scrub and forest. Despite this farm's riparian location, the initial ASC audit report for this farm (from 2017) states that no wetlands were converted for the farm or are present within 5 km (ASC, 2017).

The SEPEC map also shows that tilapia farms (and UPAs for other species) in Colombia are dispersed. That is, though there may be groups of farms in any one area or region, there are no large areas of adjoining farms (unlike what might easily be seen in Google Earth for shrimp farms in Southern Vietnam, for example). Although this does not negate any concern regarding the total combined pond area or contributions to habitat fragmentation, it further supports a conclusion that the construction of dispersed ponds in already modified agricultural landscapes is unlikely to have a substantial cumulative impact.

Ricaurte et al. (2017) studied the perceived importance of a suite of potential drivers of land-use change and habitat loss in Colombia, particularly for 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 17 shows that inland aquaculture was perceived to be a relatively low driver of wetland land-use change and habitat loss.

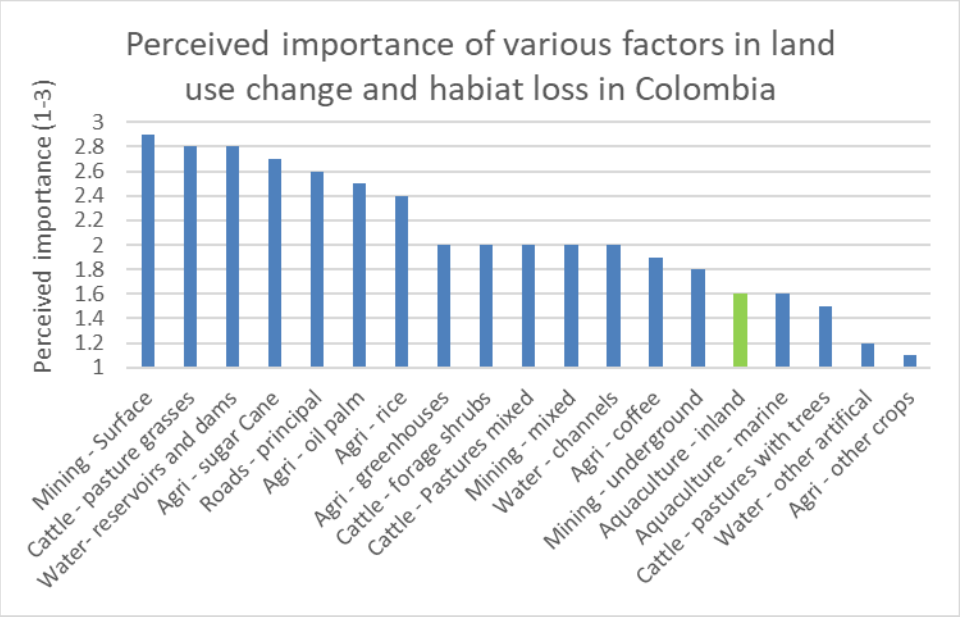

Figure 17: Perceived importance of various drivers of change in land-use and habitat loss regarding wetland ecosystem services in Colombia. Inland aquaculture is highlighted in green. Data from Ricuarte et al. (2017).

From the random survey of farms from satellite images, the “average” or “typical” tilapia farm in Colombia appears to be built on 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). Therefore, considering the results of Ricaurte et al. (2017) in addition to the ability to study a sample of farms from satellite images, and with some application of precaution given the minimal amount of formal data, tilapia farms are considered to be maintaining the functionality of the ecosystems in which they were constructed, but with moderate impacts. Therefore, the score for Factor 3.1a for ponds is 7 out of 10.

Factor 3.2a—Content of Habitat Regulations

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 highly limited regarding aquaculture. The success of the 2018 to 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[57] (accessed in October 2022).

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 Huila, this is the Regional Autonomous Corporation of Alto Magdalena—CAM). FEDEACUA (2016) noted that, of 47 existing reservoirs and lagoons in Colombia, only 4[58] have POPAs, but they considered at least 19 additional bodies of water in Colombia to have fish farming potential because of their 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 6 years later in 2022, the Betania Reservoir remains the only waterbody used for net pen tilapia production (pers. comm., Cezar Pinzon, FEDEACUA, September 2022).

Each net pen farm occupying a reservoir, or any other body of water, must have a permit from CAM (FEDEACUA, 2018a), but the management of the numbers of net pens and the scale of production in Betania appears to be focused primarily on the carrying capacity of the reservoir to assimilate nutrient wastes from the farms. Given the artificial nature of the reservoir, there are not expected to be specific management measures or regulations regarding habitat impacts of the floating net pens. Therefore, regarding the apparent process to limit and/or manage the development of net pen tilapia farming in other waterbodies in Colombia through the POPA process, 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 3.1a—Content of Habitat Regulations is 4 out of 5 for net pens.

Ponds

As will be discussed in Factor 3.2, the primary challenge with understanding the regulatory system for 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).

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

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

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 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 Huila, this is CAM. 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[59]) within the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible—MADS[60]), 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 tilapia farming in Colombia[61]—specifically, the "suitability for the commercial cultivation of silver tilapia *Oreochromis niloticus* and the red hybrid *Oreochromis sp.* [sic] in excavated ponds whose production is destined for human consumption." 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 suitability map for tilapia (Figure 18) appears to be based primarily on a previous national aquaculture zoning process conducted in 2013 (AUNAP, 2013), and defines detailed areas according to five suitability categories (high, medium, low, not suitable, and legally excluded) based on biophysical and socioeconomic factors.

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

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

[61] Available from Metadata Catalog - UPRA "Aptitud para el cultivo comercial de tilapia plateada y el híbrido rojo en estanques de tierra. Febrero 2018."

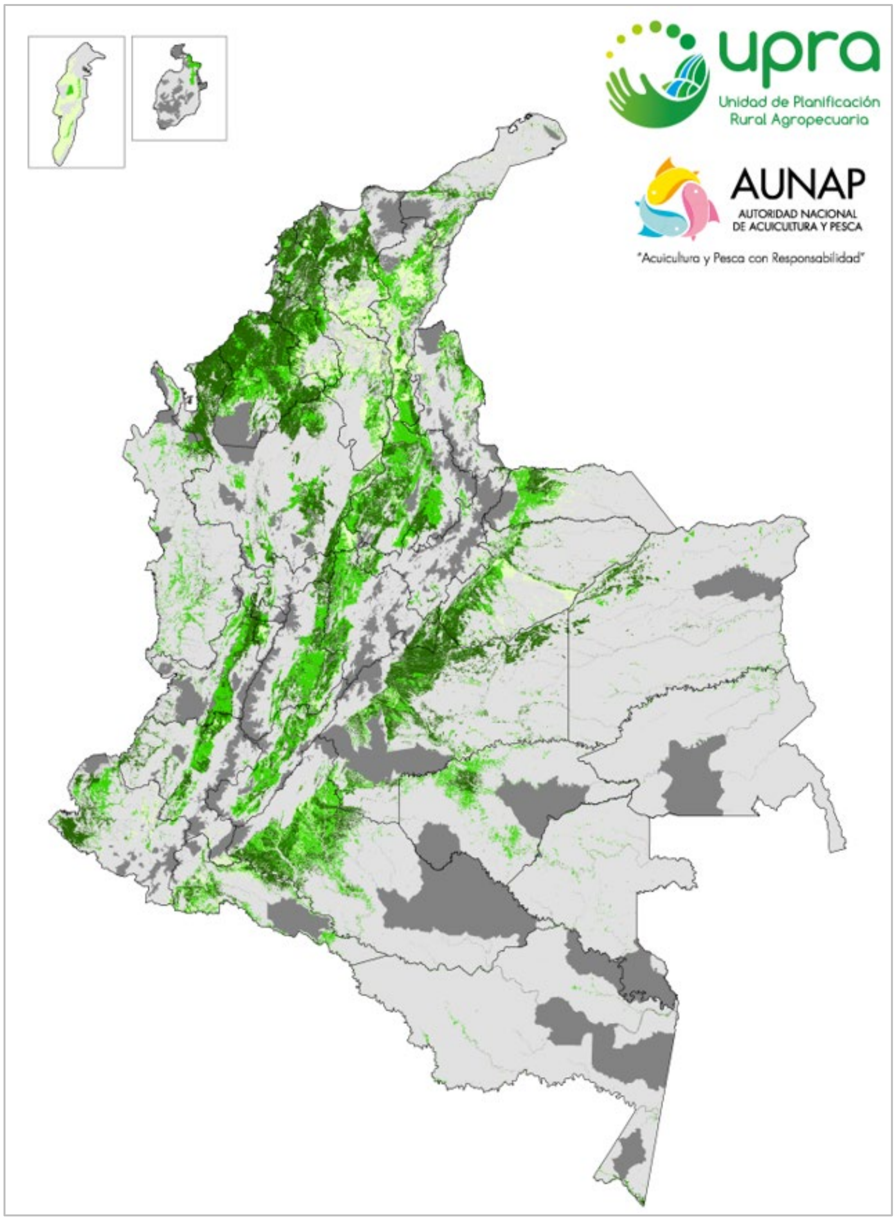

Figure 18: Suitability map for commercial tilapia aquaculture in ponds in Colombia. Dark green areas are highly suitable, mid green areas are moderately suitable, pale green areas have low suitability, pale grey areas are not suitable, and dark grey areas are legal exclusions. Map reproduced from UPRA.[62]

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

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[62] Metadata Catalog - UPRA

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 environment or an artificial environment. This decree has subsequently been updated multiple times, and the current version appears to be 2041 of 2014.[63] 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); although specific terms of reference relating to aquaculture (or other related activities such as agriculture) do not appear to be available from MADS,[64] the preparation methodology for environmental studies (MADS, 2020) applies to all activities.

MADS (2020) clearly establishes that a robust EIA process is in place for the preparation of environmental studies in Colombia. The 300-plus-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:[65]

- 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 parameters qualitative or quantitative.
- 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

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

[64] 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/

[65] As machine translated by Google.

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 impacts in addition to the cumulative and synergistic impacts relating to other aquaculture operations, or other industries. But, it appears that large numbers of tilapia 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 ponds is 3 out of 5.

