



Monterey Bay Aquarium Seafood Watch

Environmental sustainability assessment of farmed Nile tilapia (*Oreochromis niloticus*) from Indonesia produced in freshwater net pens.



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Species: Nile tilapia (*Oreochromis niloticus*)
Location: Indonesia
Gear: Freshwater net pen
Type: Farmed
Author: Seafood Watch
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Assessed using [Seafood Watch Aquaculture Standard v2](#)

About Seafood Watch®

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

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

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

Disclaimer

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

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished¹ 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 practices for some criteria may lead to more energy-intensive production systems (e.g. promoting more energy-intensive closed recirculation systems).

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

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.

Final Seafood Recommendation

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.17	YELLOW	
C2 Effluent	5.00	YELLOW	NO
C3 Habitat	6.67	GREEN	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	7.25	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	10.00	GREEN	
C 9X Predator and Wildlife mortalities	-6.00	YELLOW	NO
C 10X Escape of unintentionally Introduced species	0.00	GREEN	
Total	43.08		
Final score	5.39		

OVERALL RANKING

Final Score	5.39
Initial rank	YELLOW
Red criteria	0
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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

Summary

Tilapia raised in net pens in Indonesia that is certified by the Aquaculture Stewardship Council (ASC) have final score of 5.39 out of 10. With no red or critical scores, it is ranked “Yellow” with a recommendation of a “Good Alternative”.

Executive Summary

Introduction. Tilapia are one of the most important food fish produced. Tilapia farming occurs all over the world in various production systems, including closed containment, ponds, raceways, and open net pens. Tilapia are native to Africa but have been introduced by governments around the world because of their ability to control mosquitos and consume weeds in irrigation systems and provide a food source for growing populations. PT Aquafarm Nusantara (market name, Regal Springs), the largest producer and exporter of tilapia to the US in Indonesia, is currently one of the largest tilapia farming companies in the world and began their operations in Indonesia in 1988; they produced almost 50,000 mt of tilapia at their Indonesian facilities in 2013. A secondary producer, PT Suri Tani Pemuka (market name, Toba Tilapia), began farming operations in 2012, but both production and US exports have since been rising steadily; production in 2015 was 4,300 mt. Exported tilapia is mostly produced in net pens that are placed in artificial reservoirs and natural lakes. Both producers have farm sites that are certified by ASC.

Data. There is a notable lack of recent academic and peer-reviewed literature which assesses the ecological impacts of net pen tilapia farming in Indonesia. This assessment focuses on tilapia farms in Indonesia that have ASC certification, therefore the majority of data informing the recommendations is from ASC farm-level audits. Published literature that was focused on or applicable to the broader national industry was taken in context. Data was also collected through personal communication with ASC certified farms. The final score for Criterion 1 – Data is 4.16 out of 10.

Effluent. There is a notable lack of data on the effluent-related impacts of tilapia aquaculture in Indonesia. The impacts of ASC certified farms are difficult to tease out as separate from those occurring from other aquaculture and non-aquaculture activities. As such, the Risk-Based Assessment Method was used. With a feed protein content of 32% and FCR of 1.9, it is estimated that nearly 75 kg of waste nitrogen is produced per ton of farmed tilapia. As net pen systems are considered to discharge 80% of total waste production beyond the farm boundary, 59.9 kg of waste nitrogen enters the larger ecosystem for every ton of harvested farmed tilapia. The most ecologically-protective measures which manage effluent impact are contained in the ASC tilapia standard. These compliance criteria are farm-level effluent restrictions that are not specific to the waterbodies in which these farms operate and do not wholly mitigate cumulative-scale impact. However, enforcement is considered to be mostly effective, as successful achievement of certification demonstrates overall compliance and non-compliances during audits were identified and rectified. Ultimately, the final score for Criterion 2 –Effluent is 5 out of 10.

Habitat. While there is evidence that some waterbodies in which Indonesian tilapia farming occurs has experienced a loss in habitat functionality, those in which ASC-certified farms operate have seen more judicious farm siting, and as a result, only minor-moderate impacts to the habitat have occurred. The score for Factor 3.1 is 8 out of 10. Despite the lack of strong

government regulation of Indonesian tilapia farms, ASC certification – verified by audits conducted in 2012, 2013, 2014, and 2015 – strengthens the content and enforcement of habitat regulations PT Aquafarm Nusantara and PT Suri Tani Pemuka operate under. While individual farms may be sited according to ecological principles, there are no control measures for cumulative-level impacts to habitat. The score for Factor 3.2 is 4 out of 10. The final score for Criterion 3 – Habitat is 6.67 out of 10.

Chemical Use. Historically, tilapia aquaculture has had a demonstrably low need for chemical use. Audit data for ASC certification for both companies in 2013, 2014, and 2015 show no use of chemotherapeutants or antibiotics. However, legal therapeutants are permitted for pathogen treatment under the ASC standard, and as production takes place in net pens, these products would be released directly into the environment if used. The final score for Criterion 4 – Chemical Use is 8 out of 10.

Feed. Tilapia operations in Indonesia use commercial pelleted feeds. These feeds have a low inclusion level of marine ingredients (8.8% fishmeal and 1.5% fish oil, with byproducts accounting for 50% of each). The fishmeal inclusion level and FCR of 1.9 determine the FIFO value (0.37), which results in a basic score of 9 out of 10. The source fishery sustainability score (-2 out of -10) results in an adjusted Factor 5.1 score of 9.07 out of 10. With a small inclusion of non-edible ingredient inputs, the production of tilapia in Indonesia ultimately results in a net protein loss of 65%, equating to a Factor 5.2 score of 3 out of 10. The high inclusion of crop-derived ingredients, low inclusion of marine ingredients, and absence of land animal ingredients in tilapia feeds result in a feed footprint of 5.74 hectares appropriated per one ton of farmed tilapia, and a Factor 5.3 score of 8 out of 10. The combination of the three feed factors results in a final score for Criterion 5 – Feed of 7.25 out of 10.

