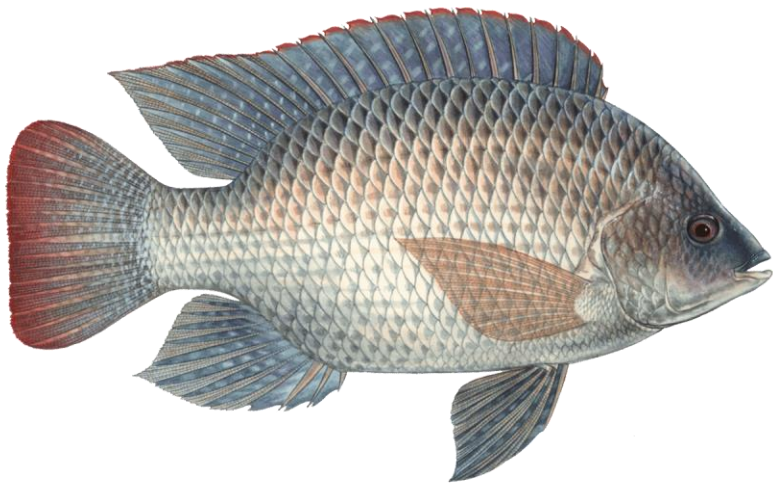
Monterey Bay Aquarium Seafood Watch®

Tilapia

Oreochromis spp.



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Colombia

Net Pens

Aquaculture Standard Version A3.2

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Seafood Watch Consulting Researchers

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Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	3.41	YELLOW	
C2 Effluent	4.00	YELLOW	NO
C3 Habitat	5.47	YELLOW	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	8.24	GREEN	NO
C6 Escapes	5.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	–6.00	YELLOW	NO
C10X Introduced species escape	–0.40	GREEN	
Total	**27.72**		
Final score (0–10)	**3.96**		

OVERALL RANKING

Final Score	3.96
Initial rank	YELLOW
Red criteria	0
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
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 result in a Red final result.

Summary

The final numerical score for tilapia produced in net pen cages in Colombia is 3.96 out of 10, which is at the lower end of the Yellow range. With no red criteria, the final recommendation is "Yellow" or "Good Alternative."

Executive Summary

Global production of tilapia is currently estimated to be approximately 4.5 million metric tons (MT), and is predicted to increase to 7.3 million MT by 2030. With an annual production of approximately 52,000 MT (2012 data), Colombia is one of the world's largest producers (following China, Egypt, Philippines, Thailand, Indonesia, Laos, Costa Rica, and Ecuador), and one of the top three exporters into the U.S. market, with China and Indonesia. The United States is the world's largest importer of tilapia, consuming 225,000 MT 2014 and importing 5,394 tons from Colombia in 2015.

Small-scale extensive tilapia farms that produce for local consumption are common in Colombia, but farms that export to the United States primarily use intensive net pen production systems. Approximately 30,000 MT (more than half of Colombia's total production) is produced in floating net pens in the Betania Reservoir in the Department of Huila. Huila accounts for 44% of Colombia's total aquaculture production (103,000 tons in 2015).

The industry is regulated through the National Authority for Aquaculture and Fisheries (Autoridad Nacional de Acuicultura y Pesca, AUNAP), under various government ministries including the Ministry of Agriculture and Rural Development (Ministerio de Agricultura y Desarrollo Rural), the Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible), and the Colombian Agricultural Institute (Instituto Colombiano Agropecuario, ICA). The industry is also represented by the Colombian Aquaculture Federation (Federación Colombiana de Acuicultores—FEDEACUA). There have been considerable changes to the industry's management over the last decade, and new regulations continued to be issued while this Seafood Watch assessment was made in 2015–2016. A number of companies are certified to schemes such as the Global Aquaculture Alliance Best Aquaculture Practices (GAA BAP) or the Aquaculture Stewardship Council (ASC), and FEDEACUA has projects to encourage farms to improve and to obtain certification.

In November 2015, the government in the Department of Huila in southwest Colombia funded and initiated a project to improve the sustainability of production in the Betania Reservoir by improving environmental monitoring and data availability, providing better training for farmers, improving fish health management, and fostering greater cooperation between the producers. The results of this new project will be of considerable interest to future revisions of this assessment.

Overall, there is considerable room for improvement in the quality of data available on environmental impacts and their management with regard to tilapia aquaculture in Colombia. Piecemeal information is available from a variety of sources, and many of them are anecdotal. Information from the Colombian Aquaculture Federation (FEDEACUA) is useful (particularly a summary of regulations, and its magazine *Acuicultores*) but is sometimes aggregated, as are data from the various regulatory bodies. There are a limited number of peer-reviewed studies that focus on tilapia production systems, and many are dated and of little current relevance.

Some detailed feed data were provided on request. Three tilapia farms in the Betania reservoir are currently certified to one or both of the Aquaculture Stewardship Council (ASC) and the Global Aquaculture Alliance (GAA); public availability of data within these audit reports is highly variable, but GAA audit reports (which are not usually publicly available) were provided by FEDEACUA. Across the range of subjects assessed by Seafood Watch, multiple gaps in data availability are apparent. Overall, the score for Data Quality and Availability is 3.4 out of 10.

Despite the open nature of net pen cages and resulting loss of soluble and particulate wastes, the relatively low protein content of tilapia feed results in a moderate amount of nitrogenous waste discharged per ton of fish produced (40.1 kg N ton^{-1}). With the establishment of AUNAP in 2011, carrying capacity limits for Betania Reservoir were established, and more recently (in 2015), production models have been created to enable better control of production capacity and site licenses. Nevertheless, large fish die-offs in early 2015 were potentially caused by secondary factors related to overproduction (such as higher than average water temperatures) and there is limited evidence (i.e., publicly available data) to understand if the cumulative impacts of the industry are being collectively managed. The government of the Department of Huila has begun a project to improve the monitoring and management of the industry in the reservoir with the aim of making the production more sustainable, but the outcomes are not yet known. Until the improvements are supported with robust monitoring data, the final score for the Effluent Criterion is 4 out of 10.

With regard to habitat impacts, the Betania Dam was commissioned in 1987, and the human-made nature of the waterbody makes it challenging to assess the habitat impacts of the tilapia production. The floating net pen structures have little direct impact on habitats; however, the operations at the scale and intensity seen in the Betania Reservoir clearly have the potential to affect the waterbody (which was primarily assessed in Criterion 2 – Effluents) and thus affect the ecosystem services it provides. The tilapia industry depends on the ongoing functionality and the ecosystem services of the reservoir, yet the scale and intensity of production appears to be approaching and potentially exceeding the reservoir's carrying capacity on occasion, particularly in extreme circumstances such as high temperature and low water flows. There is some overlap with the Effluent Criterion with regard to the management of cumulative impacts, and considering the human-made nature of the site, the Habitat Criterion score is 5.47 out of 10.

Little public data are available on chemical use in Colombia, but with the intensive production and known bacterial and viral diseases of tilapia, the potential use of chemical treatments such as antibiotics must be accepted unless data can be provided that show otherwise. Encouragingly, three large farms in Betania Reservoir (including the largest) are certified to GAA and/or ASC, and audit reports show that antibiotics have not been used in recent production cycles. The most recent regulations on the control of chemical use are from 2007, and the AUNAP project initiated in late 2015 to improve the sustainability of production in the Betania Reservoir mentions the testing of antibiotics as one potential tool to improve fish health. The use of low levels of hormones for short periods in the hatchery feeds is considered common practice to produce all-male tilapia populations, and studies show that this has minimal environmental (or human health) concerns when best practices are employed. Overall, the independent audit reports, which show that large exporting net pen farms in Colombia have not recently used antibiotics, are encouraging and dictate a high score. Yet there is clearly a concern that chemical use, particularly antibiotics, could be happening in other farms in potentially increasing amounts to treat disease outbreaks when they occur. Therefore, the lack of publicly available data and a precautionary approach mean that the most appropriate score for the Chemical Use Criterion is 4 out of 10.

Tilapia is omnivorous and typically does not require large inputs of fishmeal and fish oil in commercial feeds; data provided for multiple feeds from one feed company, and provided anonymously from FEDEACUA, give weighted average inclusion levels of fishmeal and fish oil over a typical production cycle of 4.95% and 1.02%, respectively. The data also showed that the use of fishmeal and oil from dedicated fisheries appears to be limited to starter feeds, which represent a quite small part of the total ration provided over the production cycle. Therefore, the calculated Forage Fish Efficiency Ratios were close to zero (0.004), giving a high Wild Fish Use score of 9.98 out of 10. With high levels of edible crop ingredients in the feed, there was a calculated net edible protein loss of 46.3% and a low feed footprint of 3.2 hectares per ton of production. These aspects combine to give a final Feed Criterion score of 8.24 out of 10.

Tilapia was introduced into Colombia and became established in the 1960s, before the aquaculture industry had begun, and the government had been actively stocking tilapia into the country's freshwater bodies. For aquaculture purposes, tilapia had been legally defined as an introduced invasive species by the Colombian government, but new regulations in December 2015 declared them (Nile and red tilapia, along with rainbow trout) "domesticated." Although the new resolution recognizes the threat from additional escapes and prevents further active stocking, tilapia are considered fully established for the purposes of this assessment. Net pen aquaculture systems for tilapia carry a high risk of escape, but there are no data available on escape events in Colombia or on post-escape recaptures. But potential impacts are limited when the species has been historically introduced and actively stocked into the environment, and the final Escape Criterion score is therefore a moderate 5 out of 10.

Several disease outbreaks have been recorded for tilapia produced in Colombia, and in many cases these diseases are capable of spreading to other species. Streptococcal bacterial infections are a common problem, and a viral hepatitis pathogen was one of several potential factors related to a large die-off of tilapia in the Betania Reservoir in early 2015. Net pen production systems are open, so pathogens could be released from the system and infect other wild species. But because of the human-made nature of the Betania Reservoir, the status of wild populations and the impact on them from farm-origin pathogens (if any) is unknown. Improving fish health and data availability in the Betania Reservoir is a key goal of the recently initiated project by the government of Huila. Because of the current lack of data, the Seafood Watch risk-based assessment was used. The production system's openness to the introduction and discharge of pathogens with unknown impacts on wild species leads to a moderate score of 4 out of 10.

As a nonnative species, all tilapia seed in Colombia is produced in hatcheries, with no use of wild broodstock or seed. For example, Colombia's largest producer, Piscicola Botero, has hatcheries located on islands in the Betania Reservoir and produces 6 million fingerlings per month (Welling 2015). 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.

Studies from more than 10 years ago report considerable mortalities of birds in pond tilapia farms in Colombia, but no recent data are available for the net pen farms in Betania Reservoir. Anti-bird nets are required, and farms certified to the ASC with publicly available audit reports document the lack of lethal predator controls; however, they note that the osprey *(Pandion haliaetus)* is an endangered migrant that utilizes the lake. Little is known about the predator controls on the noncertified farms in the reservoir. There are not considered to be mortalities of birds or other predators beyond exceptional cases, but the presence of ospreys requires a more precautionary approach until more data are made available. The score for Criterion 9X is therefore a moderate deduction of –6 out of –10.

Although there were some now-dated concerns that movements of tilapia fingerlings from hatcheries in Ecuador to Colombia represented a potential source of unintentionally introduced nonnative species, the now-mature industry in Colombia and the available evidence indicate that the country is self-sufficient in seed supply. Nevertheless, the recent designation of tilapia in Colombia as a "domesticated" species allows the importation of selectively improved tilapia strains to improve production. The numbers are considered likely to be low, and the biosecurity of the source breeding centers is considered to be moderate. Overall, there is a low risk of introducing nonnative species during the live animal shipments, and the score for Criterion 10X is a small deduction of 0.4 out of –10.

Overall, the final numerical score for tilapia produced in net pen cages in Colombia is 3.96, which is at the lower end of the "yellow" range. With no "red" criteria, the final recommendation is a yellow "Good Alternative."

Introduction

Scope of the analysis and ensuing recommendation

Species
Nile Tilapia and Red Tilapia (*Oreochromis niloticus* and hybrid *Oreochromis* spp.)