Factor 3.2b—Enforcement of Habitat Regulations

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 highly 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. 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

Regarding the Betania Reservoir, the establishment of AUNAP in 2011 improved the enforcement situation, and Ramirez and Gomez (2014) subsequently reported robust penalties for infringements of regulations (regarding water quality). AUNAP, CAM, and the national police had enforced the regulations 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). Although other evidence is limited, a recent 2021 example is available (ASOCARS, 2021) that shows enforcement by the regional environmental authority (CAM) in shutting down 8 illegal operations with 15 net pens. 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 is considered relevant. Although readily available information or compliance data are limited in this regard, the score for Factor 3.2b—Enforcement of Habitat Regulations for net pens, in the single reservoir in which net pen tilapia farming takes place, is 3 out of 10.

Ponds

As discussed in Factor 3.1a, there is a regulatory process for 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 that 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 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 are 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, although a list of farms in the RPEA does not appear to be readily available, the RGPA lists only 478 farms (accessed October 12, 2022).[66] Nevertheless, the ICA can also be seen to be active in promoting the formalization of farms in various departments (e.g., in Cauca in 2019[67] and Cordoba in 2018[68]). Colombia also has a National Authority for Environmental Licenses (Autoridad Nacional de Licencias Ambientales—ANLA[69]), 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 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. Using the terminology, it is clear that the large majority of farms are "informal"; however, even though 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

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[66] https://rgpacolombia.gov.co/

[67] https://www.ica.gov.co/noticias/producers-aquaculture-competitiveness-valley

[68] https://www.ica.gov.co/noticias/ica-registro-predios-acuicolas-bioseguros-cordoba

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

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, although the enforcement organizations are identifiable and active, the 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 Regulations for ponds is 2 out of 10.

Conclusions and Final Scores

The Betania Reservoir continues to be the only waterbody used for large-scale tilapia production in Colombia. The habitat impacts of floating net pens in this artificial environment appear limited; yet, given their number and distribution, they are still likely to have some impacts on the remaining ecosystem services provided by the waterbody. Production in the reservoir appears to be managed according to the legality of producers and the nutrient carrying capacity of the reservoir, but the potential for tilapia 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). Thus, the score for Criterion 3—Habitat for net pens is 7.6 out of 10.

The majority of tilapia ponds in Colombia appear to have been constructed on former agricultural land, with perhaps minor impacts to dry or riparian forests and 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 tilapia aquaculture, but it does not account for habitat impacts in its defining methodology. There is now a permitting process in place for pond farms that includes land-use and forest permits; 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 quite high proportion of farms that currently do not have the necessary permits. Although 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 quite low proportion of formalized farms, the score for Criterion 3—Habitat for ponds is 5.5 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary—Net Pens and Ponds

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

Brief Summary

The increasing disease challenges introduce the potential for the use of veterinary medicines and treatments. Nine products are specifically listed for use in fish in Colombia: four antimicrobials, one antiparasitic treatment, two vaccines, and two hormones, but there are no readily available data with which to understand their use in Colombian tilapia farms. The only specific data points are from four audit reports for four large farms from the Aquaculture Stewardship Council, showing zero antimicrobial use. Although the use of antimicrobials or other chemicals in tilapia aquaculture in other countries may be common (e.g., China), this cannot be extrapolated to the farming situation in Colombia. The potential use of alternatives, such as vaccines, probiotics, natural remedies, and the management of environmental conditions such as decreasing stocking density of fish and water quality, must also be considered.

Although there is considerable circumstantial information available, the frequency and scale of chemical use in Colombian tilapia farms is essentially unknown regarding the specific data (or lack thereof) from the thousands of farms. Circumstantial information indicates that it cannot be assumed that the production system is dependent on chemical intervention (a score of 2 out of 10), nor can it be robustly assumed that the species or production systems have a demonstrably low need for chemical use (a score of 6 out of 10), despite the assertions of FEDEACUA and the few available data points from large farms. Therefore, the final score for Criterion 4—Chemical Use is an intermediate score of 4 out of 10 for both net pens and ponds.

Justification of Ranking

There has historically been a low need for chemical use on tilapia farms because of the disease-resistant nature of these species (Boyd 2004) (Fitzsimmons 2007);, for example, Boyd (2004) stated that antibiotic use in tilapia culture is extremely rare. But, with increasing scale and intensity of production, diseases became an increasingly common and severe problem, including in Colombia (Bacharach et al., 2016) (Pulido, 2019).

Unfortunately, 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). An information request was made to the Instituto Colombiano Agropecuario (ICA); 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 (pers. comm., Anonymous, Instituto Colombiano Agropecuario, November 1, 2022). The only specific data points available from tilapia farms in Colombia are the audit reports of four large companies certified to the Aquaculture Stewardship Council (ASC[70]). They include net pen farms (four farms) and ponds (two farms), and the available annual reports (dating to 2015[71]) specify that none of these companies have used antimicrobials between 2015 and the present. FEDEACUA states that chemical use in tilapia farms in Colombia is quite low, but no data were available to support this (pers. comm., Andrea Piza, FEDEACUA, September 2022).

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.[72] [73] 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[74]) 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 thousands of small tilapia 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).

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[70] https://www.asc-aqua.org/find-a-farm/

[71] Some audit reports dating to 2013 are available, but do not include information on antimicrobials.

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

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

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

According to the ICA, Colombia has approximately 8,500 registered veterinary products (updated 27 September, 2022[75]), of which 9 are specifically permitted for use in tilapia aquaculture (or for fish more broadly). These include four antimicrobials (oxytetracycline, florfenicol, and the sulfadimethoxine-ormetoprim mix), one antiparasitic treatment (ethylenediamine dihydroiodide), two vaccines (for *Streptococcus*), and two hormones (17 alpha methyl testosterone for sex reversal in fry, and human chorionic gonadotropin for the stimulation of ovarian development and maturation). These groups of treatments are briefly discussed below.

<u>Antimicrobials</u>
An increase in the severity of bacterial diseases raises the potential for treatment with antimicrobials. There have been several documented disease outbreaks in Colombian tilapia farms, sometimes resulting in severe losses (Hernandez et al. 2009) (Garcia et al. 2012) (Iregui et al., 2012) (Pulido et al., 2015). Pulido (2019) notes that antimicrobials may be used; for example, outbreaks of *Aeromonas hydrophila* and *Flavobacterium culumnaris* can be problems in the early phases of production, and severe mortality outbreaks can be controlled by dosing antibiotics in diets. Similarly, Pulido (2019) notes that antimicrobials may be an option to control *Edwarsiella tarda* and *Streptococcus* infections during grow-out. Although these examples establish the potential for the use of antimicrobials in tilapia farms in Colombia, understanding the actual use in practice is challenging. There are minimal data, and several alternative management measures to antimicrobials exist, such as vaccines, probiotics, nonchemical treatments such as dietary additives, and better management of fish husbandry (e.g., fish density and water quality).

Understanding antimicrobial use in Colombia is also challenged by unclear statements in academic papers. For example, Arenas and Melo (2018) stated that the indiscriminate use of oxytetracycline, chloramphenicol, and metronidazole for production of red tilapia is known, referencing Osorio et al. (2013), but the latter reference makes no mention of tilapia, or aquaculture at all. And, in a study on *Streptococcus* infections in tilapia, Melo-Bolivar et al. (2019) state that there has been increased use of antibiotics to prevent diseases, referencing Chuah et al. (2016), but the referenced paper is a study on catfish, not tilapia. Serna-Ardila et al. (2022) also note that the antimicrobial metronidazole may be used to treat *Trichodina* parasites in tilapia, but their testing showed that a garlic extract had a similar efficacy, and it is not known how often the former is used (if at all) in practice in Colombia. Arenas and Melo (2018) also note that aquaculture may also be susceptible to antimicrobial contamination from external sources, because of its use of water from rivers subject to municipal wastewater discharges.

Although antimicrobial use may be common in tilapia aquaculture in other countries, e.g., China (Zang et al., 2021) (Zou et al., 2021), this cannot be extrapolated to other countries, and Vásquez-Machado et al. (2019) considers that the most common strategy for preventing disease in the Colombian tilapia sector continues to be the management of environmental

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

conditions, such as decreasing the stocking density of fish and controlling water temperature (referencing Agnew & Barnes, 2007).

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.[76] In the World Health Organization's list of Highly and Critically Important Antimicrobials for Human Medicine (WHO, 2019), florfenicol is noted as highly important (even though it is used only in veterinary medicine) because of 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. For veterinary applications, the World Organisation for Animal Health (OIE) has also prepared the List of Antimicrobial Agents of Veterinary Importance, where both florfenicol and oxytetracycline are listed as "Veterinary Critically Important Antimicrobial Agents" (OIE, 2019). The OIE (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).

The use of antimicrobials in aquaculture links it to global concerns regarding the development of bacterial resistance to one or more antimicrobials, and to 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 Colombian Program for the Integrated Surveillance of Antimicrobial Resistance (Programa Colombiano para la Vigilancia integrada de la Resistencia Antimicrobiana—COIPARS) began in 2007, and its 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[77]) did not receive a response.

Pesticides

Parasites are one of the biggest problems affecting fish health, and *Trichodina* spp. is one of the most common in the early life stages of tilapia culture (Serna-Ardila et al., 2022). The one antiparasitic treatment registered for use in tilapia in Colombia (as listed by ICA) is ethylenediamine dihydroiodide (trade name Dermo-Gard Aqua). It can be applied either in feed

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[76] https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs

[77] https://www.agrosavia.co/

or as a bath treatment. The chemical is recognized by the U.S. Food and Drug Administration as Generally Recognized As Safe (GRAS[78]), 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 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 tilapia 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 from which to understand pesticide use in aquaculture.

Hormones

It is considered common practice for methyl testosterone (MT) to be added to hatchery feeds for approximately 28 days (fish starting size of approximately 8 mm) for the production of all-male populations via sex reversal (ITALCOL[79]) (Daza and Parra, 2019). In a review of the use of hormones in fish, Hoga et al. (2018) note that, on a large scale, sexual reversal may pollute the environment because almost all (more than 99%) of the hormones are metabolized and released into the water. Hoga et al. (2018) also note that municipal wastewaters are the main source of these types of hormones in the aquatic environment. But, according to Barry et al. (2011), MT and its metabolites become tightly associated with the sediment, with half-lives for MT dissipation and mineralization in the sediment systems ranging from 2 to 9 days, depending on the sediment type and the presence or absence of oxygen. According to Macintosh (2008), and Megbowon and Mojekwu (2013), there are no known risks to the environment (or human health) from the use of MT in aquaculture.