Escapes. While both PT Aquafarm Nusantara and PT Suri Tani Pemuka comply with the escape prevention measures required for ASC certification, they are not considered to be comprehensive or robust enough to mitigate the inherently-high risk of escapement from net pens. Data contained in the audits confirm that trapping devices placed between individual net pens in an array do indeed capture fish, but there is not sufficient information to determine either the number of fish captured or whether those fish are farm escapees or resident wild individuals.

There is a long history of tilapia introduction into Indonesian waterbodies, and there is evidence that resident populations have established. While tilapia introductions to ecosystems to which they are not native have often resulted in primary and secondary alterations to their structure and functionality, these impacts have not been robustly linked directly to aquaculture escapees in Indonesia. There is significant potential, however, that escapees present additional pressure on native fish already impacted by past deliberate introductions. The final score for Criterion 6 – Escapes is 4 out of 10.

Disease. In Indonesia, bacterial diseases such as *Streptococcosis* and *Francisellosis* are the most frequently reported in tilapia farms. Even though there is no evidence of transmission to wild populations, the risk of disease transmission or retransmission from farmed to wild fish

populations is considered to be relatively high should disease events occur due to the open nature of net pens. These systems enable the transmission of the most frequent diseases in farmed tilapia, as they can be transmitted by direct contact with infected animals, or through contaminated water. However, data contained in the ASC audit reports for PT Aquafarm Nusantara and PT Suri Tani Pemuka indicate a low incidence of disease on their farms. Therefore, the final score for Criterion 7 – Disease is 4 out of 10.

Source of Stock. Both PT Aquafarm Nusantara and PT Suri Tani Pemuka own and operate their own hatcheries and source all of their seed from these facilities. As is the case throughout the world, tilapia production in Indonesia is fully independent of wild seed use, and thus, the final score for Criterion 8 – Source of Stock is 10 out of 10.

Predator and Wildlife Mortalities. Audit data indicate that there is no active lethal control of predators or other wildlife on PT Aquafarm Nusantara or PT Suri Tani Pemuka farm sites. Furthermore, there have been no mortalities of IUCN ‘red-listed’ species. However, there is no data to confirm that incidental mortalities of non-IUCN listed species do not occur, and as such, the impact is ultimately unknown. The final deductive score for Criterion 9X – Wildlife and Predator Mortalities is -2 out of -10.

Unintentional Species Introduction. No international movements of tilapia occur for PT Aquafarm Nusantara or PT Suri Tani Pemuka. Furthermore, hatcheries are located merely hours’ distance from growout sites and are not considered ecologically distinct from growout sites. As such, no trans-waterbody movements occur. There is no deduction for Criterion 10X – Escape of Unintentionally Introduced Species, and the final score is -0 out of -10.

Overall, tilapia raised in net pens by ASC-certified farms in Indonesia have final score of 5.39 out of 10. With no red or critical scores, it is ranked “Yellow” with a recommendation of a “Good Alternative”.

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Introduction

Scope of the Analysis and Ensuing Recommendation

Species: Nile tilapia (*Oreochromis niloticus*)

Geographic Coverage: Indonesia

Production Methods: Open net pens

Species Overview

Tilapia is a prolific fast-growing tropical species native to Africa, but introduced elsewhere as a valuable food fish. Tilapia is a common name applied to three genera: *Oreochromis* (maternal mouthbrooders), *Sarotherodon* (paternal mouthbrooders), and *Tilapia* (substrate spawners). Most species are unable to survive at temperatures below 50 °F (10 °C). Tilapia can live in either fresh or salt water. They are omnivores, feeding mainly on algae, aquatic macrophytes, detritus, and associated bacterial films (Fitzsimmons and Watanabe 2010).

Geographically, tilapias are the most wide-spread species for aquaculture production in the world. Close to 140 countries and territories are now recorded to have farmed tilapias in FAO database (FAO 2014). According to the National Fisheries Institute (NFI) (2014), tilapia is the fourth most consumed fish in the United States after shrimp, salmon, and canned tuna. In 2014, the average consumption of tilapia was just under 1.5 pounds per person.

Production Statistics

In 2014, global farmed tilapia production exceeded 5.3 million metric tons (FAO 2016). Like many other tilapia-farming nations, the industry in Indonesia has experienced significant growth, particularly in the last ten years. In 2005, Indonesian tilapia production was 189,000 mt, but production in 2014 surpassed 1 million mt (FAO 2016). According to Phillips et al. (2015), tilapia is Indonesia's most-produced aquaculture product, exceeding shrimp, milkfish, *Clarius* spp. catfish, carp, *Pangasius* spp. catfish, and groupers. Tilapia production dominantly occurs on the islands of Sumatra and Java, which contribute 43% and 38% to total national production, respectively, and approximately 25% of all tilapia production occurs in floating net pens in freshwater lakes. The remainder takes place in freshwater ponds.

Of the two companies reportedly exporting tilapia to the US (as discussed below), they apparently produce 50-60,000 mt annually. The larger of the two, PT Aquafarm Nusantara, the Indonesian sector of Regal Springs Group, self-reported 50,000 mt of production in 2013 (Regal Springs, undated), but more recent data is unavailable. A secondary producer, PT Suri Tani Pemuka, operating under the market name Toba Tilapia, began production in 2012, and in 2015, reported 4,300 mt of production (Budiati, pers. comm.).

Import and Export Sources and Statistics

The majority of Indonesian tilapia production is consumed domestically, but of the production that is exported, the United States and Europe account for the largest shares, with a comparatively-small percentage going to Asia. Indonesia is currently second to China in

supplying tilapia imports to the US market, but as China dominates the market, Indonesian tilapia accounted for only 4.6% of all US tilapia imports in 2015 (NMFS 2016). Honduras, Columbia, and Costa Rica are the next largest suppliers of tilapia imports to the US (NMFS 2016).

Import data from the National Marine Fisheries Service indicates that 10,428 mt of tilapia was imported from Indonesia in 2015 (NMFS 2016). Research for this assessment has indicated that there are two companies exporting tilapia to the US from Indonesia. The largest, PT Aquafarm Nusantara, is the Indonesian arm of Regal Springs, a multi-national company with farming operations in Indonesia, Mexico and Honduras; self-reported Indonesian exports have been growing steadily, from 9,626 mt in 2008 to 11,798 mt in 2013 (Huillery pers. comm.). A secondary producer, PT Suri Tani Pemuka (market name, Toba Tilapia), began exporting tilapia to the US in 2013 with 178 mt. Exports have risen in the two years since, with 736 mt and 978 mt in 2014 and 2015, respectively (Budiati pers. comm.).