Geographic coverage
Colombia

Production Methods
Freshwater net pens

Species Overview

Tilapia is farmed in over 100 countries, but is native to Africa (Fitzsimmons 2011). Three genera fall under the common name tilapia: *Oreochromis* (maternal mouthbrooders), *Sarotherodon* (paternal or biparental mouthbrooders), and *Tilapia* (substrate spawners). This assessment is based on black or Nile tilapia *(Oreochromis niloticus)* and hybrids of multiple species within the genus *Oreochromis*, collectively known as red tilapia. Tilapia is tolerant of wide environmental fluctuations (Lowe-McConnell 1987) (Boyd 2004) (Fitzsimmons 2007). It is also omnivorous, requires little inputs of fishmeal and fish oil, and is capable of spawning year-round (Lowe-McConnell 1987) (Naylor et al. 2000) (FAO 2012).

Production statistics
According to data from the United Nations Food and Agriculture Organization (FAO), global production of tilapia increased from 1,417,412 metric tons (MT) in 2002 to 4,506,877 MT in 2012 (FAO 2014a), with the majority (72%) farmed in Asia, followed by Africa (19%) and the Americas (9%) (FAO 2012). According to Bacharach et al. (2016), the largest producers (in order) are China, Egypt, Philippines, Thailand, Indonesia, Laos, Costa Rica, Ecuador, Colombia, and Honduras.

Tilapia production in Colombia was fairly steady (≈25,000 metric tons annually) from 2002 to 2007, but began to increase, reaching 52,688 MT in 2012 and representing ≈1% of global tilapia production that year (FAO 2014a). More than 50% of Colombia's tilapia production takes place in net pens in the Betania Reservoir in the Department of Huila, where approximately 30,000 MT of tilapia are produced annually (Pulido et al. 2015). The Department of Huila produced 44% of Colombia's total aquaculture production (all species) of 103,000 tons in 2015 (SIOC 2016).

Import and export statistics
The United States is the leading importer of tilapia globally, and consumes 225,000 MT of tilapia annually (Bacharach et al. 2016). Exports of tilapia to the United States from Colombia were relatively high in the early 1990s but declined rapidly into the early 2000s because of an

increase in local demand; they then increased again after the signing of the United States–Colombia Trade Promotion Agreement in 2006 (NMFS 2015). In 2012, exports of *Oreochromis* spp. from Colombia to the United States reached approximately 2,904 MT, growing to 3,876 MT in 2013 and 4,141 MT in 2014 (NMFS 2015). The Colombian Ministry of Agriculture and Rural Development claims Colombia is now the second-largest exporter of fresh fillets to the United States, with 5,394 MT in 2015 (MARD 2016).

Table 1. Scientific and market names

Scientific Name	*Oreochromis* spp.
Common Name	tilapia
United States Market Name	izumidai
Spanish	mojarra
French	tilapia du Nil
Japanese	chikadai

Product forms

Fresh or frozen fillets, but exports to the United States are dominated by fresh fillets.

Production system

Tilapia production systems in Colombia are primarily earthen ponds and floating net pen cages in human-made reservoirs, with rapid growth in the net pen production sector (FAO 2014b). The main production sectors are the departments of Huila, Tolima, Antioquia, Santander, Meta, and Valle del Cauca, which together contribute 75% of the total production (FAO 2014b). Fish produced for export to the United States are grown primarily in net pen cages in the Betania Reservoir in the Department of Huila (FAO 2014b).

The five large tilapia farms in the Betania Reservoir that export tilapia products to the United States are 1) Piscicola New York; 2) Proceal S.A.; 3) C.I. Fish Co.; 4) Piscicola Botero; and 5) Comepez S.A. (Hidrósfera 2003) (Import Genius 2014) (pers. comm., Schwarz 2015). These five farms use net pen production systems, as do almost all of those in the Huila region. Currently, more than 50% of Colombia's tilapia production occurs in net pens in the Betania Reservoir (Welling 2015), and this production for export is the focus of this assessment.

Three tilapia farms in Colombia are currently certified to both the Aquaculture Stewardship Council (ASC) and the Global Aquaculture Alliance (GAA): PezCo Aquafarming/Piscicola Botero, Piscicola Rosario (a pond farm), and Proceal Farm; and a fourth, Piscicola New York S.A., is certified to GAA only. There is a push to drive farmers in Colombia toward international certification through FEDEACUA (Bonilla 2016).

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

Data Category	Data Score	Score (0–10)
Industry or production statistics	5	5
Management	5	5
Effluent	2.5	2.5
Habitat	2.5	2.5
Chemical use	5	5
Feed	5	5
Escapes	2.5	2.5
Disease	2.5	2.5
Source of stock	5	5
Predators and wildlife	0	0
Introduced species	2.5	2.5
Other – (e.g., GHG emissions)	Not Applicable	n/a
Total		**37.5**

C1 Data Final Score (0–10)	**3.4**	**YELLOW**

Brief Summary

Overall, there is considerable room for improvement in the quality of data available on the environmental impacts and their management for tilapia aquaculture in Colombia. Piecemeal information is available from a variety of sources, and many of them are anecdotal. Public information from the Colombian Aquaculture Federation (FEDEACUA) is limited (although a summary of regulations and their magazine *Acuicultores* are useful) and aggregated, but some audit reports and feed company data were provided on request. There are a limited number of peer-reviewed studies that focus on tilapia production systems, and many are dated and of little current relevance. Overall, the score for Data Quality and Availability is 3.4 out of 10, and the limited data lead to some low scores in other criteria because of the necessary application of a precautionary approach.

Justification of Ranking

There are no central locations for the documentation of aquaculture in Colombia. Information and data must be collected piecemeal from various sources within the government, the industry, the scientific literature, gray literature, and indirect sources such as farm certification audit reports. The majority of the information is only available in Spanish, which makes it difficult for consumers and major buyers in importing countries such as the United States to understand the industry and its environmental impacts.

Industry and Production Statistics

National production statistics for tilapia are available in some FAO documents and databases (e.g., FAO-INCODER 2011 and FishStat [estimated for some years]) but are not fully up to date. Colombia's Ministry of Agriculture and Rural Affairs provides production figures in the form of news updates and articles (e.g., MARD 2016), and the website of the Colombian Aquaculture Federation (FEDEACUA) has data separated only by fish and crustacea (i.e., it is not possible to separate tilapia data specifically). Formal statistics are not readily apparent. A recent regulation (January 2016) launched the Registry of Livestock Establishments Aquaculture (Registro Pecuario de los Establecimientos de Acuicultura, RPEA), which for the first time will document farm locations and production; however, no information is published yet. AUNAP has a database of permits, but in 2012 it indicated a total of 375 "Permits for Culture," or approximately 1.3% of an estimated 29,500 farms operating in Colombia (AUNAP 2012). The locations of the industry must therefore be gathered largely from anecdotal evidence and communications with experts in the industry, or from statements in the literature and government documents (e.g., (Hidrósfera 2003) (FAO-INCODER 2011)) on the concentration of large-scale aquaculture operations for export in the country (i.e., Betania Dam, Huila region). Aquaculture industry articles and company websites (e.g., (Welling 2015) (FEDEACUA 2016)) provide further unconfirmed details. Overall, there is some useful but incomplete information available, and the data score for Industry or Production Statistics is 5 out of 10.

Management and Regulations

The industry trade body, Federación Colombiana De Acuicultores (FEDEACUA), has good information documenting and listing the regulatory structures in Colombia, and it lists sections of relevance to this assessment. But the information and the regulations are all in Spanish, and there is only occasional anecdotal evidence to articulate the practical reality of these regulations with regard to tilapia produced for export to countries such as the United States. FEDEACUA's magazine, *Acuicultores*, has some useful articles with background information on the industry and recent developments in regulations, and the organization provided some certification audit reports (and feed data – see below) on request. Overall, the data score for Management and Regulations is 5 out of 10.

Effluent and Habitat

Monitoring records relevant to effluent and habitat impacts are available in several reports but are subject to some temporal and spatial averaging and may show data gaps. For example, in-depth water quality monitoring studies were conducted in the Betania Reservoir for the periods of 2003 and 2012–2013, but these two studies did not cover all the same sites for easy temporal comparison (Hidrósfera 2003) (CAM 2014). Studies on net pen tilapia in other countries provide some useful information that can be extrapolated to similar production systems in Colombia; for example, Neto and Ostrensky (2015) examined the nutrient loads in the waste of Nile tilapia production in net pens in Brazil.

Some data on effluent and habitats are available for those farms that are audited by independent certification companies (e.g., the Aquaculture Stewardship Council [ASC] and the Global Aquaculture Alliance Best Aquaculture Practices [GAA]), but the temporal coverage of these audits is limited, and not all information is available in the audit reports (e.g., (ASC 2015)).[1] FAO reports and online databases (e.g., NALO) were the major contributors to the data used in assessing habitat functionality and effluent management effectiveness. Several governmental articles and reports (e.g., (La Nación 2013) (AUNAP 2014a) (AUNAP 2014b) (AUNAP 2014c)) make note of recent improvements in the enforcement of water quality regulations, but it is unknown whether these efforts are sufficient. Recent reports indicate that overproduction may be a factor in recent fish die-offs in the Betania Reservoir (Pulido et al. 2015), but there is insufficient evidence to confirm the cause. Attempts at direct communication with experts in Colombia were not successful, and given this practical example of an inability to understand a key aspect of the effluent and habitat impacts of the industry, the data scores for the Effluent and Habitat Criteria are 2.5 out of 10.

Chemical Use

Although regulations on permitted and prohibited chemicals are available in Spanish, the text is confusing and it is difficult to interpret the current permitted use. Data on the amount or types of antibiotics, pesticides, or other chemicals used on farms could not be found for Colombia, but specific data on antibiotic use for three of the five largest companies (two of the three are ASC-certified, and all three are GAA-certified) are available in their audit reports (either publicly from ASC 2015[2], or provided confidentially by FEDEACUA). But ultimately, useful data on chemical use in general are quite limited across all the net pen tilapia farms in Colombia, and the data score for the Chemical Use Criterion is 5 out of 10.

Feed

Published feed information specific to Colombia is quite limited, and the available academic references are considered dated (e.g., (Gonzalez 2001) (Hidrósfera 2003) (Pompa and Rodriquez 2007) (Zubieta 2007) (Tacon and Metian 2008)). But requests to FEDEACUA and feed companies yielded three feed datasets: two from the same company were for average tilapia feeds and a company-specific profile, and the third was provided anonymously through FEDEACUA. The combined data allow a detailed analysis of the ingredients and inclusion levels, but there is a possibility that all three sources are from the same company and therefore potentially do not reflect tilapia feeds overall for net pens in Colombia. Information on the use of by-products from fish processing, including the amount of each by-product created and used annually, was provided by farmers (pers. comm., Vera 2015). Overall, some detailed data were

[1] http://www.asc-aqua.org/index.cfm?act=tekst.item&iid=4&iids=204&lng=1#qdsfdswutjes

[2] http://www.asc-aqua.org/index.cfm?act=tekst.item&iid=4&iids=204&lng=1#qdsfdswutjes

provided, but it is not clear if the data fully reflect all tilapia feeds used in net pens in Colombia; thus, the data score for Feed is 5 out of 10.

Escapes

Data availability is low to moderate for escapes because no detailed records of escapees or recaptures exist. There is some evidence of Best Management Practices to limit escapees for the net pen cage systems in the Betania Reservoir, but effectiveness of and compliance with these measures is uncertain (Resolution no. 461 of 1995) (BAP 2012) (IMO Group 2013). Furthermore, detailed information exists on the invasive potential of some tilapia species, but little exists on that of red tilapia beyond anecdotal evidence that it suffers high predation mortality in the wild (Fitzsimmons 2014). Because of the recent government Resolution to describe tilapia as a “domesticated” species in Colombia, some anecdotal evidence is now available in articles that describe the previous introductions and government stocking of the species. Overall, this gives some confidence in the situation regarding potential escapes, and the data score for Escapes is 5 out of 10.

Disease

Data availability on Disease is low to moderate and is largely in the form of published peer-reviewed studies (e.g., (Camus et al. 1998) (Fitzsimmons 2000) (Iregui 2004) (Hernandez et al. 2009) (Iregui et al. 2011) (Garcia et al. 2012) (Iregui et al. 2012) (Barato 2015) (Bacharach et al. 2016)). Though tilapia diseases prevalent in Colombia are known to have the potential to influence wild populations (Camus et al. 1998) (Iregui 2004), little focus has been given to the impact of disease on the surrounding ecosystem. Furthermore, no records exist as to whether improved vaccinations for tilapia disease are being used in the country. The data score for the Disease Criterion is 2.5 out of 10.