Although registered for veterinary use in fish in Colombia, it is not clear if human chorionic gonadotropin[80] (HCG) is used in tilapia in Colombia. In the third edition of their Fundamentals of Inland Aquaculture in Colombia, Daza and Parra (2019) detailed the maturation and breeding process for tilapia, but do not mention the use of HCG. Similarly, the review by Hoga et al. (2018) also does not list the use of this hormone (or any others within this group of hormones)

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[78] https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras

[79] https://italcol.com/wp-content/uploads/tecninotas/TECNINOTAS%20ACUICULTURA%20ITALREV.pdf

[80] Used to stimulate ovarian development and maturation (Azevedo et al., 2021)

in tilapia. Therefore, the use of HCG is not considered in this assessment of tilapia aquaculture in Colombia.

Alternatives to chemical treatments

The ICA list of registered veterinary treatments includes two vaccines for *Streptococcus*, and there is a large body of research into the development of vaccines for fish, including tilapia, particularly for key pathogens such as *Streptococcus* (e.g., Odolinski, N.C., 2020; Camero-Escobar and Calderón-Calderón, 2018; Carrera-Quintana et al., 2022; Pulido, 2019; Vásquez-Machado et al., 2019; Villamil et al., 2018). But, it is not clear how widespread their use is in Colombia; for example, Odolinski (2020) notes that vaccination typically requires special facilities and labor and is cumbersome and costly work. Villamil et al. (2018) considered that, in some countries such as Colombia, vaccination is not a common practice. The use of probiotics to improve pond conditions and fish health is also now established (Melo-Bolívar et al., 2019) (Vilamil et al., 2012), but again, there do not appear to be any readily available data on their use in Colombian tilapia farms.

Conclusions and Final Scores

The increasing disease challenges introduce the potential for the use of veterinary medicines and treatments. Nine products are specifically listed for use in fish in Colombia: four antimicrobials, one antiparasitic treatment, two vaccines, and two hormones, but there are no readily available data with which to understand their use in Colombian tilapia farms. The only specific data points are from four audit reports for four large farms from the Aquaculture Stewardship Council, showing zero antimicrobial use. Although the use of antimicrobials or other chemicals in tilapia aquaculture in other countries may be common (e.g., China), this cannot be extrapolated to the farming situation in Colombia. The potential use of alternatives, such as vaccines, probiotics, natural remedies, and the management of environmental conditions such as decreasing stocking density of fish and water quality, must also be considered.

Although there is considerable circumstantial information available, the frequency and scale of chemical use in Colombian tilapia farms is essentially unknown regarding the specific data (or lack thereof) from the thousands of farms. Circumstantial information indicates that it cannot be assumed that the production system is dependent on chemical intervention (a score of 2 out of 10), nor can it be robustly assumed that the species or production systems have a demonstrably low need for chemical use (a score of 6 out of 10), despite the assertions of FEDEACUA and the few available data points from large farms. Therefore, the final score for Criterion 4—Chemical Use is an intermediate score of 4 out of 10 for both net pens and ponds.

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	Net Pens		Ponds	
	Value	Score	Value	Score
F5.1a Forage Fish Efficiency Ratio	0.25		0.25	
F5.1b Source fishery sustainability score (0–10)		5.0		5.0
F5.1: Wild fish use score (0–10)		7.2		7.2
F5.2a Protein INPUT (kg/100 kg fish harvested)	49.09		45.84	
F5.2b Protein OUT (kg/100 kg fish harvested)	14.00		14.00	
F5.2: Net Protein Gain or Loss (%)	–71.48	2.00	–69.46	3.00
F5.3: Species-specific kg CO_2-eq kg^{-1} farmed seafood protein	22.31	4.00	22.31	4.000
C5 Feed Final Score (0–10)		**5.08**		**5.33**
Critical?	No	Yellow	No	Yellow

Brief Summary

Specific data on the composition of tilapia feeds are limited, but the available information indicates that fishmeal and fish oil levels are low and the feeds are dominated by crop ingredients. Feed conversion ratios vary according to the production system and feed/fertilizer regime, but without specific details, a global average value of 1.7 was used. With an apparently high use of by-product sources of fishmeal and fish oil (from tuna fisheries), the available data indicate that the Forage Fish Efficiency Ratio (FFER) is low (0.25), meaning that, from first principles, 0.25 mt of wild fish must be caught to supply the fish oil to grow 1 mt of tilapia. Again, this value is likely to vary across farms and production systems (for example, some farms can be seen to have an FFER of zero). The source fisheries for the marine ingredients are moderately sustainable, and the Wild Fish Use score is 7.15 out of 10. Five feed company websites provide data on feed protein levels and feeding schedules, and the average weighted feed protein content over a production cycle is 27.9%, with minor variations between ponds and net pens (e.g., where tilapia are grown to a large size in net pens to produce fillets). With a whole tilapia protein content of 14% (and the eFCR of 1.7), there is a substantial net loss of protein (69.4% for ponds and a score of 3 out of 10, and 71.5% in net pens and a score of 2 out of 10). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 22.31 kg CO_2-eq kg^{-1} farmed seafood protein (score of 4 out of 10). The three scores combine to give final scores for Criterion 5—Feed of 5.08 out of 10 for net pens and 5.33 out of 10 for ponds. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Justification of Ranking

Tilapia are omnivorous and can be produced without formulated feed in natural or fertilized ponds (see Criterion 2—Effluent for a discussion on fertilizer use), and it is likely that some small subsistence farms in Colombia rely entirely on natural productivity in the ponds, perhaps supplemented with fertilizer and handmade feeds, But, the majority of farms are considered to use commercial feeds to enhance growth rates and harvest size (pers. comm., Cesar Pinzon, FEDEACUA, September 2022).

Five companies supplying tilapia feeds in Colombia have a presence online (Contegral,[81] Italcol,[82] Finca,[83] Solla/Agrinal,[84] and Cipa[85]), and their websites provide varying amounts of technical information on their feeds. Each company typically produces four or five tilapia feeds of different sizes for different stages of the production cycle.

By considering the intended start and end weights for each feed size (and therefore the weight gain on each feed), it can be seen that the bulk of growth is gained on the larger grow-out feeds that (as discussed below) typically have lower protein contents (e.g., 24%) and lower fishmeal contents (e.g., 4%) than starter or nursery feeds for small tilapia (e.g., 45% protein and 12% fishmeal). This is consistent across all the feed companies, so the focus of this assessment is on the larger-sized feeds. Nevertheless, weighted calculations for the whole production cycle are used where the data allow.

Feed Ingredients and Inclusion Levels

FEDEACUA previously provided fishmeal and fish oil inclusion levels for different nursery and grow-out feeds for tilapia in Colombia, in addition to information on the percentage of the total protein that comes from aquatic and terrestrial animals (pers. comm., Sara Patricia Bonilla, FEDEACUA, 2016). Although these values are somewhat dated, it is considered unlikely that they have changed dramatically. In these data, fishmeal inclusion levels varied from 12% in the nursery feed to 4% in an intermediate grow-out feed, and fish oil declined from 3% to 2% accordingly.

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[81] https://www.contegral.co

[82] https://italcol.com/

[83] https://www.finca.co

[84] https://www.solla.com/

[85] https://www.cipa.com.co/

ASC audit information for a certified farm using Contegral and Solla feeds in 2021 (ASC, 2022d) showed fishmeal inclusion levels declining from 20% in the first starter feed to 6% in the final grow-out feed. Using the weight gain information from all the feed companies for each feed, a weighted fishmeal inclusion level for the whole production cycle is 6.0% (noting that the large majority of growth occurs with the final grow-out feeds). For fish oil, the inclusion levels were 1.0% in the nursery feed and 2.0% for the remaining grow-out feeds. The weighted average for the production cycle was 2.0% (rounded from 1.97), and therefore similar to the values from FEDEACUA above. Although there is some uncertainty regarding the relevance of these calculated values to all feed use in Colombia, these values have been used in this assessment (i.e., 6.0% for fishmeal and 2.0% for fish oil). The sourcing of these ingredients from whole fish or from fishery by-products is discussed in Factor 5.1.

Regarding other ingredients, the UN FAO[86] notes that the ingredient composition and formulation of commercial tilapia feeds are usually proprietary. A picture of a feed bag (a 24% protein grow-out feed) with an ingredient list is available from one feed company (Solla) (Figure 19), and lists the ingredients as: soybean meal, sunflower meal, yellow corn, wheat bran, yuca flour, rice, fishmeal, meat, and bone meal. As a single feed, it is not known how representative it is of other tilapia feeds in Colombia, but is useful as a specific example from Colombia.

Mojarras 24%

COMPOSICIÓN GARANTIZADA	
Proteína mínimo	24.0 %
Grasa mínimo	2.5 %
Fibra máximo	7.0 %
Cenizas máximo	12.0 %
Humedad máximo	13.0 %

Registro ICA No. 11686 AL

Indicaciones: Mojarras 24%, es un alimento completo destinado a la alimentación de Mojarras (Tilapias), durante el periodo de engorde, como norma general, suplemente diariamente una cantidad equivalente al 1.5% del peso de la biomasa para peces de 250 gramos de peso en adelante, repartidos entre 3 a 4 porciones al día.

SIGA ESTRICTAMENTE LAS RECOMENDACIONES PARA SU USO. NO UTILICE ESTE ALIMENTO EN ESPECIES DIFERENTES A AQUELLAS PARA LAS CUALES ES RECOMENDADO.

Ingredientes: Torta de soya, torta de girasol, maíz amarillo, salvado de trigo, harina de yuca, arroz grano, harina de pescado, harina de carne y hueso, carbonato de calcio, fosfato monodicálcico, Vitaminas A, D, E, K, B1, B2, B6, C, cloruro de colina, niacina, biotina, pantotenato de calcio, ácido fólico, sulfatos de hierro, cobre y manganeso, óxidos de zinc, yodato de calcio, selenito de sodio, antioxidante BHT.