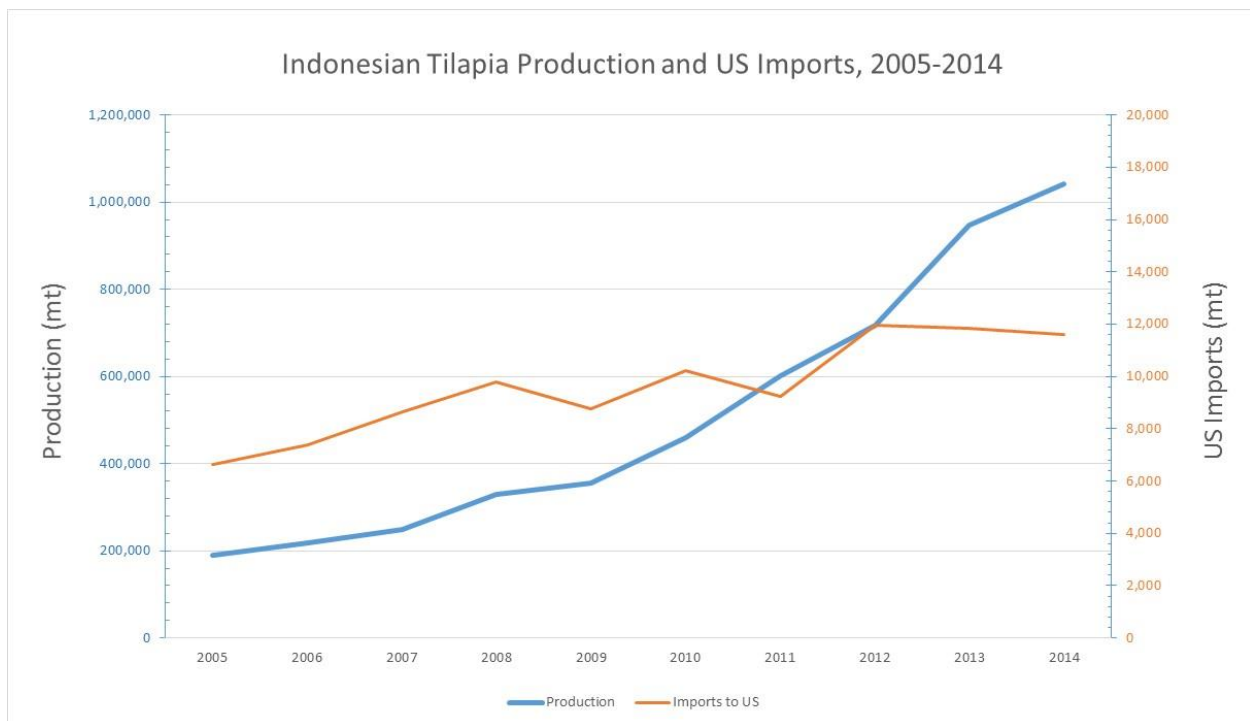


Figure 1: Tilapia production (from all production systems) in Indonesia and US exports from 2005 to 2014. Data from FAO and NOAA/NMFS.

Table 1: Self-reported exports to the US of tilapia farmed in Indonesia from each of the two exporting companies (denoted with ^a), and NOAA-reported Indonesian tilapia imports (denoted with ^b).

Year	PT Aquafarm Nusantara ^a (mt)	PT Suri Tani Pemuka ^a (mt)	Total ^b (mt)
2008	9,626	No production	9,793
2009	8,755	No production	8,769

2010	10,199	No production	10,224
2011	9,204	No production	9,227
2012	11,910	No export to US	11,967
2013	11,798	178	11,828
2014	No data	736	11,608
2015	No data	978	No data

Production System

Tilapia produced for export is raised mainly in net pens in lakes or reservoirs (100-1,500 m³ net pens) (Pelletier and Tyedmers 2010; Oakley 2015). PT Aquafarm Nusantara began farming in Indonesia in 1988 in Central Java. Initially, production was targeted at local markets, but international markets were needed to keep up with production growth as farming operations expanded. PT Aquafarm Nusantara owns and operates hatchery, growout, and processing facilities, enabling full control over all stages of tilapia growth and product preparation. PT Aquafarm Nusantara farms are located in public bodies of water: Lake Toba (North Sumatra) and Wunut, Wadas Lintang, Kedung Ombo and Wonogiri (in Central Java) (Huillery pers. comm. 2014).



Figure 2: PT Aquafarm Nusantara tilapia aquaculture operations in Indonesia.

Also operating in Sumatra's Lake Toba is PT Suri Tani Pemuka. While PT Aquafarm Nusantara operates five sites in Lake Toba (Panahatan, Sirungkungon, Silimalombu, Lontung, and Pangambatan), PT Suri Tani Pemuka operates two sites (Tigaras and Tambun Raya). Figure 3, taken directly from Oakley (2015), illustrates the location of each company's farm sites (in yellow and blue), as well as the sites of farms that supply the domestic market.