Source of stock

Data availability for Source of stock is moderate. Villaneda (2007), which is dated, provided detailed information on the source of stock in the country, but there are no updated reports with which to confirm this information for the current industry. Industry media reports on individual farms indicate that the large farms have their own hatcheries in Colombia, and in the case of the largest farm (Botero), the hatcheries for red tilapia are located on islands in Betania Reservoir itself (Welling 2015). The data score for the Source of stock Criterion is 5 out of 10.

Wildlife and Predator Mortalities

Data availability for wildlife mortalities is also quite limited. One dated study by Bechard and Marquez-Reves (2003) focused on pond production systems and found that as many as 50% use shooting as a method of reducing bird depredation, but the relevance to current net pen systems is clearly unknown. There are no farm-level records of wildlife mortalities for the production system and location of interest. The data availability score for Wildlife and Predator Mortalities is 0 of 10.

Unintentionally Introduced Species

In the past, some seed production may have originated in Ecuador, but it has not been possible to confirm if this is still the case, and the biosecurity of these production systems is unknown. The Resolution describing tilapia as a "domesticated" species has opened up the possibility of introducing genetically improved broodstock strains into Colombia; these are apparently primarily from Holland and Honduras. This information provides minimal assistance to the Introduced Species Criterion (10X), and the data score is 2.5 out of 10.

Conclusions and final score

Data availability in general is very low in Colombia, with little robust information on the aspects considered in this Seafood Watch assessment. Direct contacts made with the industry were limited in response; overall, this limits the ability to perform a robust assessment. Thus, the score for Criterion 1, Data Quality and Availability, is 3.4 out of 10.

Criterion 2: Effluents

Impact, unit of sustainability and principle

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

Criterion 2 Summary

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton^{-1})	50.10		
F2.1b Waste discharged from farm (%)	80		
F2.1 Waste discharge score (0–10)		5	
F2.2a Content of regulations (0–5)	2		
F2.2b Enforcement of regulations (0–5)	3		
F2.2 Regulatory or management effectiveness score (0–10)		2.4	
C2 Effluent Final Score		**4**	**YELLOW**
Critical?	No		

Brief Summary

Despite the open nature of net pen cages and resulting loss of soluble and particulate wastes, the relatively low protein content of tilapia feed results in a moderate amount of nitrogenous waste discharged per ton of fish produced (40.1 kg N ton^{-1}). With the establishment of AUNAP in 2011, carrying capacity limits for Betania Reservoir were established, and more recently (in 2015), production models have been created to enable better control of production capacity and site licenses. Nevertheless, large fish die-offs in early 2015 were potentially caused by secondary factors related to overproduction (such as higher than average water temperatures) and there is limited evidence (i.e., publicly available data) to understand if the cumulative impacts of the industry are being collectively managed. The government of the Department of Huila has begun a project to improve the monitoring and management of the industry in the reservoir with the aim of making the production more sustainable, but the outcomes are not yet known. Until the improvements are supported with robust monitoring data, the final score for the Effluent Criterion is 4 out of 10.

Justification of Ranking

Because the effluent data quality and availability score is only moderate (i.e., Criterion 1 score of 5 of 10 or lower for the Effluent category), the Seafood Watch Risk-Based Assessment was utilized. This method involves assessing the amount of waste produced by the fish and then the amount of that waste that is discharged from the farm. The effectiveness of the regulatory system in managing wastes from multiple farms is used to assess the potential cumulative impacts from the industry as a whole.

It is interesting to note that 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 (Pulido et al. 2015). Several other potential causes were noted (rancid diets, viral agents, high ambient temperatures and low dissolved oxygen, and other opportunistic pathogens). Therefore, high effluent waste concentrations from overproduction cannot be determined as the cause; however, they are kept in mind through the discussions in this section on a precautionary basis. A study conducted in 2003 found that the system behaved as a eutrophic one in the low water season due to a high phosphorus load, but that phosphorus levels are diluted during high water levels (Hidrósfera 2003). Thus, it is important that the management system be sophisticated enough to take account of unusual events, such as low water flows and higher temperatures also associated with the 2015 mortality event.

Factor 2.1a Waste Discharged per ton of fish

Calculations in the Seafood Watch Aquaculture Standard for the amount of waste discharged per ton of fish are based on nitrogen, because this is the most data-rich proxy indicator for aquaculture nutrient inputs and waste outputs. Phosphorous may be a more important limiting nutrient in freshwater systems, and with regard to the Betania Reservoir, Hidrósfera (2003) found that the system behaved as a eutrophic one in the low water season due to a high phosphorus load, but that phosphorus levels are diluted during high water levels. As a proxy for the nutrients discharged, the nitrogen waste produced per ton of fish is calculated using the nitrogen input per ton of fish and the harvested nitrogen per ton of fish. The nitrogen input per ton of fish is the product of the protein content of feed, a fixed protein nitrogen content factor of 0.16 (protein is 16% nitrogen), and the economic feed conversion ratio (eFCR). Although nitrogen fertilizer inputs may be added to this calculation, fertilizers are not used in net pen aquaculture in Colombia (FAO-INCODER 2011). The harvested nitrogen per ton of fish is calculated by multiplying the protein content of a harvested whole fish and the fixed protein nitrogen content factor.

The eFCR value and weighted average protein content over a production cycle are 1.59 and 28.5%, respectively (see Criterion 5 – Feed for further information on these values). The protein content of a whole harvested farmed tilapia is 14% (Boyd 2007). As a result, the nitrogen input per ton of fish produced is 72.5 kg N t^{-1} and the harvested nitrogen per ton of fish produced is 22.4 kg N t^{-1}, so that, on average, there is 50.1 kg N t^{-1} of waste nitrogen produced for every ton of fish produced. This value, calculated according to the Seafood Watch Aquaculture Standard, is quite close to that calculated by Neto and Ostrensky (2015) of 44.95 kg N per ton of production.

Factor 2.1b Production System Discharge

The amount of waste that enters the surrounding ecosystem depends on how open the production system of interest is or, in the case of a closed system, how regularly water exchanges are made throughout the grow-out process. Net pen aquaculture is generally assumed to have an increased nutrient loss compared to closed systems, given that uneaten feed and fecal waste can easily be transmitted untreated to the environment (Halwart et al. 2007). Thus, Seafood Watch considers net pens to discharge 80% of the nitrogenous waste as effluent (the remaining 20% of nitrogenous waste remains within the immediate vicinity of the farm and is considered in Criterion 3 – Habitat). An adjustment of 0.8 is therefore applied. It is important to note that water from this reservoir may be used for local irrigation and therefore aquaculture waste products may reduce the need for fertilizer use on nearby land.

The Factor 2.1 score is the product of the amount of waste produced (Factor 2.1a) and the production system discharge (Factor 2.1b). Factors 2.1a and 2.1b combine to give a net nutrient discharge of 40.1 kg N t^{-1}, and a score of 5 of 10 for Factor 2.1.

Factor 2.2 Management of farm-level and cumulative impacts

Factor 2.2a Intent and content of effluent regulations and management measures
This factor addresses the cumulative impacts of multiple farms on the receiving environment, with a focus on areas beyond the immediate vicinity of the farms.

Colombia has a variety of regulations relating to aquaculture. The Colombian Federation of Fish Farmers (Federación Colombiana De Acuicultores, FEDEACUA) provides a summary,[3] including sections on the development of the industry, conditions of culture, and environmental conservation. The large number of laws, resolutions, and decrees listed in the summary makes a detailed understanding of the regulatory content challenging for this assessment. In 2011, the National Authority for Fisheries and Aquaculture (AUNAP) was created within the Ministry of Agriculture and Rural Development (MADR), and AUNAP is in charge of implementing domestic policies (pers. comm., Rengifo, AUNAP 2017). There have also been recent developments; for example, in January 2016, Resolution 64 was enacted to require the registration of all aquaculture farms in Colombia, which had not been the case before.

Of practical relevance to this assessment of tilapia production in the Betania Reservoir is the anecdotal information available regarding a project funded and enacted in December 2015 and January 2016 to improve the sustainability of production in the lake (Pulido et al. 2015). The project was formulated in 2013 after demand from the producers for concrete actions to support the industry, and it was funded by Acuapez within the government of the Department of Huila (within the Coporación Centro de Desarrollo Tecnológico Piscícola Surcolombiano). The project has four goals relating to the division of the reservoir into eight micro-production zones, and according to a translation of Pulido (2016) they are:

[3] http://www.fedeacua.org/assets/uploads/files/3fbc1-MATRIZ-UNICA-NORMATIVA---03--03-2016.pdf. Accessed July 15, 2016.

- A network of real-time environmental water quality data will be collected and made accessible to all producers. This will complement fish health monitoring and help to give early warnings of any problems.
- Regular training in fish biology, aquaculture practices, fish health and biosecurity, and feed will be conducted for the producers. This will complement Best Practices for Production of Aquaculture (BPPA) for all producers.
- Fish health will be improved based on experiments in each microzone using experimental cages to test different alternatives to prevention and control that suit the characteristics of the lake. This will generate a health protocol for each microzone.
- Greater integration of management among the producers, particularly including small- and medium-sized growers, will help improve the sustainability of the Betania production system.

The various sectors involved came to agreement in May 2014 and the Department of Huila signed the subsequent papers in November 2015. Because this is clearly a recent development, it is not yet known how successful it will be in improving the management of total production and cumulative impacts in the reservoir.

More broadly, wastewater discharge in Colombia is regulated under one law (Law No. 9 of 1979) and two legislative decrees (Decree No. 2.811 of 1974 and Decree No. 1594 of 1984). These regulations are applicable to aquaculture, but were not specifically developed with aquaculture in mind. Water use rights for aquaculture facilities also require a permit from the Autonomous Corporation of Upper Magdalena (CAM) (Coze and Nava 2009) (FAO 2014b). Included in the functions of CAM is the development of environmental indicators that allow for the conservation of national heritage and sustainable use of biodiversity (Resolution 643 of 2004). But the limits used for these indicators are not listed in the wastewater regulations.

Regarding relevant legislation of waste management based on the cumulative impacts of multiple farms, an in-depth study on the load capacity of Betania Dam reservoir was conducted in 2003 (Hidrósfera 2003). The study produced a carrying capacity estimate of 470,402 MT of tilapia for the reservoir, using data on a number of parameters including food conversion ratios, average depth of sites, average input flow, and the phosphorus content of feed. More recently, after the establishment of AUNAP in 2011, a much smaller fish carrying capacity of 22,000 MT was established for the Betania Reservoir, and a revised infrastructure requirement to produce that volume of fish was implemented. But in 2015, a production model was created for the lake to allow current and future assessment, monitoring, and control of additional production over the carrying capacity limit (pers. comm., Rengifo, AUNAP 2017). Although it appears that such additional production will be assessed and/or approved on a site-by-site basis with specific volume allocations (pers. comm., Rengifo, AUNAP 2017), it is unclear what indicators will be used for the assessment or what parameters/thresholds must not be exceeded by those indicators for production to be approved.

The zone of the reservoir in which most tilapia production occurs has a fairly short residence time of 28.54 days, resulting in a lower impact of nutrient inputs compared to systems with a long residence time (Hidrósfera 2003). An additional carrying capacity study conducted by the Wetlands Foundation recommended that a maximum area of 2,846,391 m^2 be granted to fish farmers in the reservoir (CAM 2014). The area occupied by fish farms in the reservoir was lower than this carrying capacity in 2013 (CAM 2014). These studies indicate that it would be unlikely for the carrying capacity of the lake to be exceeded, but as noted above, recent large fish die-offs in early 2015 were linked to several factors, of which overproduction and poor water quality were two (e.g., (Pulido et al. 2015)), and the reported volume of production in the Betania Reservoir (30,000 MT) exceeds the aforementioned 22,000 MT carrying capacity. The industry has grown rapidly, with the number of net pen cages in Betania Dam increasing from 1,686 in 2005 to 7,000 in 2013 (Polinizaciones 2013).