Elaborado por Solla S.A. Itagüí Carrera 42 # 33 - 80 Autopista Sur Tel: 444 84 11
Industria Colombiana Centro de Servicio Solla 018000527111 www.solla.com

Figure 19: Images of a Solla feed bag for Mojarra 24%. The ingredients are listed (presumably in order of inclusion), with basic nutritional information. Image reproduced from https://www.sollanutricionanimal.com.

The same FAO document also notes that a full disclosure of ingredient formulation is usually only given in experimental tilapia diets published in academic journals, but warns that such

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[86] https://www.fao.org/fishery/affris/species-profiles/nile-tilapia/feed-formulation/en/ (Accessed September 2022)

experimental formulations may not reflect the typical commercial feeds used in intensive farming systems, or the feeds in any particular geographic region. But, such studies typically use a control diet that more closely reflects a “typical” commercial formulation, and in the absence of specific formulation data from the feed companies in Colombia, four such control diet formulations were obtained from recent studies (Sarker et al., 2020; Ashour et al., 2020; Magouz et al., 2020; and Dawood et al., 2020). These formulations, in addition to the available fishmeal and fish oil inclusion data previously provided by FEDEACUA, have been used to approximate a sufficiently representative tilapia grow-out feed for the purposes of this assessment. This formulation is shown in Table 2. This has some similarities to the ingredients in the grow- out feed example from Solla, but it is noted that the Solla feed does not include fish oil (the 45% protein starter feed does include it).

Table 2: Tilapia feed formulation approximated from the fishmeal and fish oil data from FEDEACUA in addition to the control feeds of four academic studies referenced in the text.

Ingredient	Inclusion %
Soybean meal	29
Corn gluten	14
Corn meal	13
Wheat bran	13
Poultry meal*	8*
Fishmeal	6
Vitamins/minerals, etc.	6
Rice bran	5.5
Vegetable oil	3.5
Fish oil	2
Total	**100**

* Data from FEDEACUA showed that 15% of the total protein in a tilapia grow-out feed comes from terrestrial animals. Without further information on the type, this has been attributed to poultry by-product meal, which is a common ingredient in aquaculture feeds. The inclusion level of 8% is calculated based on a typical protein content of poultry by-product meal of 56.6% obtained from an academic feed ingredients database.[87]

Where possible, reference is also made in the following assessment to any relevant data points from publicly available audit reports from the Aquaculture Stewardship Council (certified farms are noted to be using feeds from Contegral, Italcol, and Solla).

Feed Conversion Ratio

The economic feed conversion ratio (eFCR, calculated by dividing the total feed input by the total harvest biomass output) is an important component of this assessment. In the early 2000s, eFCR values for tilapia farms in Colombia ranged from 1.6 to 2.0, with an average of 1.8 (Gonzalez 2001) (Hidrósfera 2003) (Popma and Rodgeiquez 2000) (Zubieta 2007). Tacon and Metian (2008) predicted that eFCR values would decrease over time, but Tacon et al. (2022)

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[87] https://nutrition.ansci.illinois.edu/static/feed_database.html

indicated that this may have been modest, stating a current global average value for tilapia of 1.7.

In a review of Nile tilapia production yields, Mengistu et al. (2020) noted that many factors affect eFCR, notably survival, temperature, dissolved oxygen, pH, and the crude protein content of feed. It is also likely that yields will differ across different species (e.g., red tilapia and Nile tilapia), as will yields from production in net pens or ponds. For example, Mengistu et al. (2020, referencing Rana & Hassan, 2013) showed that reported FCR values for tilapia vary widely, ranging from 1.0 to 2.5 in different countries and production systems.

In Colombia specifically, eFCR values available from the ASC audit reports of four certified farms (including both pond and net pen sites) showed a range of 1.51 to 1.74, with an average of 1.60. It must be noted that this small number of large, certified farms is unlikely to be representative of the majority of small tilapia farms in Colombia; therefore, for the purposes of this assessment, the global average value of 1.70 from Tacon et al. (2022) has been used on a precautionary basis.

Factor 5.1—Wild Fish Use

Factor 5.1.a: Forage Fish Efficiency Ratio (FFER)

As described above, the weighted average inclusion levels of fishmeal and fish oil over a production cycle were estimated to be 6% and 2%, respectively. There is no indication from the feed companies (online) as to whether these ingredients are sourced from whole fish or from fishery by-products. Information in ASC audit reports indicates that the use of by-product sources is substantial and, in some cases, exclusive.

For example, ASC (2022a; 2022c) state that the Italcol feeds use only by-products for both fishmeal and fish oil. In both cases, the audit reports refer to the use of by-products from yellowfin tuna (*Thunnus albacares*) from Colombia and Ecuador and skipjack tuna (*Katsuwonus pelamis*) from Ecuador. Additional ASC audit reports (ASC, 2022b; ASC 2022d) for farms using Contegral and Solla feeds mention the same two tuna species, but also mention the Peruvian anchovy (*Engraulis ringens*), which is a whole-fish reduction fishery. The Forage Fish Efficiency Ratios (FFER) in the ASC audit reports (ASC 2022a, b, c, d) are mostly quite low (from zero to 0.006), with one outlier in ASC (2022c) of 0.27.[88] These values also indicate the substantial use of by-product sources of fishmeal and/or fish oil in the feeds used by these certified farms.

The information in the ASC audit reports shows that the feeds used by the certified farms are the same commercial brands displayed on each company's website; that is, the feeds are the same as those sold commercially to other tilapia farms in Colombia. But, the audit reports mention feeds from only three companies (Contegral, Solla/Agrinal, Italcol) and do not provide information on the remaining two (Cipa, Finca); although the available information shows that by-product sources dominate the marine ingredients, this cannot be assumed to be the case in

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[88] This value (referring to the Italcol feed) contradicts other audit reports using the same feed, and may have been calculated incorrectly by not accounting for by-product fishmeal sources.

all feeds used by the thousands of tilapia farms in Colombia. Therefore, some precaution must be used; although the FFER values indicate that the use of Peruvian anchovy (from a whole-fish reduction fishery) is minor, it is assumed here to be used in equal parts with the by-products of yellowfin and skipjack tuna. That is, one-third of the fishmeal and fish oil in feeds is assumed to come from whole fish, and two-thirds comes from the two by-product sources, meaning that fishmeal and fish oil from whole fish make up 2% and 0.66%, respectively, of the tilapia feeds.

With an eFCR of 1.7 and the standard yield values for fishmeal and fish oil (22.5% and 5%, respectively),[89] this equals an FFER of 0.17 for fishmeal and 0.25 for fish oil. The higher value of 0.25 is used here.

Factor 5.1b: Source fishery sustainability

As noted above, in the available information from ASC audit reports (ASC, 2022a, b, c, d), two species of fish have been identified by three feed companies in Colombia (yellowfin tuna from Colombia and Ecuador and skipjack tuna from Ecuador), and a third (Peruvian anchovy) was used by two feed companies. Although not conclusively representative of all marine ingredients used in Colombian tilapia feeds, they are used here. According to FishSource,[90] the Eastern Pacific fisheries for both yellowfin and skipjack tuna have scores >6 for management strategy, manager's compliance, fisher's compliance, stock health, and future stock health. The Seafood Watch sustainability score for these fisheries is 6 out of 10 for Factor 5.1b. Two Peruvian anchovy fisheries have high scores for all factors except the management strategy (<6) in one fishery (Southern Peru/Northern Chile), and this equals a Seafood Watch sustainability score of 5 out of 10 for Factor 5.1b. In combination, and accounting for the whole fish/by-product nature of the sources, the overall score for these sources is 5.0 out of 10 for Factor 5.1b.

With the low use of fishmeal and fish oil, and the substantial use of by-product sources, Factors 5.1a and 5.1b combine to give a final score for Factor 5.1—Wild Fish Use of 7.15 out of 10.

Factor 5.2—Net Protein Gain or Loss

The five feed companies mentioned previously all produce a range of feeds in terms of protein contents, and they provide details on their websites. All companies have four or five feeds of different sizes with declining protein contents for increasing sizes of fish; although there are some minor variations in feeding schedules for Nile versus red tilapia, ponds versus cages, and harvest size, the feeds are quite similar. All starter feeds begin at 45% protein and decline to 24% or 25% for fattening up to harvest size. Three companies also produce a single lower-protein content grow-out feed (20% protein) for use as a supplemental diet in fertilized ponds. One company produces a 32% feed for growing Nile tilapia to a large size (up to 1.2 kg) in net pens.

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[89] As stated in the Seafood Watch Aquaculture Standard.

[90] www.fishsource.org

By considering the feeding regime from each company (i.e., the different amounts of growth achieved on different sized feeds), the weighted average feed protein content can be calculated. This varies from 23.1% when a low-protein supplemental feed is used in a fertilized pond to 32.4% for intensive fattening to a large harvest size in net pens. For a "typical" production cycle without the use of these specialist feeds, the weighted average feed protein content varies from 26.8% to 29.1%, according to the feeding regimes from the five companies. By separating these feeding regimes for ponds and net pens (or applying them to both when they are not differentiated by production system), the average feed protein content for ponds is 27.0% and for net pens is 28.9%. When combined with the eFCR of 1.7, the total protein input per mt of tilapia production is calculated to be 458.4 kg in ponds and 490.9 kg in net pens.

Regarding the protein output in harvested tilapia, the protein content of a whole harvested farmed tilapia is 14% (Boyd 2007), or 140 kg protein per mt of tilapia. By considering the inputs and outputs, the net protein loss can be calculated, and with moderately high feed protein contents and relatively low whole-tilapia protein contents, the loss is substantial. Calculated values range from a 64.3% loss (using the supplemental feed) to 74.6% loss (for large tilapia in net pens). Regarding species differences, one company specifies a separate feeding regime for red versus Nile tilapia, but the weighted feed protein content over a production cycle is quite similar.

It is noted here that these calculations are based on tabulated feeding regimes and may not reflect the reality and range of tilapia farming systems in Colombia. Therefore, although the detailed analysis is of interest, some generalizations must be made. The feeding regimes in ponds, particularly in the case of the lower-protein supplemental feed, result in a lower net loss of protein (average loss of 69.4%) compared to net pens, which include intensive production to larger sizes (average loss of 71.5%). These two values span a scoring threshold in the Seafood Watch Aquaculture Standard (at 70.0%), such that the score for Factor 5.2 for net pens is 2 out of 10, and for ponds is 3 out of 10. Although this numerical difference is minor (i.e., between the 69.4% and 71.5% loss), it is likely to be larger in reality because many of the feeding regimes provided by the feed companies do not distinguish between ponds or net pens. Therefore, the different Factor 5.2 scores for the two production systems are considered to be justified, even though the calculated difference is minor.