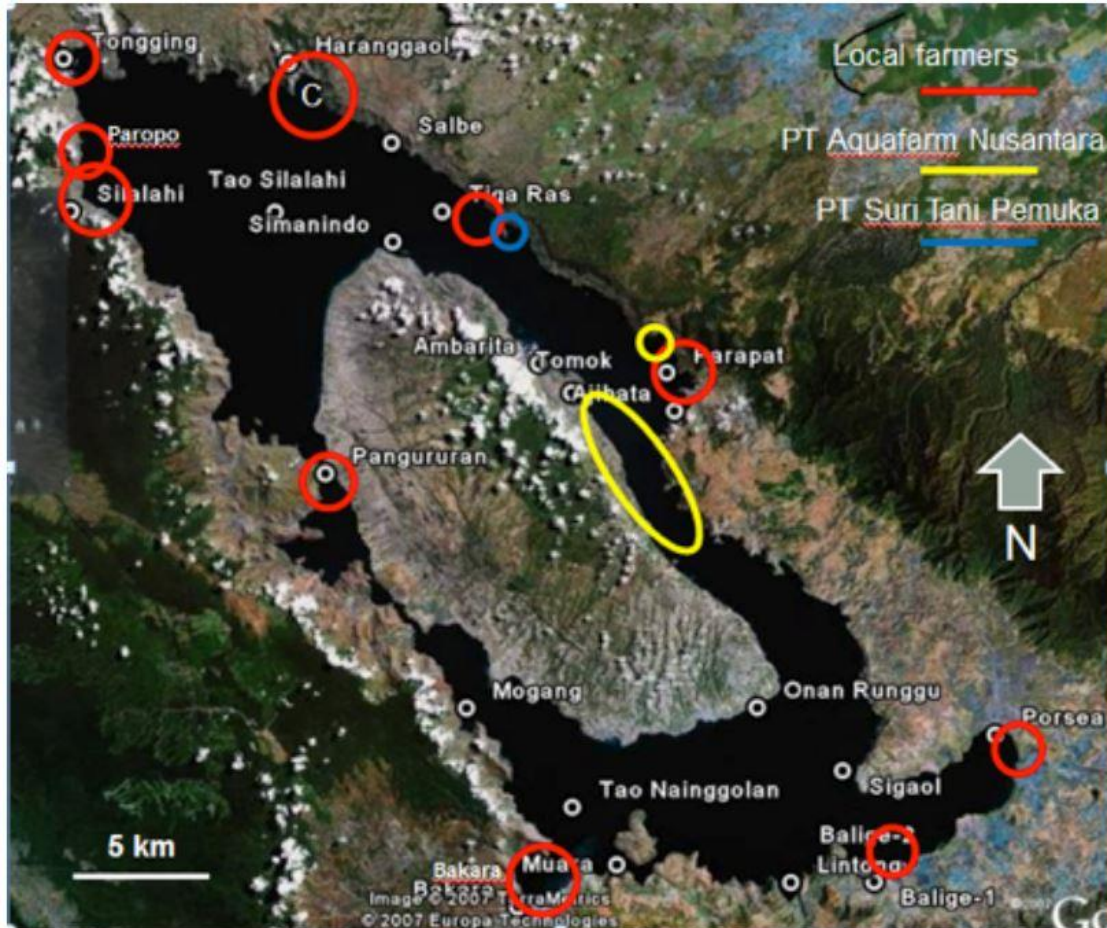


Figure 3: The location of net pen tilapia aquaculture farm sites in Lake Toba, Sumatra. Image taken directly from Oakley (2015).

Product Forms

All tilapia imported from Indonesia is frozen, with frozen fillets making up the majority (>96%). Tilapia produced by PT Aquafarm Nusantara is sold under the Regal Springs brand. Tilapia produced by PT Suri Tani Pemuka is sold under the Toba Tilapia brand.

Common and Market Names

Tilapia is also known in the market as Saint Peter fish and Izumidai (Fitzsimmons 2006).

Analysis

Scoring guide

- With the exception of the exceptional factors (3.3x and 6.2X), 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/cr/cr_seafoodwatch/content/media/mba_seafoodwatch_aquaculturecriteramethodology.pdf
- The full data values and scoring calculations are available in Annex 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: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	5	5
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			37.5

C1 Data Final Score	4.2	YELLOW
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Summary

There is a notable lack of recent academic and peer-reviewed literature which assesses the ecological impacts of net pen tilapia farming in Indonesia. Furthermore, the assessment here focuses only on two operators, PT Aquafarm Nusantara and PT Suri Tani Pemuka, who export net pen-raised tilapia to North America. As such, published literature that was focused on or applicable to the broader national industry was taken in context. PT Aquafarm Nusantara, the larger of the two companies, was consulted and provided data and information via personal communication. However, as both companies are certified by the Aquaculture Stewardship Council (ASC), and ASC audits (2012, 2013, 2014, and 2015) are publically-available, the most valuable data and information was sourced there. However, the limitation of personal communications and audit reports must be acknowledged. The final score for Criterion 1 – Data is 4.16 out of 10.

Justification of the Ranking

English-language information about the overall tilapia aquaculture industry in Indonesia is relatively limited. Production statistics are available, but research about the management and the environmental impacts of tilapia operations are lacking. Updated but dispersed information in English can only be obtained from studies performed by international organizations such as FAO and WorldFish. However, environmental impacts such as effluents, land use change, predators, and chemical use in tilapia production in Indonesia are not well represented in academic literature. Almost no publications on Indonesian tilapia production can be found in international peer-reviewed journals, and research by Indonesian institutions such as the Bogor Agricultural University is mostly based on experimental trials, and not in production facilities.

The assessment focuses solely on production by PT Aquafarm Nusantara and PT Suri Tani Pemuka, and therefore all data scores reflect data that was available specific to these farms. As the larger producer, much of the data was shared by PT Aquafarm Nusantara, which has a team of technical and management experts that manage the collection of data for the company and some of the data was shared for the purpose of the assessment. Four of the five PT Aquafarm Nusantara farms are certified to the Aquaculture Stewardship Council's (ASC) tilapia standard, meaning that the standards can be used to confirm certain production data points through third-party audits. The ASC audits conducted to date initially occurred in 2012 for 4 of the 5 farms. There were surveillance audits for 3 of the 5 farms in 2013 and surveillance audits for 4 of the 5 farms in 2015. It is possible that there were more audits conducted but the reports listed here are what appear on the ASC website. PT Suri Tani Pemuka's two sites are also ASC-certified, and the reports for an initial certification audit and a surveillance audit were available.

As this assessment focuses only on these two companies, all production information was provided directly by the company and in audits, and is considered to be a reliable representation of production, which receives a score of 7.5 out of 10. PT Aquafarm Nusantara provided some data on feed in terms of inclusion rates of fishmeal and oil, inclusion of edible ingredients, FCR, etc. and confirmed no use chemical and nor active killing of predators, and the use of domesticated broodstock. All of these data were then partially verified by the ASC Audit

reports (Stark 2012 a-d; Stark 2013 a-c, and Sang 2015a – d) which results in a score of 5 out of 10 for each category.