Overall, regulatory measures are in place but their contents appear limited with regard to cumulative impacts, including in the Betania Reservoir. The new project in Betania to monitor and improve the sustainability of production appears to be driven partly by similar concerns, but the factors included in the management of production volume are not demonstrably based on preserving the ecology (i.e., the water quality) of the reservoir. Furthermore, until this project becomes established, there is uncertainty that the management of production is fully adequate. Thus, the intent and content of effluent regulations and management measures must be considered to be limited, and the score for Factor 2.2a is 2 out of 5.

Factor 2.2b Enforcement of effluent regulations and management measures
In the early 2000s, the laws and regulations relevant to aquaculture were considered to be "complex and unmanageable," which hindered their ability to be enforced (Hernandez-Rodruquez 2001). According to Ramirez and Gomez (2014), enforcement of regulations was relatively weak throughout the first decade of the 2000s, and efforts have been made to improve guidance, regulation, and enforcement regarding aquaculture in the Betania Dam reservoir through the creation of AUNAP in 2011 (AUNAP 2014a) (AUNAP 2014b) (La Nación 2013). AUNAP replaced the fisheries and aquaculture functions held by the Sub-department for Fisheries and Aquaculture of the Colombian Institute for Rural Development (FAO INCODER, 2011). Ramirez and Gomez (2014) subsequently reported that robust penalties for infringements regarding water quality exist under the current laws.

AUNAP, CAM, and the national police have been working together to enforce aquaculture regulations in the Betania Dam reservoir and to close down any illegal projects, i.e., those without the proper environmental use permits (La Nación 2013) (AUNAP 2014a) (AUNAP 2014b) (AUNAP 2014c). For example, AUNAP staff visited over 1,400 fishery and aquaculture operations in 2013 and seized 9.6 tons of illegally captured or produced fish products, and because of these controls, all the farms in Betania Dam are legal as of 2014 (AUNAP 2014c).

CAM monitors water quality in the reservoir (CAM 2014). Recent water quality monitoring efforts have used a numerical score combining several water quality parameters, including dissolved oxygen, nitrogen as nitrite and nitrate, phosphorus, pH, total suspended solids, and *Escherichia coli* biomass. CAM monitored six sites within and downstream of the area of intense tilapia farming at bimonthly intervals in 2012 and 2013 (CAM 2014). All six sites had either “good” or “acceptable” water quality. The station downstream of the reservoir, “La Esperanza,” had the highest water quality of the stations monitored (“good” water quality), indicating a low impact on areas outside the farms’ immediate vicinity. This monitoring implies some active enforcement, but the lack of public data makes it difficult to know the regularity of this monitoring and therefore its effectiveness, particularly in relation to events such as the 2015 fish mortality (see below).

Although the available monitoring data for 2013 show that the average dissolved oxygen (5.2 mg/l), biological oxygen demand (< 2 mg/l), and nitrogen and phosphorus levels were not indicative of eutrophication (CAM 2014), declines in the water quality have been noted prior to 2015 and were often blamed on ineffective wastewater treatment in surrounding municipalities and/or periods of low water level (Hidrósfera 2003) (Zubieta 2007) (FAO-INCODER 2011) (Polinizaciones 2013). But in March and April of 2015, approximately 10% of the tilapia in the reservoir were lost to a large mortality event. As noted above, overproduction and cumulative effluent impacts leading to deteriorating water quality were two of several potential causes (in addition to rancid diets, viral agents, high ambient temperatures, low dissolved oxygen, and other opportunistic pathogens) (Pulido et al. 2015). The farms that are independently audited to either GAA or ASC should follow the requirements of these schemes’ standards, which do take some account of the carrying capacity and the total production (and feeding rate) of the water body as a whole.

Robust penalties for infringement of effluent regulations exist, and efforts have been made by CAM and AUNAP to improve enforcement. Despite these recent efforts, there is evidence of overcapacity (e.g., 30,000 MT production in light of a 22,000 MT carrying capacity limit) and resultant water quality declines in the Betania Dam reservoir. As in Factor 2.1 above, the developing projects that imply greater monitoring and enforcement in the Betania Reservoir are encouraging, but as yet unproved. Overall, the effectiveness of the enforcement is currently considered to be moderate because of the apparent lack of publicly available data and the corresponding inability to understand key problems such as fish mortality events. The score can improve with further information and public data availability. The score is 3 out of 5 for Factor 2.2b.

The score for the effectiveness of the management scheme in Betania Reservoir (combining Factors 2.2a and 2.2b) is 2.4 out of 10, indicating moderate effectiveness of control measures related to cumulative impacts of the large scale of production in the reservoir.

Conclusions and Final Score

Overall, tilapia has a relatively low level of effluent waste per ton of production due to relatively low protein feeds, but the scale and intensity of farming in the human-made Betania Reservoir, combined with some concerns over the effectiveness of the management scheme to control cumulative impacts, result in a final numerical score of 4 out of 10 for Criterion 2 – Effluent. In future assessments, it will be interesting to note the effectiveness of the project recently initiated by Acuapez and the government of Huila in improving the monitoring and management of production in the reservoir.

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

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		7.00	
F3.2a Content of habitat regulations	2		
F3.2b Enforcement of habitat regulations	3		
F3.2 Regulatory or management effectiveness score		2.4	
C3 Habitat Final Score		5.47	YELLOW
Critical?	NO		

Brief Summary

Floating net pen structures have little direct impact on habitats; however, the operations at the scale and intensity in the Betania Reservoir clearly have the potential to impact the waterbody (which was primarily assessed in Criterion 2 – Effluents) and affect the remaining ecosystem services. Although siting and other management regulations are in place and at least moderately enforced, the ongoing development project recently initiated by AUNAP indicates that there is room for improvement in the cumulative management of impacts in the reservoir, particularly the potential contributions to a loss of ecosystem services in extreme circumstances, such as high temperature and low water flows. Overall, the human-made nature of the reservoir results in a moderate Habitat Criterion score of 5.47 out of 10.

Justification of Ranking

Factor 3.1 Habitat conversion and function

The Betania Dam was constructed on the Magdalena River for hydroelectricity production in 1987 (GEO 2012). The Magdalena River is poorly studied, with the only documented study on the ecosystem's water quality, species composition, and environmental changes occurring in 2001 (Sanchez et al. 2001). This study identified 41 native fish species, with 9 of high economic importance, and noted that construction of the dam had reduced fish populations (Sanchez et al. 2001). Approximately 55% of the fish production that comes from the Magdalena River is now in the form of aquaculture production (FAO-INCODER 2011); although the number of net pen cages in Betania Reservoir increased from 1,686 in 2005 to 7,000 in 2013 (Polinizaciones

2013), the total area of fish farm sites is low compared to the total surface area of the lake (CAMS 2014).

With the large scale of tilapia production relying on the water quality (i.e., ecosystem services) of the reservoir, it is clear that ongoing production depends on maintaining habitat functionality in this respect. Because the fish die-offs in early 2015 were potentially caused directly or indirectly by overproduction (Pulido et al. 2015), it is clear that the limits of functionality may be approached on occasion. (Note that factors such as high water temperatures, rancid feed, and viral or other opportunistic pathogens were also identified as potential confounding causes of the fish die-offs.) It must be noted that problems with water quality in the reservoir as a whole resulting from cumulative effluent impacts of the industry are primarily assessed in the Effluent Criterion above.

It could be argued that benthic impacts from settling particulates (waste feed and feces) would have an impact on the lake bed, but again, the human-made nature of the reservoir diminishes this concern. Ultimately, when the human-made nature of the reservoir and its historically altered ecosystem services are considered, along with the limited direct habitat impacts from the floating net pen infrastructure, it is thought that the ecosystem maintains functionality with only moderate impacts. This equates to a score for Factor 3.1 of 7 out of 10.

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

In Colombia, management measures for effluent and habitat impacts have a high degree of overlap. Information regarding water quality in general in Betania Reservoir is included in Criterion 2.

In Colombia, high value habitats and/or easily impacted habitats are avoided for aquaculture siting. For example, Resolution 408 of 2013 banned aquaculture in the Amani Reservoir of Colombia because of the high potential for negative impacts on native species and traditional uses (e.g., river transport). Strategic plans to ensure ecosystem protection have been developed within the Magdalena River basin, which include the preservation of coral reefs and mangroves in the region—particularly against mining, aquaculture, and fisheries (Ministerio de Ambiente y Desarrollo Sostenible 2012). Colombia is also part of two intergovernmental treaties: the Ramsar Treaty, which aims to protect wetlands, and the Convention on International Trade in Endangered Species (CITES), which aims to protect wildlife against over-exploitation.

As of January 2016, it is mandatory for all aquaculture operations to comply with the Livestock Registration of Aquaculture Establishments (RPEA), issued by the Colombian Agricultural Institute (ICA) (Aquahoy 2016). An environmental impact assessment (EIS) for new sites became mandatory in 1997 and includes measures for preventing and mitigating environmental impacts (Coze and Nava 2009). In 2011, a separate unit of the Ministry of Environment, the National Environmental Authority Licenses unit (ANLA), was created to handle environmental permits (Ministerio de Ambiente y Desarrollo Sostenible 2012). As of 2009, although an EIS was required for new aquaculture operations, there were no specific requirements on its content or robustness (Coze and Nava 2009); however, it is unclear if this is still the case today, given the complexity of interpreting the regulations (e.g., as summarized by (FEDEACUA 2016)).

Ongoing developments in the management of the Betania Reservoir are apparent with the new project announced by AUNAP (Pulido et al. 2015), including the separation of the lake into eight "microzones" and improved monitoring and management of production. Though these are improvements, there is still a need to improve the cumulative management of production in the lake, particularly with respect to extreme conditions such as high water temperatures and low water flows.

Overall, there appears to be some siting according to ecological principles in Colombia in general, and within the Betania Reservoir; however, there is some uncertainty regarding the ongoing measure in place regarding cumulative management. The appropriate score for Factor 3.2a is a moderate 2 out of 5 due to a potentially limited consideration of cumulative impacts.

Factor 3.2b Enforcement of Habitat Management Measures

Limited information is available on the enforcement of habitat regulations and management measures. There are three types of environmental fees established by Law 99 of 1993 that can be applied to aquaculture facilities: retributive fees for pollution, compensation fees for the maintenance of natural resources, and fees for water use (Ramirez and Gomez 2014). Additionally, environmental licenses may be revoked if the aquaculture facility does not comply with the conditions of the license, and infractions could cause daily fees, equivalent to a maximum of 300 minimum wages (Coze and Nava 2009). In 2013, multiple farms were closed down by AUNAP because of a lack of proper environmental permits, so that all the farms in the reservoir were legal by 2014 (La Nación 2013) (AUNAP 2014a) (AUNAP 2014b) (AUNAP 2014c). Stricter enforcement has had noticeable effects, including a decrease in the total area covered by fish farms, better delineation of farm areas, and better management of solid waste and fish mortality. Factor 3.2b is also given a score of 3 of 5.

Floating net pens have little direct habitat impact, particularly considering the human-made nature of the waterbody, but the operational impacts are potentially associated with overcapacity and the loss of ecosystem services in the form of fish kills due to confounding factors. Factors 3.2a and 3.2b combine to give a Management Effectiveness score of 2.4 out of 10 for Factor 3.2, and Factors 3.1 and 3.2 combine to give a moderate final numerical score of 5.47 out of 10 for Criterion 3 – Habitats.

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

Chemical Use parameters	Score	
C4 Chemical Use Score	4	
C4 Chemical Use Final Score	**4**	**YELLOW**
Critical?	NO	

Brief Summary

Little public data are available on chemical use in Colombia, but with the intensive production and known bacterial and viral diseases of tilapia, the potential use of chemical treatments such as antibiotics must be accepted unless data can be provided that show otherwise. Encouragingly, three large farms in Betania Reservoir (including the largest) are certified to GAA and/or ASC, and audit reports show that antibiotics have not been used in recent production cycles. The most recent regulations on the control of chemical use are from 2007, and the AUNAP project initiated in late 2015 to improve the sustainability of production in the Betania Reservoir mentions the testing of antibiotics as one potential tool to improve fish health. The use of low levels of hormones for short periods in the hatchery feeds is considered common practice to produce all-male tilapia populations, and studies show that this has minimal environmental (or human health) concerns when best practices are employed. Overall, the independent audit reports, which show that large exporting net pen farms in Colombia have not recently used antibiotics, are encouraging and dictate a high score. Yet there is clearly a concern that chemical use, particularly antibiotics, could be happening in other farms in potentially increasing amounts to treat disease outbreaks when they occur. Therefore, the lack of publicly available data and a precautionary approach mean that the most appropriate score for the Chemical Use Criterion is 4 out of 10.