Factor 5.3. Feed Footprint

Factor 5.3 approximates the embedded global warming potential (kg CO_2-eq including land-use change [LUC]) of the feed ingredients required to grow 1 kilogram of farmed seafood protein. This calculation is performed by mapping the ingredient composition of a typical feed used against the Global Feed Lifecycle Institute (GFLI) database[91] to estimate the global warming potential 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 encourage data transparency and

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

provision. The detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

Table 3 shows the ingredient categories selected from the GFLI database according to the above methodology for ingredients of unknown origins. Because of the licensing agreement, the specific values for each ingredient from the GFLI database are not reproduced here, but the calculated value per mt of feed for each ingredient is shown.

Table 3: Estimated embedded global warming potential of 1 mt of tilapia feed used in Colombia. GFLI refers to the Global Feed Lifecycle Institute.

Ingredient	Ingredient listing in the GFLI Database	Inclusion %	kg CO_2 eq/ mt feed
Fishmeal	Anchoveta (Peru and Chile) and general sources[1]	6.0	65.40
Fish oil	Anchoveta (Peru and Chile) and general sources[1]	2.0	14.99
Soybean meal	Soybean expeller, from crushing (pressing), at plant/GLO Economic Soybean expeller, from crushing (pressing), at plant/AR Economic	29.0	1,135.3
Poultry meal*	Animal meal, poultry, from dry rendering, at plant/RER Economic S	8	98.67
Maize	Maize flour, from dry milling, at plant/GLO Economic S Maize flour, from dry milling, at plant/PL Economic S	13	158.86
Maize gluten	Maize gluten meal, from wet milling (gluten drying), at plant/GLO Economic S Maize gluten feed, from wet milling (gluten feed production, with drying), at plant/GLO Economic S	14	185.1
Wheat	Wheat flour, from dry milling, at plant/GLO Economic Wheat flour, from dry milling, at plant/ES Economic	13	101.56
Rice bran	Rice bran, from dry milling, parboiled, at plant/CN Economic S Rice bran, from dry milling, raw, at plant/CN Economic S	5.5	57.87
Vegetable oil	Crude vegetable oil blend, from crushing, at plant/GLO Economic Crude vegetable oil blend, from crushing, at plant/RER Economic	3.5	209.67
Vitamins, minerals*	Total minerals, additives, vitamins, at plant/RER Economic	6.0	70.58
Total		**100.0**	**1,837.65**

[1] Yellowfin tuna and skipjack tuna are not listed in the GFLI database.

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

As can be seen in Table 3, the estimated embedded GWP of 1 mt of tilapia feed is 1,837.65 kg CO_2-eq. Considering a whole harvested farmed tilapia protein content of 14% (Boyd, 2007) and an eFCR of 1.7, it is estimated that the feed-related GWP of 1 kg farmed tilapia protein is 22.31 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

Specific data on the composition of tilapia feeds are limited, but the available information indicates that fishmeal and fish oil levels are low and the feeds are dominated by crop ingredients. Feed conversion ratios vary according to the production system and feed/fertilizer regime, but without specific details, a global average value of 1.7 was used. With an apparently high use of by-product sources of fishmeal and fish oil (from tuna fisheries), the available data indicate that the Forage Fish Efficiency Ratio (FFER) is low (0.25), meaning that, from first principles, 0.25 mt of wild fish must be caught to supply the fish oil to grow 1 mt of tilapia. Again, this value is likely to vary across farms and production systems (for example, some farms can be seen to have an FFER of zero). The source fisheries for the marine ingredients are moderately sustainable, and the Wild Fish Use score is 7.15 out of 10. Five feed company websites provide data on feed protein levels and feeding schedules, and the average weighted feed protein content over a production cycle is 27.9%, with minor variations between ponds and net pens (e.g., where tilapia are grown to a large size in net pens to produce fillets). With a whole tilapia protein content of 14% (and the eFCR of 1.7), there is a substantial net loss of protein (69.4% for ponds and a score of 3 out of 10, and 71.5% in net pens and a score of 2 out of 10). The feed footprint calculated as the embedded climate change impact (kg CO_2-eq) of the feed ingredients was 22.31 kg CO_2-eq kg^{-1} farmed seafood protein (score of 4 out of 10). The three scores combine to give final scores for Criterion 5—Feed of 5.08 out of 10 for net pens and 5.33 out of 10 for ponds. (See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.)

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

C6 Escape parameters	Value	Score	Value	Score
	Net Pens		Ponds	
F6.1 System escape risk (0–10)	2		4	
F6.1 Recapture adjustment (0–10)	0		0	
F6.1 Final escape risk score (0–10)		2		4
F6.2 Competitive and genetic interactions (0–10)		6		6
C6 Escape Final Score (0–10)		**4**		**5**
Critical?	No	Yellow	No	Yellow

Brief Summary

Tilapia was initially introduced into Colombia for aquaculture purposes, but with active government stocking in the country’s freshwater bodies (in addition to aquaculture escapes), it became established in the 1960s, before the large-scale development of the aquaculture industry. Until recently, tilapia had been legally defined as an introduced, invasive species by the Colombian government, but new regulations in December 2015 declared Nile and red tilapia (and rainbow trout) “domesticated.” Although the new resolution recognizes the threat from additional escapes and prevents further active stocking, tilapia is considered fully established for the purposes of this assessment. Net pen aquaculture systems for tilapia carry a high risk of escape, but best practices for escape management, including the use of all male or sterile fish, are considered widespread. There are no data available on escape events in Colombia or on post-escape recaptures, but potential impacts are reduced when the species has been historically introduced and actively stocked into the environment. The final escape criterion score is based on the interaction of the risk of escape (Factor 6.1; scores of 2 of 10 for net pens and 4 out of 10 for ponds) and the risk of competitive and genetic interactions with wild species (Factor 6.2; score of 6 of 10 for tilapia in Colombia). These result in moderate final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 5 out of 10 for ponds.

Justification of Ranking

Factor 6.1—Escape Risk

All aquaculture operations carry the risk of escapes (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 escapes (Halwart et al., 2007) (Jensen et al., 2010). Net-pen production systems are associated with a high risk of escape, given their open nature (Naylor et al., 2005) (Halwart et al., 2007). At the global level, Xiong et al. (2022) note that tilapia have escaped culture facilities (net pens and ponds) numerous times and established feral populations in many tropical and subtropical countries.

In Colombia, Resolution 2879 of 2017 (AUNAP) lays out the requirements that must be met by aquaculture establishments to “minimize the risk of escape of exotic, domesticated and/or transplanted species to natural or artificial bodies of water.” This builds on Resolution 461 of 1995, which set out broader requirements for the cultivation of tilapia, and Resolution 2287 of 2015, which declared tilapia to be “domesticated” for the development of Aquaculture (see Factor 6.2).

Resolution 2879 lists escape minimization requirements for ponds and net pens, and includes the following:[92]

For ponds:

- 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 in) 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 waters into any aquatic environment.
- Ensure that the drains of the ponds have sufficient capacity to evacuate excess water from rains, runoff, or floods.

For net pens:

- 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.

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[92] Based on a machine translation by Google

- 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 tilapia to be monosex (single sex).

Finally, all transport and handling operations must avoid escape; for example, by the use of double plastic bags, nets, and/or secure (e.g., closed) transport tanks.

Regarding the risk of escapes due to flooding (and noting again that, according to Resolution 2879, all facilities are to be located in areas that are not at risk of flooding), it must be noted that ,according to IDEAM,[93] Colombia is a country with high vulnerability to flooding, both in flood plains and flat areas, and 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 20 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 during that period.

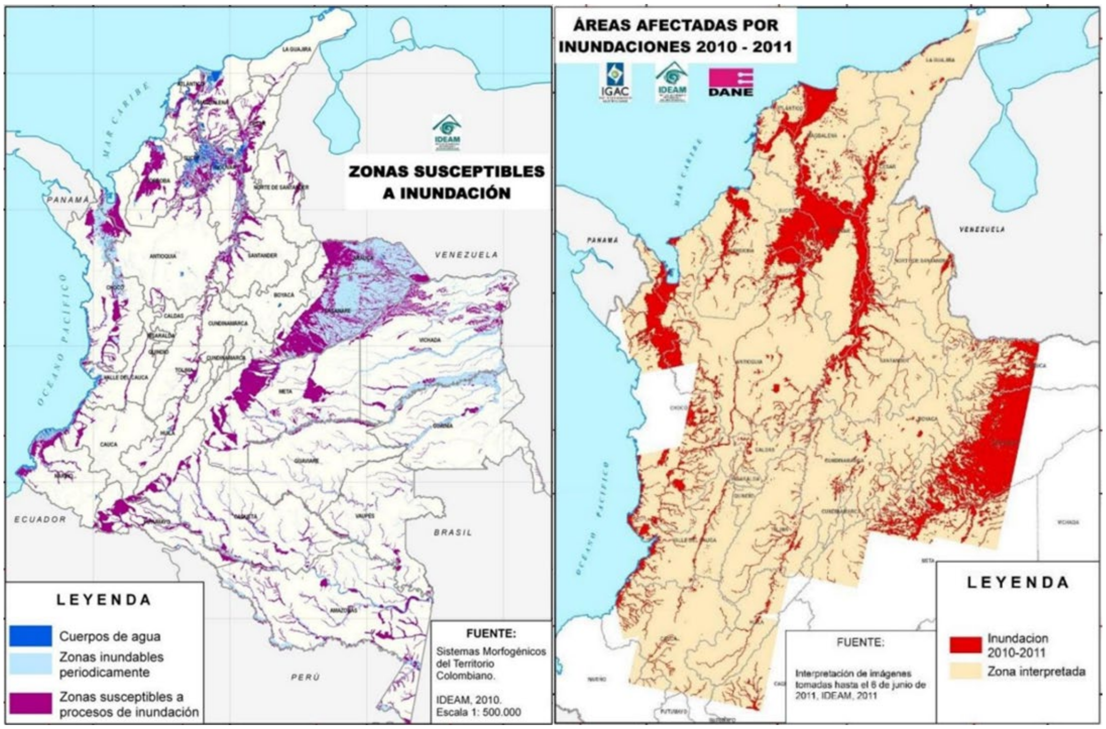

Figure 20: Two examples of flood maps from IDEAM. The left image shows the areas susceptible to flooding (dark blue is existing bodies of water, light blue is areas at risk of periodic flooding, and purple shows areas at risk of general flooding). The right image (note the different area of Colombia covered compared to the left image) shows areas that were flooded during 2010–11. Images reproduced from IDEAM.