Data scores for Effluent, Habitat, and Disease are all 2.5 out of 10 due the limitations of the ASC standards in terms of their relevance to Seafood Watch criteria and the limited data set available. PT Aquafarm Nusantara has data from their ecological monitoring programs, but none of it was shared for use in this assessment. In addition, there is no verification of any data provided to Seafood Watch and of the data that was provided, it is not directly applicable to the Seafood Watch criteria.

The final score for Criterion 1 – Data is 4.2 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: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	74.88		
F2.1b Waste discharged from farm (%)	80		
F2 .1 Waste discharge score (0-10)		4	
F2.2a Content of regulations (0-5)	2.75		
F2.2b Enforcement of regulations (0-5)	4.75		
F2.2 Regulatory or management effectiveness score (0-10)		5.3	
C2 Effluent Final Score		5.00	YELLOW
Critical?	NO		

Summary

There is a notable lack of data on the effluent-related impacts of tilapia aquaculture in Indonesia, and the impacts of the farms under assessment here in isolation of those occurring from other aquaculture and non-aquaculture activities is even harder to evaluate. As such, the Risk-Based Assessment Method was used. With a feed protein content of 32% and FCR of 1.9, it is estimated that nearly 75 kg of waste nitrogen is produced per ton of farmed tilapia. As net pen systems are considered to discharge 80% of total waste production beyond the farm boundary, 59.9 kg of waste nitrogen enters the larger ecosystem for every ton of harvested farmed tilapia. The most ecologically-protective measures which manage effluent impact are contained in the ASC tilapia standard. These compliance criteria are farm-level effluent restrictions that are not specific to the waterbodies in which these farms operate and do not wholly mitigate cumulative-scale impact. However, enforcement is considered to be mostly effective, as successful achievement of certification demonstrates overall compliance and non-compliances during audits were identified and rectified. Ultimately, the final score for Criterion 2 –Effluent is 5 out of 10.

Justification of Ranking

Risk-based Assessment

There is a notable lack of data on the effluent-related impacts of tilapia aquaculture in Indonesia, and the impacts of the farms under assessment here (i.e. those growing tilapia in net pen systems destined for the US market) in isolation of those occurring from other aquaculture and non-aquaculture activities is even harder to evaluate. In Lake Toba, for example, nitrogen- and phosphorus-based inputs to the lake include the aquaculture production from the farms under assessment here, farms supplying fish to non-North American markets, fertilizer and land animal waste runoff from nearby agricultural lands, and domestic sewage (Lehmusluoto 2000, Saragih and Sunito, 2001, Oakley 2015). Some additional, more specific context can be drawn by considering that of the estimated 76,284 mt of annual aquaculture production in Lake Toba (see Oakley 2015), the PT Aquafarm Nusantara and PT Suri Tani Pemuka collectively contribute only one-half (~38,500 mt) of the total; in 2013, >75% of PT Aquafarm Nusantara's total production of 50,000 mt and 100% of PT Suri Tani Pemuka's production of 1,000 mt was in Lake Toba. Importantly, peer-reviewed estimates of Lake Toba's carrying capacity have not been developed (see Oakley 2015). Ultimately, despite reports of declining water quality in Lake Toba (Saragih and Sunito 2001, Lehmusluoto 2000, Lukman 2014, Oakley 2015), attribution to the aquaculture production under assessment here (or any one of, or combination of, the inputs to the ecosystem) is not robustly possible.

With a data score of 2.5 of 10 for the Effluent Criterion, the risk-based assessment was used.

Factor 2.1

Factor 2.1a Biological waste produced per ton of production

Nitrogen (N) production is used as a proxy measure representing the amount of waste being produced per ton of fish harvested. A feed conversion ratio (FCR) of 1.90 and a feed protein content of 32% (of which, 16% is nitrogen) were used in the calculation (Huillery pers. comm. 2014). It is considered that 74.9 kg of nitrogen waste is produced per ton of farmed tilapia.

Factor 2.1b Production system discharge

Both PT Aquafarm Nusantara and PT Suri Tani Pemuka use net pen production systems which, according to the Seafood Watch criteria, are estimated to release 80% of fish wastes to the surrounding waterbody as soluble effluent. The remaining 20% are assumed to be solid wastes that settle on the benthic environment below the net pen (and are therefore assessed in the Habitat Criterion). As such, the discharge score for Factor 2.1b is 0.8 out of 1.

The combined values for Factors 2.1a and 2.1b result in an estimated 59.9 kg of nitrogen waste discharged beyond the farm boundaries per ton of harvested tilapia, and results in a score for Factor 2.1 – Waste Discharged of 4 out of 10.

Factor 2.2a Regulatory or management effectiveness

A basic requirement for ASC tilapia certification is that production must be in compliance with all regulations set by the regional or national government(s) of Indonesia, but PT Aquafarm

Nusantara and PT Suri Tani Pemuka must also meet the criteria outlined in the ASC standard. It is therefore important to distinguish between the broader Indonesian tilapia aquaculture industry and the fish produced by these two producers for the US marketplace. Under the ASC tilapia standard, the requirements include monthly monitoring, testing, and recording of water quality and receiving waterbody quality; parameters include turbidity, temperature, nitrite, nitrate, ammonia, dissolved oxygen, pH, Secchi disk reading, conductivity, chlorophyll a, cumulative oxygen deficit, and total phosphorus. While the ASC effluent and water quality performance requirements for these parameters are designed for and specific to aquaculture, and they are specific to the site scale, they are not specific to the sites (i.e. waterbodies or ecosystems) in which each farm operates. In addition, ASC standards are farm-level in scope and therefore do not wholly address or prevent cumulative effluent impacts – especially considering not all farms in an area are certified by ASC – but they may work to partially reduce potential cumulative impact through siting, effluent, and monitoring requirements. Lastly, because water quality testing is required on a monthly basis, it can only be considered to moderately include times of peak biomass.

The score for Factor 2.2a – Intent and Content is 2.75 out of 5.