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), but with increasing scale and intensity of production, diseases are now a common problem (Bacharach et al. 2016). There have been several recent outbreaks of diseases on Colombian farms, sometimes resulting in severe losses (Hernandez et al. 2009) (Garcia et al. 2012) (Iregui et al. 2012) (Pulido et al. 2015).

Unfortunately, data availability on recent or current chemical use in Colombia is quite limited, but these disease outbreaks imply a potential for treatment with antibiotics or other chemicals.

The summary of regulations provided by FEDEACUA[4] includes a section on chemical products and supplies. The most recent resolution was made in 2007 (Resolution 676 on the control of chemical products), but other measures include registered products and uses, prohibited products, and various requirements relating to practical use. The large number of laws, resolutions, and decrees in Spanish makes a detailed understanding of the content challenging for buyers and consumers of the products on the U.S. market. Resolution 1326 of 1981 relates to the veterinary use of antibiotics, but does not appear to limit the type or total quantity (or frequency) of use. According to the European Commission, the antibiotics florenicol and sulfadimethoxine and veterinary products containing the hormone 17-alpha methyltestosterone are authorized for use in fish in Colombia, with 17-alpha methyltestosterone used regularly for sex reversal in closed systems producing fingerlings (European Commission 2011). Villaneda (2007) reported that farmers are known to use human and animal chemicals and antibiotics, such as malachite green, formaldehyde, methylene blue, and furazone; however, this 2007 publication must be considered dated and cannot be robustly relied upon to represent current practice. It is considered common practice for methyltestosterone to be used in hatchery feeds for the production of all-male populations via sex reversal, but according to Macintosh (2008), there are no known risks to the environment (or human health) from its use, provided that best management practices are employed.

Global surveys on antibiotic use in aquaculture, such as Tusevljak et al. (2012), have limited coverage of South America but do indicate that antibiotic groups such as tetracyclines, quinolones, and sulphonamides are used in tilapia production globally. This cannot be robustly extrapolated to Colombia, and the most reliable data sources for chemical use in the tilapia produced for export to the United States are the few public audit reports for the large farms certified to the ASC and GAA (the latter reports were provided for this assessment by FEDEACUA). The combined information across these farm audits, including the largest tilapia farm in Colombia (Welling 2015), shows that antibiotics have not been used in recent production cycles. The project to improve the sustainability of tilapia production in Betania Reservoir that was recently initiated by the government of the Department of Huila mentions testing of antibiotics as one strategy to improve health management of the farms, so antibiotic use could potentially increase (Pulido et al. 2015).

The European Commission published a study in 2011 that was conducted on beef, fish, and shrimp farms in Colombia for compliance with the European Commission's chemical bans. The report noted that the governmental laboratories had limited methods to screen for nitrofurans, steroids, dyes, or antibacterial substances (European Commission 2011). The same study noted further that there were issues with internal quality controls, such as proper sampling methods and satisfactory sealing of samples, thus hindering the ability to accurately test for chemical use. There has been some improvement in the control of chemical use in aquaculture and

[4] http://www.fedeacua.org/assets/uploads/files/3fbc1-MATRIZ-UNICA-NORMATIVA---03--03-2016.pdf

agriculture in Colombia; for example, as of March 2011, veterinary prescriptions must be obtained for a number of products that were previously sold over the counter, including antibiotics and pesticides (European Commission 2011).

Disease outbreaks in Colombian aquaculture have been common (Camus et al. 1998) (Fitzsimmons 2000) (Iregui 2004) (Hernandez et al. 2009) (Iregui et al. 2011) (Garcia et al. 2012) (Iregui et al. 2012) (Pulido et al. 2015), suggesting the potential need for chemical use. Vaccines for leading tilapia diseases have made considerable progress over the last decade (e.g., (Evans et al. 2004) (Kwon et al. 2006) (Agnew and Barnes 2007) (Shoemaker et al. 2010) (Huang et al. 2014)) and, if used in Colombia, could lead to a reduced need for chemicals (pers. comm., Fitzsimmons 2015), but there are no records to suggest that this is yet the case.

Conclusions and Final Score

Overall, the independent audit reports showing that large exporting net pen farms in Colombia have not recently used antibiotics are encouraging and dictate a high score. But there is clearly a concern that chemical use, particularly antibiotics, could be happening in other farms in potentially increasing amounts to treat disease outbreaks when they occur. Although it could be argued (based on the audit reports) that the species and the production system in Colombia have a low need for chemical use (score 6 out of 10), the lack of publicly available data covering all farms combined with a precautionary approach mean that the most appropriate score for the Chemical Use Criterion is 4 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

Feed parameters	Value	Score
F5.1a Fish In:Fish Out ratio (FIFO)	0.00	9.99
F5.1b Source fishery sustainability score	–6.00	
F5.1 Wild fish use score		9.98
F5.2a Protein IN (kg/100 kg fish harvested)	31.26	
F5.2b Protein OUT (kg/100 kg fish harvested)	16.77	
F5.2 Net Protein Gain or Loss (%)	–46.34	5
F5.3 Feed Footprint (hectares)	3.17	8
C5 Feed Final Score (0–10)		**8.24**
Critical?	NO	**GREEN**

Brief Summary

Tilapia is omnivorous and typically does not require large inputs of fishmeal and fish oil in commercial feeds; data provided for multiple feeds from one feed company, and provided anonymously from FEDEACUA, give weighted average inclusion levels of fishmeal and fish oil over a typical production cycle of 4.95% and 1.02%, respectively. The data also showed that the use of fishmeal and oil from dedicated (i.e., reduction) fisheries appears to be limited to starter feeds, which represent a quite small part of the total ration provided over the production cycle. Therefore, the calculated Forage Fish Efficiency Ratios were close to zero (0.004), giving a high Wild Fish Use score of 9.98 out of 10. With high levels of edible crop ingredients in the feed, there was a calculated net edible protein loss of 46.3% and a low feed footprint of 3.2 hectares of area appropriated per ton of production. These aspects combine to give a final Feed Criterion score of 8.24 out of 10.

Justification of Ranking

Factor 5.1 Wild Fish Use

Tilapia is omnivorous and commercial feeds typically do not contain a high proportion of animal proteins, but inclusion levels often exceed those required (Naylor et al. 2000) (FAO 2012), in order to maximize growth rates and flesh quality.

Typical values for fishmeal inclusion (8.3%) in the somewhat dated reference paper of Tacon and Metian (2008) were confirmed by direct contacts in Colombia to broadly represent current feeds (pers. comm., Pino 2015). But data for two tilapia feeds from a large feed company in Colombia (Contegral), in addition to anonymous feed data provided by FEDEACUA, show lower fishmeal levels, with a weighted average inclusion of 4.95%. Weighted averages were calculated based on average consumption figures provided by the feed company for starter, growout, and finishing feeds (10 g, 158 g, and 580 g, respectively, in a typical production cycle).

Although Tacon and Metian (2008) report a fish oil inclusion level of 2% for tilapia feeds, three of the large farms that export to the U.S. are reported to not use any fish oil (pers. comm., Pino 2015). Feed company data show fish oil inclusion varies from 3% in starter feeds to between 0% and 2% in finishing feeds, with a weighted average across the feeds of 1.02%.

Three of the large farms exporting tilapia to the United States (those that are GAA- and ASC-certified) are considered to use 100% fisheries by-products (e.g., tuna offal) to supply marine ingredients in their feeds (pers. comm., Pino 2015). Only one dataset from the feed company identified the use of by-products, and confirmed the use of 100% by-product fishmeal ingredients after the starter feeds (which used 100% whole fish fishmeal). Information on the use of fish oil from by-products was not specifically stated, but for the feeds that used fish oil (beyond starter feeds), the source was identified as farmed salmon processing by-products. Recent ASC audit reports confirm the use of by-products for both fishmeal and oil in the certified farms and, although it is accepted that these data may not reflect all tilapia feeds used in net pens in Colombia, the weighted averages of by-product marine ingredient use are based on these values and are calculated to be 98.7% of fishmeal and 100% of fish oil.

Economic feed conversion values (eFCR) were available from two ASC audit reports for Colombian net pen farms from audits in 2016 and 2017 (the most recent reports available on the ASC website), and from the feed company Contegral. The average of the three values (1.47, 1.6, and 1.7) is 1.59. This value indicates that 1.59 kg of feed inputs are required to product 1 kg of tilapia.

Calculations according to the Seafood Watch Aquaculture Standard result in Forage Fish Efficiency Ratios (FFER; i.e., the amount of wild fish used to produce farmed fish) of 0.004 and 0.0 for fishmeal and fish oil, respectively.[5] This equates to an FFER score of 9.99 out of 10.

[5] Although these values disagree with the ASC audit reports, it is not clear that their audit calculations ignored the use of fishmeal and fish oil from by-products (which they are also supposed to do).

For the small amount of fishmeal and fish oil considered to be sourced from dedicated fisheries for starter feeds (i.e., whole fish-derived marine ingredients), the sources were provided by the feed company and FEDEACUA. The feed company has a policy of sourcing from fisheries with FishSource[6] scores > 6, but data from FEDEACUA indicate at least one fishery with one or more FishSource scores < 6. Therefore, a sustainability factor score of –6 leads to a small adjustment of –0.01, which is deducted from the initial score of 9.99 to give a final Wild Fish Use score (Factor 5.1) of 9.98 out of 10.

Factor 5.2 Net Protein Gain or Loss

Data on the protein content and its primary source ingredients were provided for a range of feeds produced by the feed company and by FEDEACUA. Total protein content varied from 45% for starter feeds to 25% in finishing feeds; the weighted average of these values (weighted on relative feed consumption over a production cycle) is 28.5%. Dated references indicate ranges from 24% to 34%, with an average value of 28% (Pompa and Rodriquez 2000) (Vallaneda 2007) (Zubieta 2007) (FAO 2014b). Neto and Ostrensky (2015) evaluated tilapia feeds in Brazil, which in this report are considered similar to those in Colombia, and found that protein content averaged 27.6% for the growth stage—similar to the figures stated above.

The feed data from Colombia show that protein is supplied by a variety of ingredients, including fishmeal, crops, and terrestrial animal by-products. A similar weighted average calculation for all the available data shows that 11.0% of total feed protein comes from fishmeal, 69.2% from crops, and 19.8% from terrestrial animals. Calculations to estimate the percentage of the total protein coming from edible ingredients show that 68.9% of ingredients come from edible sources (non–by-product fishmeal and edible crops) and 31.1% come from nonedible sources (by-product ingredients from fishmeal and terrestrial animals).

The protein content of a whole harvested farmed tilapia is 14% (Boyd 2007). For tilapia farmed in Colombia, the edible yield (i.e., fillet) is 33%, which is fairly low compared to other finfish species (Borderias and Sanchez-Alonso 2010). Although the edible portion of the tilapia used to make fillets is low, a large portion of the by-products from the tilapia farms in Betania Dam reservoir (≈75%) is used for other food production (pers. comm., Vera 2015). By-products from the processing of tilapia are suitable sources of protein for feed for other farmed species (Osorio et al. 2013). Skins, scales, bones, and viscera are sold to animal feed supplement companies (e.g., Industry Flour Meat Huila SAS) to produce fishmeal and fish oil. Heads and some trim are washed and frozen for wholesale in the domestic market. Any whole animals not suitable for consumption (i.e., mortalities) are also sold to animal feed supplement companies (pers. comm., Vera 2015). Therefore, there is a net utilized protein output of 11.7 kg per 100 kg of harvested fish, which is adjusted to 16.8 kg to account for the increase in protein quality from crop ingredients to farmed fish.

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[6] www.fishsource.org

Comparing the inputs and outputs of edible and utilized protein (31.3 kg/ton and 16.7 kg/ton, respectively), there is a net protein loss in Colombian production of tilapia of 46.3%. This results in a score of 5 out of 10 for Factor 5.2.