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

Given the widespread distribution of tilapia aquaculture in Colombia, these maps are of limited use for understanding the flooding risk of tilapia farms, except to highlight the fundamental risk, particularly since aquaculture operations are typically closely associated with a water supply and perhaps at greater risk of flooding.

Compliance with the regulations described above also requires the completion of a risk matrix that covers the risks associated with the design and construction of the net pens (e.g., mesh sizes, anchoring, and vulnerability to storms), stocking, production operations such as fish movements or transfers, harvest, and sampling for escapes. It is unclear how these regulations are enforced, or how many farms comply (see Factor 2.2b in Criterion 2—Effluent on the limited number of "formalized" farms in Colombia). Similarly, there does not appear to be any readily available information or data on escape numbers. Limited information from four recent ASC audits note zero escapes in the most recent production cycles, but Nakata (2021) noted that there was limited accuracy or control of the stock numbers due to not knowing how many juvenile fish are being received. Therefore, detection of escapes, particularly small losses (so called trickle or leakage losses) is challenging in typical net pens or ponds holding 100,000 fish or more (Daza and Parra, 2019).

Overall, there is a clear risk of escapes. Net pens are particularly vulnerable, but ponds are also likely to be at risk of flooding or other losses during production (e.g., if ponds are drained at harvest). The initial Escape Risk score (Factor 6.1a) is 2 out of 10 for open systems with Best Management Practices, and 4 out of 10 for ponds with moderate water exchanges and flood risk. With no information available on recapture efforts or their outcomes, a recapture adjustment is not applied.

Factor 6.2—Competitive and Genetic Interactions

Tilapia can thrive in virtually any tropical freshwater and estuarine habitat, it easily changes its feeding behavior depending on which other fish species co-occur, and it spawns year-round (Xiong et al., 2022) (Shipton et al., 2008) (Njiru et al., 2004) (Zengeya et al., 2012). All these factors contribute to the popularity of tilapia as a culture species, but also make it a potentially dangerous invasive species (Xiong et al., 2022) (Zengeya et al., 2015). Nevertheless, tilapia is one of the most widely introduced species in the world (Xiong et al., 2022), and it follows that there is ample evidence regarding the invasive nature of tilapia and its impacts on native populations in ecosystems worldwide (e.g., Lowe et al., 2000; Starling et al., 2002; Canonico et al., 2005; Narváez et al., 2005; Oliveria 2005; Caraballo 2009).

According to Salgado et al. (2022), there are currently more than 50 alien species introduced in the Magdalena River in Colombia (on which the Betania dam was constructed), including fish, macrophytes, mollusks, and mammals. The introduction and subsequent establishment of tilapia in Colombia is thought to date to the 1960s (Pullin et al., 1997) (Daza and Parra, 2019). According to Daza and Para (2019), the initial introductions of tilapia to Colombia were for aquaculture purposes, but the government also actively stocked freshwater bodies in the country with tilapia from hatcheries (Caraballo 2009) (FAO-INCODER 2011). Similarly, additional tilapia species were introduced in the 1970s for aquaculture, but they were also actively stocked into natural waterbodies and became widely established (Carrera-Quintana et al., 2022). It can be seen (or at least extrapolated) from Figure 1 that the aquaculture production of tilapia was quite low in the 1960s and 70s. Although the relative importance of the different causes of tilapia's introduction to the wild is not apparent (i.e., aquaculture escapes or active stocking), it is clear that various species of tilapia (including those commonly cultured and assessed here) have become ecologically established in Colombia and are actively reproducing in the wild in freshwater, estuarine water, and alkaline waters (Narváez et al., 2005).

Considering its nature (described above), tilapia was defined as an introduced, invasive species by the Colombian government until Decree 1071 and Resolution 228 were passed in December 2015 (AUNUP 2013a). Resolution 228 declared Nile tilapia and red tilapia (along with rainbow trout [*Oncorhynchus mykiss*]) "domesticated" in Colombia. The resolution recognizes the threat from additional escapes, and the practice of stocking freshwater bodies in the country with tilapia from hatcheries now appears to be prohibited (under Resolution 228). As described in Criterion 3—Habitat (and Figure 18), UPRA has developed a zoning map of suitable locations for tilapia farming in Colombia,[94] developed under an agreement with AUNAP, but the defining methodology (in AUNAP, 2013b) does not include any aspects relating to tilapia's potential escape, further establishment, or any other subsequent ecological impacts in Colombia.

Overall, the nonnative species of tilapia farmed in Colombia became ecologically established in the wild due to their initial introduction for aquaculture and subsequent escapes, but also due to active stocking by the government. This occurred several decades ago, but it remains unclear if there is an ongoing potential for tilapia to be introduced to additional waterbodies in Colombia where they are not yet present. Despite these timeframes (and as reflected in the concerns in Resolution 228), the potential for direct impacts to wild species or habitats following a large escape remains. Therefore, on a precautionary basis, the score for Factor 6.2 is 6 out of 10.

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[94] Available from Metadata Catalog - UPRA "Aptitud para el cultivo comercial de tilapia plateada y el híbrido rojo en estanques de tierra. Febrero 2018."

Conclusions and Final Score

Tilapia was initially introduced into Colombia for aquaculture purposes, but with active government stocking in the country’s freshwater bodies (in addition to aquaculture escapes), it became established in the 1960s, before the large-scale development of the aquaculture industry. Until recently, tilapia had been legally defined as an introduced, invasive species by the Colombian government, but new regulations in December 2015 declared Nile and red tilapia (and rainbow trout) “domesticated.” Although the new resolution recognizes the threat from additional escapes and prevents further active stocking, tilapia is considered fully established for the purposes of this assessment. Net pen aquaculture systems for tilapia carry a high risk of escape, but best practices for escape management, including the use of all male or sterile fish, are considered widespread. There are no data available on escapes events in Colombia or on post-escape recaptures, but potential impacts are reduced when the species has been historically introduced and actively stocked into the environment. The final escape criterion score is based on the interaction of the risk of escape (Factor 6.1; scores of 2 of 10 for net pens and 4 out of 10 for ponds) and the risk of competitive and genetic interactions with wild species (Factor 6.2; score of 6 of 10 for tilapia in Colombia). These result in moderate final numerical scores for Criterion 6—Escapes of 4 out of 10 for net pens and 5 out of 10 for 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

Risk-based assessment

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

Brief Summary

Although it is clear that pathogens and parasites have become increasingly problematic in tilapia aquaculture in Colombia as it has intensified and increased in scale, there is little recent information on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and 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. Although there is evidence of large mortality events associated with disease, this appears to be limited to intensive farms (often intensive net pen farms), and considering the dominant sector of small farms in Colombia, it is less likely that there are high disease-related infections or mortalities. 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 tilapia farms, the final score for Criterion 7—Disease for both net pens and ponds is 4 out of 10.

Justification of Ranking

As noted in Criterion 4—Chemical Use, tilapia has been considered a disease-resistant species (Boyd 2004) (Fitzsimmons 2007). But, with the increasing scale and intensity of production, diseases in tilapia aquaculture have become an increasingly common and severe problem, including in Colombia, and a wide range of bacteria, fungi, protozoa, and viruses have been described as challenges to tilapia aquaculture (Bacharach et al, 2016) (Pulido, 2019). In Colombia specifically, Pulido (2019) provided a review of the causes of mortality in intensive tilapia farms and noted that an increase in intensification is usually accompanied by increased reporting of health disorders. It must be noted that many of the thousands of small-scale tilapia farms in Colombia probably operate at a relatively low intensity, at least compared to net pen production, where the color of red tilapia can be seen in satellite images (Figure 21).

Figure 21: Satellite image of red tilapia production in net pens in Betania Reservoir. Dense areas of red tilapia can be seen, and a large quantity of tilapia is present in a small area within this farm site. Image reproduced from Google Earth.

At the country level, numerous diseases have been documented on tilapia farms in Colombia, including tilapia lake virus (Contrearas et al., 2021) (Criollo-Joaquin et al, 2019), *Edwardsiella* species (Garcia et al., 2012) (Iregui et al., 2012), *Aeromonas motile* (Camus et al., 1998) (Iregui 2004), rickettsia (Iregui et al., 2011), and *Streptococcus* and *Enterococcus* (Hernandez et al., 2009) (Osman et al., 2017) (Villamil et al., 2012). According to Daza and Parra (2019), the most common pathogens are four bacterial pathogens (*Streptococcus algalactia*, *Aeromonas hydrophilia*, *Flavobacterium culumnaris*, and *Edwardsiella tarda*), the virus tilapia lake virus (TiLV), and the parasites *Trichodina* spp, *Trematode* spp, and *Eimeria* spp. The ICA lists the same set of pathogens (accessed October 24, 2022[95]).

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

In a review of the main mortality factors in intensive farms, Pulido (2019) noted that health problems are usually multicausal; that is, they are generally not related to a single factor that triggers them, On the contrary, in any one outbreak, there may be several pathogens present during a time of nutritional or water quality alterations. For example, one of several potential factors in the large die-offs of grow-out tilapia in the Betania Reservoir in 2015 was a viral infection of *Hepatitis syncytial*, but there were also systemic infections by several opportunistic pathogens, in addition to overproduction and poor water quality (Pulido et al., 2015). The pathogens listed above also typically cause mortalities at different stages of the production cycle; for example, Pulido (2019) noted that, although most of these pathogens caused mortality in the early stages of production, *Streptococcus* bacteria were the main factor in the grow-out phase.