Factor 2.2b Enforcement level of effluent regulations or management

While the capacity and efficacy of regional and national government enforcement over all Indonesian tilapia farming is not fully known, the oversight of PT Aquafarm Nusantara and PT Suri Tani Pemuka (i.e. those exporting to the US) by ASC is more easily identified. ASC, the certification bodies issuing compliance certificates, and the auditors conducting site assessments are all identifiable through the ASC website (<http://www.asc-aqua.org/>) and its publically-available audit reports. These entities are contactable and appropriate to the scale of certification. Though effluent and water quality monitoring data were not made available for the purpose of this assessment, they are mandatory for demonstrating compliance with ASC standards and were therefore made available to the certification body conducting the audits. Compliance with the standards are outlined in the audit and surveillance audit reports (Stark 2012 a-d; Stark 2013 a-c, Unger 2014, Frank 2015, Sang 2015a – d) for both PT Aquafarm Nusantara and PT Suri Tani Pemuka. The ASC farm-level audits released in 2012, 2013, 2014, and 2015 for the certified operations in Indonesia indicate minor non-conformities due to improperly calibrated instruments, improper handling of samples, and inconsistent testing methods (Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Frank 2015, Sang 2015a – d). However, as action plans were developed and non-conformities rectified, it can be concluded that enforcement of ASC requirements includes (and demonstrably results in) compliance with set limits. Finally, there is stipulation that, in the event that non-conformities are not rectified based on the agreed-upon action plan and timeframe, certification is revoked; this demonstrates penalties for infringements on water quality performance requirements. However, as noted previously, the requirement for water quality monitoring on only a monthly basis leaves open the possibility of not capturing snapshots of ecological performance at times of peak biomass.

The score for Factor 2.2b – Enforcement is 4.75 out of 5.

For Factor 2.2 – Management of Farm-Level and Cumulative Impacts, the effluent regulatory and management score that results from compliance with the ASC tilapia standards is 5.3 out of 10.

Conclusion

Approximately 59.9 kg of waste nitrogen per ton of farmed tilapia is discharged from PT Aquafarm Nusantara and PT Suri Tani Pemuka farm sites, resulting in a score of 4 out of 10 for Factor 2.1. For Factor 2.2, the combination of farm-level effluent restrictions that are not specific to the waterbodies in which these farms operate or wholly mitigate cumulative-scale impacts and mostly-effective enforcement of the compliance criteria that are necessary for ASC certification results in a score of 4.55 out of 10. Ultimately, the final score for Criterion 2 – Effluent is 5 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		8.00	
F3.2a Content of habitat regulations	2.50		
F3.2b Enforcement of habitat regulations	4.00		
F3.2 Regulatory or management effectiveness score		4.00	
C3 Habitat Final Score		6.67	GREEN
Critical?	NO		

Summary

While there is evidence that some waterbodies in which tilapia farming occurs has experienced a loss in habitat functionality, those in which PT Aquafarm Nusantara and PT Suri Tani Pemuka have seen more judicious farm siting, and as a result, only minor-moderate impacts to the habitat have occurred. The score for Factor 3.1 is 8 out of 10. Despite the lack of strong government regulation of Indonesian tilapia farms, ASC certification – verified by audits conducted in 2012, 2013, 2014, and 2015 – strengthens the content and enforcement of habitat regulations PT Aquafarm Nusantara and PT Suri Tani Pemuka operate under. While individual farms may be sited according to ecological principles, there are no control measures for cumulative-level impacts to habitat. The score for Factor 3.2 is 4 out of 10. The final score for Criterion 3 – Habitat is 6.67 out of 10.

Justification of Ranking

Factor 3.1. Habitat conversion and function

Floating net pens have little direct impact to the physical nature of the habitat; rather, the most significant impacts result from the deposition of nutrient-rich feeds and fish waste, and their consequent encouragement of shifts in the chemical composition and biological community under and surrounding the farms.

In Indonesia, net pens for tilapia aquaculture are located in public water bodies such as reservoirs and lakes (Edwards 2010, ASC 2014, Oakley 2015). Monitoring impacts to the

benthos below farm sites is not required by regulation nor for ASC certification; there are no data, therefore, which help to describe the degree to which these potential impacts are occurring as a result of tilapia farming by PT Aquafarm Nusantara and PT Suri Tani Pemuka. While it was found by Hayami et al. (2008) that 25% of organic matter in sediments of the Cirata Reservoir in Indonesia was derived from fish feed, neither PT Aquafarm Nusantara or PT Suri Tani Pemuka operate in waterbodies with the same degree of aquaculture development. For example, the volume of Lake Toba is approximately 240 km³ with an annual aquaculture production of 76,000 mt (Oakley 2015). By contrast, Cirata Reservoir's maximum capacity is approximately 2.16 km³ (Costa-Pierce and Soermarwoto 1990) – less than 1% of Lake Toba's – but whose >50,000 cages (Bengtson 2014) are likely producing >50,000 mt collectively (see Prihadi 2003, Mungkung et al. 2013) – an estimated 75% of the production in Lake Toba. The enrichment of the sediments and the water column can have impacts on nutrient recycling and fisheries production, but it is recognized that other factors are contributing to the enrichment of the bottom (Donohue and Garcia Molinos 2009, Jørgensen et al. 2005, Karakassis et al. 1999).

PT Aquafarm Nusantara and PT Suri Tani Pemuka tilapia farms in Indonesia are sited and managed in a way to minimize the habitat disturbance. In the case of Lake Toba, where >75% of production under assessment takes place, the lake is very deep (up to 500 m) and there are only a few subsistence farms in the same waterbody. Other farm sites operated by PT Aquafarm Nusantara operate in artificial reservoirs. ASC tilapia standards do not account for benthic impacts directly. Therefore, due the lack of exact information on pond depths and benthic monitoring, it is expected that minor-moderate impacts will occur from the tilapia farms under assessment, even while habitat functionality is maintained (at least in the case of natural systems such as Lake Toba). The score for Factor 3.1 is 8 out of 10.

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

The impact of habitat conversion should be considered cumulatively, with individual farms contributing incrementally to effects at the landscape level. In order to determine the cumulative impact of aquaculture on habitat function, this factor assesses the existence and enforcement of regulations that control aquaculture industry size and concentration.