Factor 5.3 Feed Footprint

The creation of feeds for aquaculture requires the use of global ocean and land resources. The global ocean and land area required to feed tilapia can be estimated using inclusion levels of different feed ingredients and yield values per hectare of production area. For tilapia farmed in Colombia, the total inclusion level of aquatic feed ingredients (FM% + FO%) is 9.3% (by-products are included in this calculation). The average carbon required for the necessary aquatic feed ingredients is 69.7 tC t^{-1}, and the average ocean productivity for the continental shelf area is 2.68 tC ha^{-1} (fixed values in the Seafood Watch Aquaculture Standard). Using these values, the ocean area of primary productivity appropriated by feed ingredients is calculated as 2.47 ha/ton tilapia.

The average yield of major feed ingredient crops is 2.64 tons crops per ha^{-1}, and with conversion factors for land animal products (also fixed values in the Seafood Watch Aquaculture Standard), the total land area appropriated by crop and land animal feed ingredients is calculated to be 0.70 ha to produce 1 ton of tilapia, and the total global area appropriated per ton of farmed fish (ocean area + land area) is 3.17 ha to produce 1 ton of farmed fish. Given the low requirements for global resources, the score for feed footprint, Factor 5.3, is 8 out of 10.

Final Score

Factors 5.1, 5.2, and 5.3 combine to give a final numerical score of 8.24 out of 10 for Criterion 5 – Feed.

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

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		8.0	
C6 Escape Final Score		**5.00**	**YELLOW**
Critical?	NO		

Brief Summary

Tilapia was introduced into Colombia and became established in the 1960s, before the aquaculture industry had begun. The government had been actively stocking tilapia into the country's freshwater bodies. For aquaculture purposes, tilapia had been legally defined as an introduced invasive species by the Colombian government, but new regulations in December 2015 declared them (Nile and red tilapia, along with rainbow trout) "domesticated." Though 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 there are no data available on escapes events in Colombia or on post-escape recaptures; however, potential impacts are limited when the species has been historically introduced and actively stocked into the environment, and the final Escape Criterion score is therefore a moderate 5 out of 10.

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 higher risk of escape given their open nature (Naylor et al. 2005) (Halwart et al. 2007). For net pen farms in the Betania Reservoir, best management practices (BMPs) are employed to reduce the risk of escapes; for example, Resolution no. 461 (1995) outlines the requirements for mesh size and borders around net pens, and requires that all farmed fish are single sex or sterile. And the certification requirements for both ASC and GAA will require the use of BMPs to minimize escapes. No data are available on escape events in the reservoir or for other farms in Colombia, and data on recapture after escape events are also unavailable. Audit reports indicate that trapping or recapture nets cannot be used because they are considered illegal (IMO Group 2013), so the initial Escape Risk score (Factor 6.1a) in the Seafood Watch Aquaculture Standard is 2 out of 10 for an open system with best management practices.

Factor 6.2 Invasiveness

There is ample evidence regarding the invasive nature of tilapia and their 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)). Various species of tilapia (including those commonly cultured and assessed here) are established in Colombia, including in freshwaters, estuarine waters, and alkaline waters (Narváez et al. 2005). These are largely the result of historic introductions, and establishment is thought to date to the 1960s (Pullin et al. 1997).

Until Decree 1071 and Resolution 228 were passed in December 2015, tilapia had been defined as an introduced invasive species by the Colombian government (AUNAP 2013a). Resolution 228 declared them (Nile tilapia and red tilapia, along with rainbow trout) “domesticated” in Colombia. The resolution recognizes the threat from additional escapes, and although the Colombian government historically actively stocked freshwater bodies in the country with tilapia from hatcheries (Caraballo 2009) (FAO-INCODER 2011), this practice now appears to be prohibited under Resolution 228.

It is recognized that there is potential for ongoing escapes to have some impact on the natural species and habitats in the area. To take this into account, a score of 8 out of 10 is set for Factor 6.2. This score reflects that the nonnative species of tilapia farmed in Colombia are considered ecologically established in the region (i.e., actively reproducing in the wild); however, they were intentionally introduced for purposes prior to the growth of the aquaculture industry.

The final escape criterion score is based on the interaction of the risk of escape (Factor 6.1; score 2 of 10) and the invasiveness of the farmed species (Factor 6.2; score 8 of 10) and results in a moderate final numerical score of 5 out of 10 for Criterion 6 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Risk-based assessment

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

Brief Summary

Several disease outbreaks have been recorded for tilapia produced in Colombia, and in many cases these diseases are capable of spreading to other species. Streptococcal bacterial infections are a common problem, and a viral hepatitis pathogen was one of several potential factors related to a large die-off of tilapia in the Betania Reservoir in early 2015. Net pen production systems are open, so pathogens could be released from the system and infect other wild species. But because of the human-made nature of the Betania Reservoir, the status of wild populations and the impact on them from farm-origin pathogens (if any) is unknown. Improving fish health and data availability in the Betania Reservoir is a key goal of the recently initiated project by the government of Huila. Because of the current lack of data, the Seafood Watch risk-based assessment was used, from which the open nature of the production system to the introduction and discharge of pathogens with unknown impacts on wild species leads to a moderate score of 4 out of 10.

Justification of Ranking

A wide range of bacteria, fungi, protozoa, and viruses has been described as challenges to tilapia aquaculture (Bacharach et al. 2016). Numerous diseases have been documented on tilapia farms in Colombia, including *Edwardsiella* spp. (Garcia et al. 2012) (Iregui et al. 2012), *Aeromonas motile* (Camus et al. 1998) (Iregui 2004), *Rickettsia* (Iregui et al. 2011), and *Streptococcus* (Hernandez et al. 2009). With the primary disease problems in tilapia being bacterial (e.g., *Streptococcus*), viruses were not implicated as substantive threats until 2009, when massive losses of tilapia, presumed to be caused by viral infection, were described in Israel and Ecuador (Bacharach et al. 2016). It is interesting to note that one of several potential factors in the large die-offs of tilapia in the Betania Reservoir in 2015 was a viral infection of *Hepatitis syncytial*, in addition to systemic infection by several opportunistic pathogens (Pulido et al. 2015).

In the past, disease-induced mortality in net pen cages in Colombia has sometimes produced serious losses, particularly due to *Streptococcal* infections (Fitzsimmons 2000). In the regions of Huila, Valle, Risaralda, and Tolima, which represent some of the highest producers of tilapia in the country, information from more than 10 years ago suggests disease infection 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 only 5.03%, even in the highest density treatments (120 kg/m^3). Current data on disease outbreaks and mortality rates are not available in Colombia, aside from anecdotal evidence such as Pulido et al. (2015), but over the past 10 years, substantial progress has been made in vaccinating tilapia against common aquaculture diseases, particularly those caused by *Edwardsiella* (e.g., (Kwon et al. 2006)) and *Streptococcus* (Evans et al. 2004) (Agnew and Barnes 2007) (Shoemaker et al. 2010) (Huang et al. 2014). It is possible that farms in Colombia are now vaccinating tilapia, which would lead to fewer disease outbreaks (pers. comm., Fitzsimmons 2015); however, due to the lack of reliable data, the prevalence of vaccinations is currently unknown.

Aquaculture operations may increase the likelihood of pathogen and/or parasite amplification in nearby environments (e.g., (Naylor et al. 2000) (Johansen 2011)). The threat is significant for aquaculture operations employing net pens because of the open nature of these production systems, and wild populations may be impacted when disease spreads from the production system. Although all the diseases recorded for tilapia produced in Colombia have the potential to spread to other organisms, the published work referenced above on this topic either did not study wild populations (e.g., (Iregui et al. 2012)) or studied low sample sizes of wild populations and found no incidence of disease (e.g., (Hernandez et al. 2009)).

With regard to the Seafood Watch assessment, the limited amount of data means that the risk-based assessment has been used (the Data Criterion score for the disease section is < 5 out of 10). Net pen production systems are open to the environment and therefore may allow for the transmission of disease from farmed tilapia to wild species. Disease outbreaks are common on tilapia farms in Colombia and are often linked to overstocking; however, the human-made nature of the Betania Reservoir has likely had a significant impact on the wild species in the area, and the presence and vulnerability of wild species in the vicinity of the farms is unknown. Considering the open nature of the net pens, but also the uncertain status of wild species in the human-made reservoir, the most appropriate score in the Seafood Watch risk assessment is 4 out of 10 for the Disease Criterion because the system is open to the introduction and discharge of local pathogens.

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

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

Source of stock parameters	Score	
C8X Independence from unsustainable wild fisheries (0–10)	0	
Critical?	NO	GREEN

Justification of Ranking (and Summary)

All tilapia grown in Colombia are produced in hatcheries with no use of wild broodstock or seed. For example, Colombia’s largest producer, Piscicola Botero, has hatcheries located on islands in the Betania Reservoir and produces 6 million fingerlings per month (Welling 2015). Therefore, Colombian tilapia aquaculture 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

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**–6.00**	**YELLOW**
Critical?	NO	

Brief Summary

Studies from more than 10 years ago report considerable mortalities of birds in pond tilapia farms in Colombia, but no recent data are available for the net pen farms in Betania Reservoir. Anti-bird nets are required on all farms, and farms certified to the ASC with publicly available audit reports document the lack of lethal predator controls; however, they note that the osprey *(Pandion haliaetus)* is an endangered migrant that utilizes the lake. Little is known about the predator controls on the noncertified farms in the reservoir. Although there are not considered to be mortalities of birds or other predators beyond exceptional cases, the presence of ospreys requires a more precautionary approach until more data are made available. The score for Criterion 9X is therefore a moderate deduction of –6 out of –10.

Justification of Ranking

High densities of fish in aquaculture facilities in Colombia attract a number of predatory bird species, including kingfishers, egrets, herons, and osprey. Although there are dated documented bird mortalities in pond systems (Bechard and Marquez-Reves 2003), less is known about bird mortalities in net pen systems in reservoirs in Colombia. Resolution no. 461 (1995) outlines the anti-bird mesh requirements that all farms must comply with, and any farms that do not comply with these requirements can have their permits revoked. The enforcement of these regulations is unknown, and there do not appear to be any national laws related to the destruction of birds or other predators (BAP 2012).

Public independent audit reports for two ASC-certified farms (Piscicola Botero and Proceal) show that no lethal control methods are used (ASC 2016).[7] These audit reports note that there are no International Union for the Conservation of Nature (IUCN) Red-Listed species present in the lake, but the osprey *(Pandion haliaetus)* is noted as an endangered migratory species for which additional precautionary measures are in place. Though these practices on large exporting farms are encouraging, there are no data available for the other farms.

The good practices of the certified farms indicate that a large proportion of the fish produced for export to the United States may be produced responsibly, but the lack of data for other farms demands a more precautionary scoring approach. Considering the potential (but unverified) concern regarding the presence of endangered osprey in the reservoir, the final score for Criterion 9X is a precautionary deduction of –6 out of –10 because of the unknown status.

[7] http://www.asc-aqua.org/upload/20131213_C.I.%20Pisciola%20Botero_SA%20Farm_FINAL.pdf
http://www.asc-aqua.org/upload/3_20150331_Procesadora%20y%20Comercializadora%20de%20Alimentos_Proceal%20Farm_FINAL-bilingual.pdf

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

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	9	
C10Xb Biosecurity of source/destination	6	
C10X Escape of unintentionally introduced species Final Score	**–0.40**	**GREEN**

Brief Summary

Historically, there have been concerns that movements of tilapia fingerlings from hatcheries in Ecuador to Colombia represented a potential source of unintentionally introduced nonnative species. But the now-mature industry in Colombia and the available evidence indicate that the country is self-sufficient in seed supply, with hatcheries in different regions supplying local producers. Nevertheless, the recent designation of tilapia in Colombia as a “domesticated” species allows the importation of selectively improved tilapia strains to improve production. The numbers are considered likely to be low, and the biosecurity of the source breeding centers is considered to be moderate. Overall, there is a low risk of introducing nonnative species during the live animal shipments, and the score for Criterion 10X is a small deduction of 0.4 out of –10.

Justification of Ranking

This criterion provides a measure of the escape risk (introduction to the wild) of invasive alien species (other than the principle farmed species) that are unintentionally transported during animal shipments.