Regarding mortality levels due to disease, Pulido (2019) did not indicate typical mortality levels in Colombia (in intensive or other systems). In the past, disease-induced mortality in Colombia has sometimes produced serious losses, particularly due to streptococcal infections (Fitzsimmons 2000). In the departments of Huila, Valle, Risaralda, and Tolima, which represent some of the highest producers of tilapia in the country, information from more than 15 years ago suggested disease infection rates (note: not mortality rates) of over 50% for tilapia production (Iregui 2004). It is not fully understood how more recent production practices and biosecurity protocols have changed this situation, but for comparison, in stocking density studies conducted by Garcia et al. (2013), mortality rates averaged 5.03%, even in the highest density treatments (120 kg/m^3). Current data on disease outbreaks and mortality rates are not readily available in Colombia.

Substantial progress has been made globally in vaccinating tilapia against common aquaculture diseases, particularly *Streptococcus* (Vásquez-Machado et al., 2019) (Carrera-Quintana et al., 2022) (Camero-Escobar and Calderón-Calderón, 2018). But, as noted in Criterion 4—Chemical Use, it is not clear how widespread the use of vaccines is in Colombia; for example, Odolinski (2020) notes that vaccination typically requires special facilities and labor and is cumbersome and costly work. Villamil et al. (2018) considered that, in some countries such as Colombia, vaccination is not a common practice. It is considered in this report that vaccination rates are likely to vary among the different types of producers, with the large, technically advanced farms more likely to use them compared to the more numerous small pond farms (noting again that by operating at a lower intensity, these farms may not have the same disease concern as large intensive farms, and therefore less need for vaccination).

The ICA has a certification process for “Biosafe Aquaculture Establishments” (Establecimiento de Acuicultura Bioseguro), established under Resolution 20186 of 2006, and provides an informational booklet describing the biosecurity measures.[96] These measures include common biosecurity best practices such as control and cleanliness of equipment and personnel, use of tested and quarantined sources of fry, veterinary oversight, barriers to wildlife entry, water

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[96] Available from FEDEACU - https://www.fedeacua.org/page/eduaqua

treatment, notifications of disease outbreaks, and record-keeping). Because the ICA considers[97] that many of the diseases in aquatic animals are generated by ignorance and poor management practices of farmed animals, these educational developments (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.

Regarding 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). Although all the diseases recorded for tilapia being produced in Colombia have the potential to spread to other organisms, the studies referenced above on this topic either did not study wild populations or studied low sample sizes of wild populations and found no incidence of disease (e.g., Hernandez et al., 2009). In general, there appears to be little information on diseases in wild fish in Colombia, so it is challenging to determine if any pathogens discharged from net pen or ponds farms in Colombia would affect wild fish in the wild (i.e., outside of the farm environment, where the conditions such as unnatural stocking densities and reduced water quality are considered to increase the susceptibility of tilapia to pathogens).

Conclusions and Final score

Although it is clear that pathogens and parasites have become increasingly problematic in tilapia aquaculture in Colombia as it has intensified and increased in scale, there is little recent information on disease-related mortality rates, particularly in small farms that dominate production in Colombia. Both net pens and 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. Although there is evidence of large mortality events associated with disease, this appears to be limited to intensive farms (often intensive net pen farms), and considering the dominant sector of small farms in Colombia, it is less likely that there are high disease-related infections or mortalities. 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 tilapia farms, the final score for Criterion 7—Disease for both net pens and ponds is 4 out of 10.

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[97] 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 8 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	
Lowest score if multiple species farmed (0–10)		n/a
C8X Source of Stock Final Score (0–10)		**0**
Critical?	No	Green

Justification of Ranking (and Summary).
Tilapia strains used in aquaculture have been domesticated for decades; for example, Watanabe et al. (2002) describe the process to develop red tilapia stocks in the 1980s, along with the domestication of Nile tilapia. As noted in Criterion 6—Escapes, Resolution 228 of 2015 declared Nile tilapia and red tilapia "domesticated" in Colombia. Also, as a nonnative species, all tilapia grown in Colombia are produced in hatcheries with no use of wild broodstock or seed. Further, if any "wild" tilapia from Colombia were used as broodstock, they would not be included in the scoring of this criterion (i.e., there would not be any sustainability concerns with their capture and use). Therefore, Colombian tilapia culture is considered to be fully independent of wild fisheries for stock, and the score for the exceptional Criterion 8X is a deduction score of 0 out of –10.

Criterion 9X: Wildlife and Predator Mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with 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
Net pens and ponds

C9X Wildlife Mortality parameters			Score
Single species wildlife mortality score			–6
System score if multiple species assessed together			n/a
C9X Wildlife Mortality Final Score			**–6**
	Critical?	No	Yellow

Brief Summary

Because of the visually attractive nature of surface feeding tilapia (particularly red tilapia) to avian predators, interactions are to be expected. ASC audit reports provide some information on the likely species present in Colombia (including birds, otters, and crocodiles), some of which are listed as "Near Threatened" or "Vulnerable" by the International Union for the Conservation of Nature (IUCN). There are regulations in place regarding the use of predator netting; although examples of their deployment can be found, the extent of their use across the thousands of tilapia farms in Colombia is not known. A risk of entanglement remains. Although there is minor anecdotal evidence of injuries to some animals, including vulnerable species, there are no data available with which to understand if mortalities occur, and if so, at what scale. The extent of interactions with wildlife is therefore largely unknown. Overall, some regulations or management measures are in place that aim to limit wildlife mortalities, but enforcement is unknown, and mortality numbers are unknown. The final score for Criterion 9X is a precautionary deduction of –6 out of –10 because of the unknown status.

Justification of Ranking

As a surface feeding fish, tilapia is visually attractive to avian predators (ASC, 2022d), and this is particularly the case for red tilapia. According to a now-dated reference, high densities of fish in aquaculture facilities in Colombia attract a number of predatory bird species, including kingfisher, egret, heron, and osprey (Bechard and Marquez-Reves, 2003). Recent audit reports from a small number of farms certified to the Aquaculture Stewardship Council show examples of the typical predatory species of interest at one tilapia farm in Colombia (ASC, 2021b), including several bird species: ringed kingfisher (*Megaceryle torquate*), Amazon kingfisher (*Chloroceryle amazona*), crested caracara (*Caracara cheriway*), black skimmer (*Rynchops niger*), black-bellied whistling duck (*Dendrocygna autumnalis*), purple gallinule (*Porphyrio martinicus*), osprey (*Pandion haliaetus*), and snake bird (*Anhinga anhinga*), as well as the neotropical otter (*Lontra longicaudis*) and the American crocodile (*Crocodylus acutus*). This audit report and others note that there are no IUCN Red List species affected, but note that the otter is “Near Threatened” and the American crocodile is “Vulnerable.” This can be confirmed directly at the IUCN.[98]

There do not appear to be any readily available public 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. ASC audit reports note that lethal predator control is not used in this small subset of farms (as a requirement of the standards—Indicator 4.4.1, unless the animal is entangled and must be euthanized), but typical practices in the thousands of other tilapia farms in Colombia are uncertain. 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. Anecdotal reports note an instance of an injured golden eagle in 2016 and crocodile in a net pen farm in 2020 (ASC, 2022d), and an osprey entangled in a predator net of a pond farm, also in 2016.[99]

As noted in Criterion 6—Escapes, Resolution 2879 requires 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. Regarding grow-out ponds, Resolution no. 461 (1995) outlines the anti-bird mesh requirements that all farms must comply with (see Figure 22 and Figure 23), and any farms that do not comply with these requirements can have their permits revoked. But, 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). Although predator nets reduce the interactions with predators, they create an additional risk of entanglement injuries and/or mortalities.

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[98] https://www.iucnredlist.org/

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

Figure 22: Example of bird netting above a fish farm in Colombia. Image source: SEPEC (http://sepec.aunap.gov.co/BancoImagenes/Consulta).

Figure 23: Example of net pen farms in Betania Reservoir covered by bird netting. Image reproduced from ICA.[100]

It can be expected that where there is a risk of significant interactions with wildlife or predators (i.e., a significant risk of predation on the farmed stock), netting or other exclusion devices would be used. Although this is possible for most or all net pen farms in the Betania Reservoir, it appears more challenging in pond farms, particularly those that cover large areas (e.g., the farm in Figure 14).

Conclusions and Final Scores

Because of the visually attractive nature of surface feeding tilapia (particularly red tilapia) to avian predators, interactions are to be expected. ASC audit reports provide some information

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[100] https://www.ica.gov.co/noticias/pecuaria/2015/el-ica-levanta-restriccion-que-prohibia-la-siembra

on the likely species present in Colombia (including birds, otters, and crocodiles), some of which are listed as “Near Threatened” or “Vulnerable” by the IUCN. There are regulations in place regarding the use of predator netting; although examples of their deployment can be found, the extent of their use across the thousands of tilapia farms in Colombia is not known. A risk of entanglement remains. Although there is minor anecdotal evidence of injuries to some animals, including vulnerable species, there are no data available with which to understand if mortalities occur, and if so, at what scale. The extent of interactions with wildlife is therefore largely unknown. Overall, some regulations or management measures are in place that aim to limit wildlife mortalities, but enforcement is unknown and mortality numbers are unknown. The final score for Criterion 9X is a precautionary deduction of –6 out of –10 because of the unknown status.

Criterion 10X: Escape of Unintentionally Introduced Species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- Impact: aquaculture operations by design, management or regulation avoid reliance on the movement of live animals, therefore reducing the risk of introduction of unintended species.

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

Net pens and ponds

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on trans-waterbody movements (%)	100.0	0
Biosecurity score of the source of animal movements (0–10)		6
Biosecurity score of the farm destination of animal movements (0–10)		0
Species-specific score 10X Score		–4.0
C10X Introduction of Secondary Species Final Score		**–4.0**
Critical?	No	Yellow

Brief Summary

New species of zooplankton in the Betania Reservoir and the spread of pathogens such as tilapia lake virus are examples of unintentional introductions of nonnative species during movements of live tilapia into and within Colombia. Although tilapia fingerlings were previously known to be shipped into Colombia from hatcheries in Ecuador, the current scale of this practice is unclear. But, the development of hatcheries in the main tilapia producing departments of Colombia is likely to have reduced it substantially. The importation of smaller numbers of selectively bred tilapia broodstock from breeding centers in Honduras or elsewhere likely continues, but is now accompanied by quarantine and inspection requirements at the port of entry. Although the sources of live animal movements have some potential for biosecurity (e.g., reduced or zero water exchange, along with quarantine and monitoring), the movements of tilapia into and within Colombia continue to present a risk of unintentionally introducing nonnative species. The final score for Criterion 10X—Escape of unintentionally introduced species is –4 out of –10.