Factor 3.2a Regulatory or management effectiveness

PT Aquafarm Nusantara and PT Suri Tani Pemuka operations are subject to both government regulations and ASC requirements. Farm siting and cumulative aquaculture impact in Indonesia falls under the purview of the General Directorate of Aquaculture Production and Development (GDAPD) and is dependent on the Ministry of Marine Affairs and Fisheries. The Indonesian Fisheries Act No 31 (2004) regulates the aquaculture sector in terms of environmental impacts. The law on regional administration (Law No.22/1999) places responsibility upon provincial governments for management, use, conservation, and spatial planning of aquatic environments in their own territories (USAID 2007). However, the central government maintains control of license issuance for foreign investors. A set of directives (Pedoman Umum–Pedum) has been issued to guide the implementation of responsible and sustainable aquaculture procedures for

brackish water shrimp culture and fish culture in reservoirs (Nurdjana 2006). Implementation guidelines (Petunjuk Pelaksanaan–Juklak) and technical guidelines and regulations for ‘Good Aquaculture Practices’ (KEP.02/MEN/2007) have been developed to promote environmentally friendly aquaculture practices, including tilapia farming (Nurdjana 2006, Santoso 2011).

In the application of siting requirements and impact assessment, there is a need to differentiate habitat governance between ASC certified tilapia farms and the wider Indonesian tilapia aquaculture industry. Farm location in Indonesia is not based on ecological principles, and regulations do not account for its cumulative impacts (Nurdjana 2006). Indonesia does not include farm siting as part of a wider zoning plan, and carrying capacity models are not yet developed.

The ASC standards contain a limited number of measures to reduce habitat impact (e.g., avoidance of wetland habitat, site selection based on ecological principles, and monitoring of farm expansion activities). Considering the total size and concentration of the industry, as well as designation of suitable areas, it is clear that neither the ASC tilapia standard nor the government oversight offer any promise of managing expansion based on ecological principles. The future expansion of the industry does not fall under the more restrictive standards set by the ASC, as those limitations are only relevant to farms that apply for certification. In addition, the ASC standards are farm-level in scope and therefore do not robustly manage cumulative impacts. There is some evidence that high-value habitats are being avoided for siting. Finally, the ASC standards do not address important freshwater habitats beyond wetlands.

The score for Factor 3.2a is 2.5 out of 5.

Factor 3.2b Siting regulatory or management enforcement

The effectiveness of aquaculture regulations in Indonesia is constrained by the different levels of organizational responsibility, the lack of coordination among them, and the resultant incapability of implementing the controls at the district levels. The existence of multiple agencies with limited enforcement capacity results in weak implementation of spatial regulations (Phillips et al. 2009). In some waterbodies, the unlimited proliferation of net pens is promoted by the absence of a licensing system (Phillips and De Silva 2006).

PT Aquafarm Nusantara and PT Suri Tani Pemuka operations are subject to both government regulations and ASC standards and are required to be fully compliant to maintain certification. The enforcement organizations are identifiable, contactable, and appropriate to the scale of the industry under ASC certification, and all of the audit reports are publically-available. While there is a difference between the regulations required for government and for ASC certification, operating under the guidance of both reduces the potential risk for habitat impact from the farms under assessment here. However, neither the ASC nor the Indonesian government actively manage potential cumulative impacts.

The score for Factor 3.2b is 4 out of 5.

For Factor 3.2 – Farm Siting Management and Effectiveness, the final score is 4 out of 10.

Conclusion

While there is evidence that some waterbodies in which tilapia farming occurs has experienced a loss in habitat functionality, those in which PT Aquafarm Nusantara and PT Suri Tani Pemuka have seen more judicious farm siting, and as a result, only minor-moderate impacts to the habitat have occurred; the score for Factor 3.1 is 8 out of 10. Despite the lack of strong government regulation of Indonesian tilapia farms, ASC certification – verified by audits conducted in 2012, 2013, 2014, and 2015 – strengthens the content and enforcement of habitat regulations PT Aquafarm Nusantara and PT Suri Tani Pemuka operate under; the score for Factor 3.2 is 4 out of 10. The final score for Criterion 3 – Habitat is 6.67 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	8.00	
C4 Chemical Use Final Score	8.00	GREEN
Critical?	NO	

Summary

Historically, tilapia aquaculture has had a demonstrably low need for chemical use. Audit data for ASC certification for both companies in 2013, 2014, and 2015 show no use of chemotherapeutants or antibiotics. However, legal therapeutants are permitted for pathogen treatment under the ASC standard, and as production takes place in net pens, these products would be released directly into the environment if used. The final score for Criterion 4 – Chemical Use is 8 out of 10.

Justification of the Ranking

Although data for chemical use in tilapia farms in Indonesia is very scarce, conversations with farm managers along with ASC audits for both PT Aquafarm Nusantara and PT Suri Tani Pemuka demonstrate the absence of chemical therapeutant and antibiotic use (Subyakto 2011, Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Frank 2015, Sang 2015a – d). The ASC standard monitors the use of banned chemicals, prophylactic use of antibiotics, treatment of water if use occurs, records of use, and calculation of the total amount used. The only reported chemical is the use of male hormones in hatcheries, which are not assessed within the scope of this report. Tilapia fingerlings are fed with crumbled feeds containing 17-alpha-methyl testosterone (MT) to produce all-male tilapia populations (Budhiman 2007, Zairin and Raswin 2005). MT use is considered a low risk to human health and the environment if the recommended best practices are being observed (Macintosh 2008).

Typically, tilapia production involves a low and infrequent use of chemicals. Indeed, data contained in audits for ASC certification confirm that at farms exporting tilapia to the US, no

chemicals or antibiotics are used during growout production. However, there are no regulatory or management measures that would limit the therapeutic use of chemicals or antibiotics in the event of disease incident, and as tilapia are grown in open net pens, these products would be released directly to the environment. Some degree of concern, therefore, is warranted.