Factor 10Xa International or trans-waterbody live animal shipments

Nearly 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 lower cost, but it is considered unlikely that the now-mature industry in Colombia continues this practice. As noted in Criterion 8X, Welling (2015) described the local hatchery production for Colombia’s largest tilapia producer in Betania Reservoir (i.e., the hatcheries were located on islands within the reservoir), and there is evidence of other hatcheries in the lesser tilapia producing regions of Colombia (Acuicultores 2016).

The recent declaration of tilapia as “domesticated” in Colombia (Decree 1071 and Resolution 228, December 2015) allows the importation of genetically improved strains of tilapia in order to improve production. These international movements will present a risk of importing unintentional “hitchhiker” species along with the intended tilapia, but the scale is considered to be infrequent and of small numbers of broodstock. According to Resolution 228, the origins for new tilapia strains are limited to Holland and Honduras (Acuicultores 2016).

For the purposes of this assessment, and considering the established nature of tilapia hatchery production for the now-mature industry in Colombia, the minor import of tilapia broodstock into Colombia is recognized with a score of 9 out of 10 for Factor 10Xa, which represents an estimated and arbitrary 10% of production in Colombia.

Factor 10Xb Biosecurity of source/destination

Although no specific data are available, the origin of the imports in Holland or Honduras will be tilapia selective breeding centers. Considering the climate in Holland, these will be closed recirculating systems with high biosecurity. The holding systems in Honduras are unknown, but for the purposes of domestication and selective breeding, they are likely to be somewhat contained with moderate to good biosecurity. The destinations in terms of hatcheries and subsequently open net pens in Colombia are considered to be of a lower biosecurity status than the sources discussed above. Therefore, a score of 6 out of 10 for Factor 10Xb represents the higher biosecurity of the source of live fish shipments.

Overall, the likely low numbers of broodstock shipped lead to a high score for Factor 10Xa, and combined with the moderate biosecurity in Factor 10Xb give a final deduction score for the exceptional Criterion 10X of 0.4 out of –10.

Overall Recommendation

The overall recommendation is as follows:

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

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

Criterion	Score	Rank	Critical?
C1 Data	3.41	YELLOW	
C2 Effluent	4.00	YELLOW	NO
C3 Habitat	5.47	YELLOW	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	8.24	GREEN	NO
C6 Escapes	5.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	–6.00	YELLOW	NO
C10X Introduced species escape	–0.40	GREEN	
Total	**27.72**		
Final score (0–10)	**3.96**		

OVERALL RANKING

Final Score	3.96
Initial rank	YELLOW
Red criteria	0
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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References

Acuicultores. (2016) Tilapia y trucha ya son especies domesticadas. ACUICULTORES • enero/febrero 2016 - No. 03. http://www.fedeacua.org/descargas/revista_descargar_2016_05_12_10_23FEDEACUA%20ED%203%20OK_ok.pdf

Agnew, W. and A. C. Barnes (2007). "*Streptococcus iniae*: An aquatic pathogen of global veterinary significance and a challenging candidate for reliable vaccination." Veterinary Microbiology 122(1): 1-15.

Alceste, C.C. (2001). "Red tilapia cage farming in Colombia and Brazil". Aquaculture Magazine. 27(5): 82-86.

Alder, J., B. Campbell, V. Karpouzi, K. Kaschner and D. Pauly (2008). "Forage fish: from ecosystems to markets." Annual Review of Environment and Resources 33(1): 153.

Alvarez, J. (2010). Manual of Procedures and Protocols: Escape Handbook of Fish in New York Pisciocola". Document Code PNY-0 06.

Álvarez-León, R. (2007). "Asociaciones y patologías en los peces dulceacuícolas, estuarinos y marinos de Colombia:aguas libres y controladas." Boletín Científico. Centro de Museos. Museo de Historia Natural 11(1): 81-129.

Aquahoy (2016) Será obligatorio el cumplimiento del registro pecuario de los establecimiento de acuicultura colombianos. www.aquahoy.com. 18 February 2016. http://www.aquahoy.com/noticias/general/25662-sera-obligatorio-el-cumplimiento-del-registro-pecuario-de-los-establecimineto-de-acuicultura-Colombianos

AUNUP (2013a). Merino, M. C., Bonilla, S., & Bages, F. Diagnóstico del estado de la acuicultura en colombia. Plan Nacional De Desarrollo De La Acuicultura Sostenible En Colombia. Bogotá, Colombia: Ministerio De Agricultura y Desarrollo Rural.

AUNAP (2014a). The National Authority of Aquaculture and Fisheries. "La AUNAP y su dirección regional Bogotá constituyen y reactivan comité acuicola y pesquero del embalse de Betania – Huila". <www.aunap.gov.co>

AUNAP (2014b). The National Authority of Aquaculture and Fisheries. "La AUNAP – Dirección regional Bogotá, trabaja para compatibilizar el llenado de la represa del Quimbo con la actividad pisícola - pesquera de Betania." <www.aunap.gov.co>

AUNAP (2014c). The National Authority of Aquaculture and Fisheries. "Informe de Gestion 2013: Presentación del Informe". Bógóta D.C., Colombia.

Bacharach E, Mishra N, Briese T, Zody MC, Tsofack JEK, Zamostiano R, Berkowitz A, Ng J, Nitido A, Corvelo A, Toussaint NC, Abel Nielsen SC, Hornig M, Del Pozo J, Bloom T, Ferguson H, Eldar A, Lipkin WI. (2016). Characterization of a novel orthomyxo-like virus causing mass die-offs of tilapia. mBio 7(2):e00431-16. doi:10.1128/mBio.00431-16.

BAP (2012). Best Aquaculture Practices. Audit of Pisciocola New York. BAP Evaluator Number 10040.

Barato, P., E. R. Martins, J. Melo-Cristino, C. A. Iregui, and M. Ramirez (2015). "Persistence of a single clone of *Streptococcus agalactiae* causing disease in tilapia (*Oreochromis sp.*) cultured in Colombia over 8 years." Journal of fish diseases 38(12): 1083:1087.

Bechard, M. J. and C. Márquez-Reyes (2003). "Mortality of wintering Ospreys and other birds at aquaculture facilities in Colombia." Journal of Raptor Research. 37(4): 292-298.

BirdLife International 2012. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>

Bondad-Reantaso, M. G. (2007). Assessment of freshwater fish seed resources for sustainable aquaculture, Food & Agriculture Org.

Bonilla, S., 2016. Implementation of Good Aquaculture Practices (BPA) in Colombia. Advocate. Global Aquaculture Alliance. Feb 2 2016.

Borderías, A. J. and I. Sánchez-Alonso (2011). "First processing steps and the quality of wild and farmed fish." Journal of Food Science 76(1): R1-R5.

Boyd, C. E. (2004). "Farm-level issues in aquaculture certification: tilapia." Report commissioned by WWF-US in.

CAM. (2014). Autonomous Corporation of Upper Magdalena. "Concepto Técnico CAM sobre embalse Betania".

Camus, A., R. Durborow, W. Hemstreet, R. Thune and J. Hawke (1998). Aeromonas Bacterial Infections: Motile Aeromonad Septicemia, Southern Regional Aquaculture Center.

Canonico, G. C., A. Arthington, J. K. McCrary and M. L. Thieme (2005). "The effects of introduced tilapias on native biodiversity." Aquatic Conservation: Marine and Freshwater Ecosystems 15(5): 463-483.

Caraballo, G. (2009). "Effect of tilapia *Oreochromis niloticus* over the fisheries in El Guájaro reservoir Atlántico-Colombia." Revista MVZ Córdoba 14(3): 1796-1802.

Coze, S.A. and F. Nava, A. 2009. Review of environmental impact assessment and monitoring of aquaculture in Latin America. In FAO. Environmental impact assessment and monitoring of aquaculture. FAO Fisheries and Aquaculture Technical Paper. No. 527. Rome, FAO. pp. 395–454

Diana, J. S. (2009). "Aquaculture production and biodiversity conservation." BioScience 59(1): 27-38.

El-Sayed, A.-F. M. (2004). Protein nutrition of farmed tilapia: searching for unconventional sources. New dimensions in farmed tilapia: proceedings of the Sixth International Symposium on Tilapia Aquaculture.

European Commission. (2011). Final Report of a Mission Carried out in Colombia From 19 to 27 January 2011 in Order to Evaluate the Monitoring of Residues and Contaminants in Live Animals and Animal Products, Including Controls on Veterinary Medicinal Products.

Evans, J. J., P.H. Klesius, and C.A. Shoemaker (2004). "Efficacy of *Streptococcus agalactiae* (group B) vaccine in tilapia (*Oreochromis niloticus*) by intraperitoneal and bath immersion administration." Vaccine 22(27): 3769-3773.

FAO (2012). State of world fisheries and aquaculture. FAO, Rome.

FAO. (2014c). National Aquaculture Legislation Overview Colombia. FAO, Rome. http://www.fao.org/fishery/legalframework/nalo_colombia/en

FAO FishStat. (2014a). Fisheries and Aquaculture Information and Statistics Service www.fao.org/fishery/statistics/software/fishstat/en

FAO. (2014b). National Aquaculture Sector Overview Colombia. FAO, Rome. http://www.fao.org/fishery/countrysector/naso_colombia/en

FAO. (2014d). Nile Tilapia- Nutritional Requirements. FAO, Rome. http://www.fao.org/fishery/affris/species-profiles/nile-tilapia/nutritional-requirements/en/

FAO-INCODER. (2011). Diagnóstico del Estado de la Acuicultura en Colombia. Plan Nacional de Desarrollo de la Acuicultura Sostenible en Colombia .

Fitzsimmons, K. 2000. Future trends of tilapia aquaculture in the Americas. Pages 252–264 in B.A. Costa-Pierce and J.E. Rakocy, eds. Tilapia Aquaculture in the Americas, Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana, United States.

Fitzsimmons, K. "Tilapia quality and safety in global markets". Honolulu. Conference Presentation. 23 Oct 2007.

Fitzsimmons, K., R. Martinez-Garcia and P. Gonzalez-Alanis (2011). Why tilapia is becoming the most important food fish on the planet. Better science, better fish, better life. Proceedings of the 9 th International Symposium on Tilapia in Aquaculture. Shanghai Ocean University, Shanghai. AquaFish Collaborative Research Support Program, Corvallis.

Fitzsimmons, K. (2014). *Oreochromis niloticus*. http://www.cabi.org/isc/datasheet/72086

Garcia, F., D. M. Romera, K. S. Gozi, E. M. Onaka, F. S. Fonseca, S. H. Schalch, P. G. Candeira, L. O. Guerra, F. J. Carmo and D. J. Carneiro (2013). "Stocking density of Nile tilapia in cages placed in a hydroelectric reservoir." Aquaculture 410: 51-56.

Garcia, N. V., C. A. Iregui and I. Hirono (2012). "*Edwardsiellosis*, common and novel manifestations of the disease: A review." Revista Colombiana de Ciencia Animal 5(1): 82-90.

Global Energy Observatory (GEO). (2012). Betania Hydroelectric Power Plant Colombia http://globalenergyobservatory.org/geoid/43451

Gonzalez, C.E. (2001). “Red tilapia culture in Colombia”. The Advocate.

Halwart, M., D. Soto and J. R. Arthur (2007). Cage aquaculture: regional reviews and global overview, Food & Agriculture Org.

Hernández, E., J. Figueroa and C. Iregui (2009). "Streptococcosis on a red tilapia, *Oreochromis sp.*, farm: a case study." Journal of Fish Diseases 32(3): 247-252.

Hernández-Rodríguez, A., C. Alceste-Oliviero, R. Sanchez, D. Jory, L. Vidal and L.-F. Constain-Franco (2001). "Aquaculture development trends in Latin America and the Caribbean." Aquaculture in the Third Millenium. Subasinghe, R., Bueno, PB, Phillips, MJ, Hough, C., McGladdery, SE y Arthur, JR (eds.): 317-340.

Hidrósfera (2003). Capacidad de Carga Pisciocola del Embalse de Betania- 2003.

Huang, L. Y., K.Y. Wang, D. Xiao, D. F. Chen, Y. Geng, J. Wang and G.Y. Xiao (2014). “Safety and immunogenicity of an oral DNA vaccine encoding Sip of *Streptococcus agalactiae* from Nile tilapia *Oreochromis niloticus* delivered by live attenuated *Salmonella typhimurium*.” Fish & Shellfish Immunology 38(1): 34-41.