Justification of Ranking

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 movements of live fish. For example, by comparing zooplankton samples from 1999, 2007, and 2017 in the Betania Reservoir, Martinez-Silva (2018) noted several new species in the later samples. Although 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 (i.e., tilapia) are transported from other regions of the country in water tanks, bringing microorganisms not found previously in the reservoir. Once these new species get to the Betania Reservoir, they find ideal conditions for their development and establishment and can cause an imbalance in the zooplanktonic community (Martinez-Silva et al., 2018). Similarly, the spread of emerging viruses such as tilapia lake virus (TiLV), which have spread globally, and the sudden arrival in new locations are often associated with live animal movements (Aich et al., 2021).

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

Over a decade ago, Villaneda (2007) reported concerns that unregistered imports of tilapia fingerlings could be entering Colombia from Ecuador and competing with local production by offering a lower price. Later, Welling (2015) noted that local hatchery production had become sufficient to supply net pen farms in Betania Reservoir in Huila. Acuicultores (2016) noted the presence of tilapia hatcheries in Huila and in the lesser tilapia-producing regions of Colombia, and Rojas (2020) noted that there is now production of tilapia fingerlings (both Nile and red tilapia) in all the main productive departments of the country. Thus, the current scale of any international trade in fingerlings (e.g., from Ecuador) in the light of the developing national production of tilapia fingerlings is uncertain.

Nevertheless, the declaration of tilapia as “domesticated” in Colombia (Decree 1071 and Resolution 228, December 2015) allows the importation of genetically improved strains (GIS) of tilapia in order to improve production. These international movements will present a risk of importing unintentional “hitchhiker” species along with the intended tilapia. It is also relevant to note that, in 2019, the ICA and FEDEACUA developed biosecurity (“sanitary”) protocols for the quarantine and monitoring program for imports of live fish (SAC, 2019). These measures imply that importations of live tilapia are ongoing, but it is unclear if these are of limited numbers of GIS tilapia, or larger numbers of fingerlings from international hatcheries (e.g., across the southern border in Ecuador). Acuicultores (2016) implied the former, noting that the scale of international movements is considered to be infrequent, and comprises small numbers of broodstock. According to Resolution 228, the permitted sources of new tilapia strains are limited to breeding centers in the Netherlands and Honduras.

For the purposes of this assessment, considering the apparent established nature of hatchery production in Colombia, it is considered that international imports of live tilapia are indeed likely limited to small numbers of GIS broodstock. Nevertheless, it still appears likely that there are “trans-waterbody”[101] movements of tilapia fingerlings from hatcheries or nurseries to pond farms; however, with the development of hatcheries in all the main productive departments in Colombia (Rojas, 2020), this is perhaps minimized. Without better data on sources and typical movement practices within the tilapia farming system in Colombia, and reflecting the concerns regarding the referenced movements of zooplankton or pathogens within Colombia (Martinez-

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[101] Meaning movements that have the potential to move a hitchhiker species from one waterbody to another where it may not be present.

Silva et al., 2018; Aich et al., 2021), a precautionary assumption is made here that all production is based on trans-waterbody movements of live tilapia. The score for Factor 10Xa is therefore 0 out of 10.

Factor 10Xb—Biosecurity of Source/Destination

Regarding the sources of live tilapia movements, international movements of GIS tilapia are likely to come from tank-based systems with high biosecurity, which is the common practice in selective breeding centers. The quarantine requirements (30 days) are also noted (SAC, 2019). Regarding the movements originating in hatcheries and nurseries within Colombia, these sources are considered to be tank-based systems for hatcheries, with various modified pond systems for the nursery. The latter are considered the least biosecure but likely to have low or zero water exchange, particularly while using hormonal feeds (Daza and Parra, 2019). The biosecurity score for the source is therefore 6 out of 10.

The destinations of live tilapia movements are net pen or pond farms. Net pen farms are considered to be "open" to the environment in terms of the potential release of any hitchhiker species unintentionally included in live tilapia movements. Ponds are considered to be a moderate risk system, with uncertainty regarding the robustness of biosecurity prevention measures. The biosecurity score for the destination of movements is therefore 0 out of 10 for net pens, and 2 out of 10 for ponds.

The final score for Factor 10Xb—Biosecurity of Source/Destination is based on the higher biosecurity score of either the source or the destination (in this case the source), and is 6 out of 10.

Conclusions and Final Score

New species of zooplankton in the Betania Reservoir and the spread of pathogens such as tilapia lake virus are examples of unintentional introductions of nonnative species during movements of live tilapia into and within Colombia. Although tilapia fingerlings were previously known to be shipped into Colombia from hatcheries in Ecuador, the current scale of this practice is unclear. But, the development of hatcheries in the main tilapia-producing departments of Colombia is likely to have reduced it substantially. The importation of smaller numbers of selectively bred tilapia broodstock from breeding centers in Honduras or elsewhere likely continues, but is now accompanied by quarantine and inspection requirements at the port of entry. Although the sources of live animal movements have some potential for biosecurity (e.g., reduced or zero water exchange, along with quarantine and monitoring), the movements of tilapia into and within Colombia continue to present a risk of unintentionally introducing nonnative species. The final score for Criterion 10X—Escape of Unintentionally Introduced Species is –4 out of –10.

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Appendix 1—Data Points and all Scoring Calculations

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

Criterion 1: Data	**Net Pens**	**Ponds**
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	2.5	2.5
Feed	5.0	5.0
Escapes	5.0	5.0
Disease	5.0	5.0
Source of stock	10.0	10.0
Wildlife mortalities	2.5	2.5
Escape of secondary species	2.5	2.5
C1 Data Final Score (0–10)	**5.227**	**4.773**
	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—Ponds
Risk-based assessment

2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	26.964
eFCR	1.700
Fertilizer N input (kg N/ton fish)	17.500
Protein content of harvested fish (%)	14.000
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	90.841
N output in each ton of fish harvested (kg)	22.400
Waste N produced per ton of fish (kg)	68.441

2.1b Production System discharge	**Data and Scores**
Basic production system score	0.510
Adjustment 1 (if applicable)	0.000
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)	0.510
Waste discharged per ton of production (kg N ton^{-1})	34.905
Waste discharge score (0–10)	6.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	4
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	3.200
C2 Effluent Final Score (0–-10)	**5**
Critical?	No

Criterion 3: Habitat	**Net Pens**	**Ponds**
F3.1. Habitat conversion and function	**Data and Scores**	**Data and Scores**
F3.1 Score (0–10)	9	7
F3.2. Management of farm-level and cumulative habitat impacts		
3.2a Content of habitat management measure	4	3
3.2b Enforcement of habitat management measures	3	2
3.2 Habitat management effectiveness	4.800	2.400
C3 Habitat Final Score (0–10)	**7.600**	**5.467**
Critical?	No	No

Criterion 4: Chemical Use—Net Pens and Ponds	
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	**Net Pens**	**Ponds**

5.1 Wild Fish Use		
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	2.000	2.000
Fishmeal from by-products, weighted inclusion %	4.000	4.000
By-product fishmeal inclusion (@ 5%)	0.200	0.200
Fishmeal yield value, weighted %	22.500	22.500
Fish oil from whole fish, weighted inclusion level %	0.660	0.666
Fish oil from by-products, weighted inclusion %	1.333	1.333
By-product fish oil inclusion (@ 5%)	0.067	0.067
Fish oil yield value, weighted %	5.000	5.000
eFCR	1.700	1.700
FFER Fishmeal value	**0.166**	**0.166**
FFER Fish oil value	**0.247**	**0.249**
Critical (FFER >4)?	No	No

5.1b Sustainability of Source fisheries	**Data and Scores**	**Data and Scores**
Source fishery sustainability score	5.050	5.050
Critical Source fisheries?	No	No
SFW “Red” Source fisheries?	No	No
FFER for Red-rated fisheries	n/a	n/a
Critical (SFW Red and FFER ≥1)?	No	No
Final Factor 5.1 Score	**7.150**	**7.150**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**	**Data and Scores**
Weighted total feed protein content	28.874	26.964
Protein INPUT kg/100 kg harvest	49.086	45.838
Whole body harvested fish protein content	14.000	14.000
Net protein gain or loss	–71.478	–69.458
Species-specific Factor 5.2 score	**2**	**3**
Critical (Score = 0)?	No	No
Critical (FFER >3 and 5.2 score <2)?	No	No

5.3 Feed Footprint	**Data and Scores**	**Data and Scores**
GWP (kg CO_2-eq kg^{-1} farmed seafood protein)	**22.383**	**22.382**
Contribution (%) from fishmeal from whole fish	0.939	0.939
Contribution (%) from fish oil from whole fish	0.212	0.214
Contribution (%) from fishmeal from by-products	2.852	2.852
Contribution (%) from fish oil from by-products	0.656	0.656
Contribution (%) from crop ingredients	86.158	86.156
Contribution (%) from land animal ingredients	5.354	5.354
Contribution (%) from other ingredients	3.829	3.829

Factor 5.3 score	**4**	**4**
C5 Final Feed Criterion Score	**5.1**	**5.3**
Critical?	**No**	**No**

Criterion 6: Escapes	**Net Pens**	**Ponds**
	Data and Scores	**Data and Scores**
F6.1 System escape risk	2	4
Percent of escapees recaptured (%)	0.000	0.000
F6.1 Recapture adjustment	0.000	0.000
F6.1 Final escape risk score	2.000	4.000
F6.2 Invasiveness score	6	6
C6 Escape Final Score (0–10)	**4.0**	**5.0**
Critical?	No	No

Criterion 7: Disease—Net Pens and Ponds	**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—Net Pens and Ponds	**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—Net Pens and Ponds	**Data and Scores**
Single species wildlife mortality score	–6
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**–6**
Critical?	No

Criterion 10X: Introduction of Secondary Species—Net Pens and Ponds	**Data and Scores**
Production reliant on trans-waterbody movements (%)	100
Factor 10Xa score	0
Biosecurity of the source of movements (0–10)	6
Biosecurity of the farm destination of movements (0–10)	0
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