IMO Group. (2013). Aquaculture Stewardship Council Final Audit Report: C.I. Pisciocola Botera, S.A.

Invasive Species Specialist Group (ISSG). (2006). Ecology of *Oreochromis spp.* Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=813&fr=1&sts=sss.

Iregui, C., E. Hernández, A. Jiménez, A. Pulido, A. Rey, J. Comas, L. Peña and M. Rodríguez (2004). "Primer mapa epidemiológico de las lesiones y enfermedades de los peces en Colombia." Universidad Nacional de Colombia. Ministerio de Agricultura. Pronatta. Bogotá. Colombia.

Iregui, C. A., M. Guarín, V. M. Tibatá and H. W. Ferguson (2012). "Novel brain lesions caused by *Edwardsiella tarda* in a red tilapia (*Oreochromis spp.*)." Journal of Veterinary Diagnostic Investigation 24(2): 446-449.

Iregui, C. A., G. M. Vasquez, A. L. Rey and N. Verjan (2011). "Piscirickettsia-like organisms as a cause of acute necrotic lesions in Colombian tilapia larvae." Journal of Veterinary Diagnostic Investigation 23(1): 147-151.

Jensen, Ø., T. Dempster, E. B. Thorstad, I. Uglem and A. Fredheim (2010). "Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention." Aquaculture Environment Interactions 1(1): 71-83.

Johansen, L.-H., I. Jensen, H. Mikkelsen, P.-A. Bjørn, P. Jansen and Ø. Bergh (2011). "Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway." Aquaculture 315(3): 167-186.

Kwon, S. R., Y. K. Nam, S. K. Kim, and K. H. Kim (2006). Protection of tilapia (*Oreochromis mosambicus*) from edwardsiellosis by vaccination with *Edwardsiella tarda* ghosts. Fish & Shellfish Immunology. 20(4): 621-626.

La Nation. (2014). "Los controles en Betania serán permanentes". <www.lanacion.com.co>

Leung, T. L. and A. E. Bates (2013). "More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security." Journal of Applied Ecology 50(1): 215-222.

Lowe, S., M. Browne, S. Boudjelas and M. De Poorter (2000). 100 of the world's worst invasive alien species: a selection from the global invasive species database, Invasive Species Specialist Group Auckland, New Zealand.

Luvizotto-Santos, R., P. J. M. Cordeiro and E. M. Vieira (2009). "Analysis of diflubenzuron in tilapia filet by HPLC-DAD." Journal of Chromatographic Science 47(9): 785-788.

Macintosh, D. 2008. Risks Associated with Using Methyl Testosterone in Tilapia Farming. Sustainable Fisheries Partnership. http://cmsdevelopment.sustainablefish.org.s3.amazonaws.com/2013/02/28/SFP%20MT%20paper-b3d73fec.pdf

MARD 2016. Colombia se afianza como el segundo exportador de trucha y tilapia a Estados Unidos. Ministro de Agricultura y Desarrollo Rural.

https://www.minagricultura.gov.co/noticias/Paginas/colombia-se-afianza-como-exportador-de-trucha-y-tilapia.aspx

McConnell, R. and R. Lowe-McConnell (1987). Ecological studies in tropical fish communities, Cambridge University Press.

Ministerio de Ambientey Desarrollo Sostenible. (2012). Informe de Gestion al Congreso.

Ministerio del Medio Ambiente. (2002). Guia Ambienta Para el Subsector Camaronicultor.

Narváez, J. C., A. Acero and J. Blanco (2005). "Variación morfométrica en poblaciones naturalizadas y domesticadas de la tilapia del Nilo *Oreochromis niloticus* (Teleostei: Cichlidae) en el norte de Colombia." Rev. Acad. Colomb. Cienc 29: 383-394.

National Marine Fisheries Service (NMFS). 2015. “Imports and Exports of Fishery Products” http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/raw-data/imports-exports-annual

Naylor, R., K. Hindar, I. A. Fleming, R. Goldburg, S. Williams, J. Volpe, F. Whoriskey, J. Eagle, D. Kelso and M. Mangel (2005). "Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture." BioScience 55(5): 427-437.

Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsky, M. C. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney and M. Troell (2000). "Effect of aquaculture on world fish supplies." Nature 405(6790): 1017-1024.

Naylor, R. L., R. W. Hardy, D. P. Bureau, A. Chiu, M. Elliott, A. P. Farrell, I. Forster, D. M. Gatlin, R. J. Goldburg and K. Hua (2009). "Feeding aquaculture in an era of finite resources." Proceedings of the National Academy of Sciences 106(36): 15103-15110.

Neto, R., Ostrensky, A. (2015). Nutrient load estimation in the waste of Nile tilapia Oreochromis niloticus (L.) reared in cages in tropical climate conditions. Aquaculture Research, 46, 6, p1365-2109.

Osorio, A., A. Wills and A. Muñoz (2013). "Characterization of byproducts from the filleting industry of Nile tilapia (Oreochromis niloticus) and Rainbow trout (*Oncorhynchus mykiss*) in Colombia." Revista de la Facultad de Medicina Veterinaria y de Zootecnia 60(3): 182-195.

Pikitch, E. K., K. J. Rountos, T. E. Essington, C. Santora, D. Pauly, R. Watson, U. R. Sumaila, P. D. Boersma, I. L. Boyd and D. O. Conover (2014). "The global contribution of forage fish to marine fisheries and ecosystems." Fish and Fisheries 15(1): 43-64.

Pillay, T. (2008). Aquaculture and the Environment, John Wiley & Sons.

Polinizaciones. (2013). “Colombia: Communities of Huila Continue to Defend Mother Earth from Mega-development Projects”. Upside Down World.

Pompa, T.J. and F.B. Rodriquez. (2000). Tilapia Aquaculture in Colombia. Pages 141-150 in B.A. Costa-Pierce and J.E. Rakocy, ed. Tilapia Aquaculture in the Americas, Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana, United States.

Pulido, A., G. Vasquez, C. Rivera, C. Iregui (2015). Factors related to the outbreaks of mortality in tilapia farms in Betania Dam – Colombia. World Aquaculture Society Meetings.

Pullin, R., M.-L. Palomares, C. Casal, M. Dey and D. Pauly (1997). Environmental impacts of tilapias. Tilapia Aquaculture. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture.

Ramirez, L.M and J.D.M. Gomez. (2014). The Environmental Licensing Scheme in Colombia. http://www.minambiente.gov.co/contenido/contenido.aspx?conID=7050&catID=1200

Ramsar. (2014). Contracting Parties to the Ramsar Convention on Wetlands. http://www.ramsar.org/cda/en/ramsar-about-parties-parties/main/ramsar/1-36-123%5E23808_4000_0__

Sanchez, M., A. Olaya, J. Rojas and H.I. Zambrano. (2001). Preliminary Composition of Aquaculture Funa in the Upper Magdalena River, Huila, Colombia. Society for Freshwater Science Conference Presentation. La Cross, Wisconsin.

Schwarz, L. (2007). Freshwater fish seed resources in Ecuador, pp. 233–240. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 628p.

Shoemaker, C. A., B. R. LaFrentz, P. H. Klesius, and J. J. Evans (2010). “Protection against heterologous *Streptococcus iniae* isolates using a modified bacterin vaccine in Nile tilapia, *Oreochromis niloticus* (L.).” Journal of Fish Diseases 33(7): 537-544.

SIOC. 2016. Sistema De Información De Gestión Y Desempeño De Organizaciones De Cadenas. Cadena Productiva Acuicultura. http://sioc.minagricultura.gov.co/index.php/art-inicio-cadena-acuicultura/?ide=51

Starling, F., X. Lazzaro, C. Cavalcanti and R. Moreira (2002). "Contribution of omnivorous tilapia to eutrophication of a shallow tropical reservoir: evidence from a fish kill." Freshwater Biology 47(12): 2443-2452.

Tacon, A. G. and M. Metian (2008). "Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects." Aquaculture 285(1): 146-158.

USDA. (2005). USDA National Nutrient Database for Standard Reference: Tilapia, raw.

Villaneda, A.A. (2007). Freshwater fish seed resources in Colombia, pp. 201–218. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 628p.

Welling, D. 2015. The Colombian tilapia farmer that's ready to take on the world. Fish Farming International. Digital Edition, http://fishfarminginternational.com/the-colombian-tilapia-farmer-thats-ready-to-take-on-the-world/

Zubieta, D.U., G. U. Zubieta, C.V. Barbosa and A. Espinosa. (2007). "Tialpia informe general del studio de prospective tecnologica de la cadena Colombiana de la tilapia en Colombia".

About Seafood Watch®

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

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

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

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[8] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

Seafood Watch will:

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

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

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

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

Best Choices/Green: Are well managed and caught or farmed in environmentally friendly ways.

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

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

Appendix 1 - Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	5
Management	5
Effluent	2.5
Habitats	2.5
Chemical use	5
Feed	5
Escapes	2.5
Disease	2.5
Source of stock	5
Predators and wildlife	0
Unintentional introduction	2.5
Other – (e.g., GHG emissions)	n/a
Total	**37.5**

C1 Data Final Score (0-10)	**3.41**	**YELLOW**

Criterion 2: Effluents

Factor 2.1 - Biological waste production and discharge

Factor 2.1a - Biological waste production

Protein content of feed (%)	28.5
eFCR	1.59
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	14
N content factor (fixed)	0.16
N input per ton of fish produced (kg)	72.504
N in each ton of fish harvested (kg)	22.4
Waste N produced per ton of fish (kg)	**50.104**

Factor 2.1b - Production System discharge

Basic production system score	0.8
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0

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

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

Factor 2.1 Score - Waste discharge score

Waste discharged per ton of production (kg N ton-1)	40.08
Waste discharge score (0-10)	**5**

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

2.2a Content of effluent management measures	2
2.2b Enforcement of effluent management measures	3
2.2 Effluent management effectiveness	**2.4**

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

Criterion 3: Habitat

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	7

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

3.2a Content of habitat management measures	2
3.2b Enforcement of habitat management measures	3
3.2 Habitat management effectiveness	**2.4**

C3 Habitat Final Score (0-10)	**5.47**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**4**	
C4 Chemical Use Final Score (0-10)	**4**	**YELLOW**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	Score

5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	4.95
Fishmeal from by-products (%)	98.7
% FM	0.06435
Fish oil inclusion level (%)	1.02
Fish oil from by-products (%)	100
% FO	0
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.59
FIFO fishmeal	0.00
FIFO fish oil	0.00
FIFO Score (0-10)	**9.99**
Critical?	NO
5.1b Susutainability of Source fisheries	
Sustainability score	-6
Calculated sustainability adjustment	-0.01
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**9.98**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	28.5
eFCR	1.59
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	68.98
Feed protein from NON-EDIBLE sources (%)	31.02
Protein OUTPUTS	
Protein content of whole harvested fish (%)	14
Edible yield of harvested fish (%)	33
Use of non-edible by-products from harvested fish (%)	75
Total protein input kg/100kg fish	45.315
Edible protein IN kg/100kg fish	31.26
Utilized protein OUT kg/100kg fish	16.77
Net protein gain or loss (%)	-46.34
Critical?	NO
F5.2 Net protein Score (0-10)	**5**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	5.97
eFCR	1.59
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	2.47
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	81.24
Inclusion level of land animal products (%)	12.26
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	1.59
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.70
Total area (Ocean + Land Area) (ha)	3.17
F5.3 Feed Footprint Score (0-10)	8

Feed Final Score

C5 Feed Final Score (0-10)	**8.24**	**GREEN**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	2	
6.1a Adjustment for recpatures (0-10)	0	
6.1a Escape Risk Score (0-10)	**2**	
6.2. Invasiveness score (0-10)	**8**	
C6 Escapes Final Score (0-10)	**5**	**YELLOW**
CriticaL?	**NO**	

Criterion 7: Diseases

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

Criterion 8X: Source of Stock

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

Criterion 9X: Wildlife and predator mortalities

C9X Wildlife and Predator Score (0-10)	**-6**	
C9X Wildlife and Predator Final Score (0-10)	**-6**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

F10Xa live animal shipments score (0-10)	9.00	
F10Xb Biosecurity of source/destination score (0-10)	6.00	
C10X Escape of unintentionally introduced species Final Score (0-10)	**-0.40**	**GREEN**
Critical?	n/a	