The final score for Criterion 4 – Chemical Use is 8 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	0.37	9.07	
F5.1b Source fishery sustainability score		-2.00	
F5.1: Wild Fish Use		9.00	
F5.2a Protein IN	39.46		
F5.2b Protein OUT	13.56		
F5.2: Net Protein Gain or Loss (%)	-65.64	3	
F5.3: Feed Footprint (hectares)	5.74	8	
C5 Feed Final Score		7.25	GREEN
Critical?	NO		

Summary

Tilapia operations in Indonesia use commercial pelleted feeds. These feeds have a low inclusion level of marine ingredients (8.8% fishmeal and 1.5% fish oil, with byproducts accounting for 50% of each). The fishmeal inclusion level and FCR of 1.9 determine the FIFO value (0.37), which results in a basic score of 9 out of 10. The source fishery sustainability score (-2 out of -10) results in an adjusted Factor 5.1 score of 9.07 out of 10. With a small inclusion of non-edible ingredient inputs, the production of tilapia in Indonesia ultimately results in a net protein loss of 65%, equating to a Factor 5.2 score of 3 out of 10. The high inclusion of crop-derived ingredients, low inclusion of marine ingredients, and absence of land animal ingredients in tilapia feeds result in a feed footprint of 5.74 hectares appropriated per one ton of farmed tilapia, and a Factor 5.3 score of 8 out of 10. The combination of the three feed factors results in a final score for Criterion 5 – Feed of 7.25 out of 10.

Justification of Ranking

All data used for Criterion 5 – Feed was obtained from personal communication with Anne-Laurence Huillery, the sustainability officer and production coordinator for PT Aquafarm Nusantara and represent weighted average values for ingredients from all feeds used for growout. Though PT Suri Tani Pemuka is an additional tilapia producer in Indonesia, their production, and thus feed usage, relative to PT Aquafarm Nusantara is small. As such, feed data from PT Aquafarm Nusantara alone is considered to be sufficiently representative of feed usage and sustainability for nationwide net pen tilapia production in Indonesia.

Factor 5.1. Wild Fish Use

Factor 5.1 – Wild Fish Use combines the calculated fish in: fish out (FIFO) ratio to with an adjustment dictated by the sustainability of the source of marine ingredients. The FIFO is calculated for both fishmeal and fish oil using their inclusion level (i.e. the percentage of total feed composition they account for), their yields (i.e., the proportion of meal and oil obtained from processing the fish), and the feed conversion ratio (FCR) (i.e., the weight of feed required to obtain one equivalent unit of fish weight). Tilapia feeds in Indonesia have a 10.3% total inclusion of marine ingredients, where fishmeal is included at 8.8%, and fish oil at 1.5%, and one-half of each is sourced from byproducts. Unless otherwise specified, fish meal and oil yields are assumed to be 22.5% and 5%, respectively (Tacon and Metian 2008). The FCR was reported to be 1.9. The FIFO calculated for fishmeal is the higher of the two (0.37), and is therefore used as the final value in the scoring calculations, and results in a Factor 5.1a – FIFO score of 9.07 out of 10.

Table 2: The parameters used and their calculated values to determine the use of wild fish in feeding farmed tilapia in Indonesia.

Parameter	Data
Fishmeal inclusion level	8.8%
Percentage of fishmeal from byproducts	50.0%
Fishmeal yield (from wild fish)	22.5% ²
Fish oil inclusion level	1.5%
Percentage of fish oil from byproducts	50.0%
Fish oil yield	5.0% ³
Economic Feed Conversion Ratio (eFCR)	1.9
Calculated Values	
Fish In : Fish Out ratio (fishmeal)	0.37
Fish In : Fish Out ratio (fish oil)	0.29
Seafood Watch FIFO Score (0-10)	9.07

² 22.5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fishmeal from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

³ 5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fish oil from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

The basic 5.1a score is adjusted by Factor 5.1b – Sustainability of the Source of Wild Fish (SSWF), which assesses the sustainability of the marine ingredients sourced in the production of tilapia feed. The main source of fishmeal is Peruvian anchoveta, which has FishSource scores all greater than 6 (FishSource 2012), and thus the SSWF score is -2 out of -10.

The combination of Factors 5.1a (9.07 out of 10) and 5.1b (-2 out of -10) result in an overall 5.1 – Wild Fish Use score of 9 out of 10.

Factor 5.2. Net Protein Gain or Loss

PT Aquafarm Nusantara tilapia feeds contain 32% crude protein. At an inclusion rate of 8.8% and an average protein content of 66.5% (see Seafood Watch Aquaculture Criteria), fishmeal is calculated to provide approximately 18% of total feed protein. As stated, the composition of fishmeal includes whole fish and byproducts at 50% each, so approximately 9% of total protein is provided by non-edible marine ingredients. Without data on specific non-marine feed ingredients, it is assumed that all non-marine protein in feed is derived from edible crop ingredients. , and therefore the remainder of the protein in feed (91%) is assumed to be from edible crops.

The edible yield of tilapia is 37% (DeLong et al. 2009), but head and skins are sold in local markets. The average protein content of whole harvested fish is 14% (Boyd 2007). Even though tilapia fillet yield is 37%, 95% of the processing byproducts are used for further feed protein production.

Table 3: The protein budget for net pen tilapia aquaculture in Indonesia.

Parameter	Data
Protein content of feed	32%
Percentage of total protein from non-edible sources (byproducts, etc.)	9.1%
Percentage of protein from edible crop sources	90.9%
Feed Conversion Ratio	1.9
Protein INPUT per ton of farmed tilapia	39.5 kg
Protein content of whole harvested tilapia	14%
Edible yield of harvested tilapia	37%
Percentage of farmed tilapia byproducts utilized	95%
Utilized protein OUTPUT per ton of farmed tilapia	13.6 kg
Net protein loss	- 65.6%
Seafood Watch Score (0-10)	3

The edible protein balance between inputs (39.5 kg per ton) and outputs (13.6 kg per ton) yields a net loss of 65.6% of the edible protein. This results in a Factor 5.2 – Net Protein Gain or Loss score of 3 out of 10.

Factor 5.3. Feed Footprint

The feed footprint is estimated through the sum of the ocean and land areas required to produce the marine, crop, land animal ingredients in feeds. Although the use of non-edible ingredients (i.e. byproducts) help offset total ingredient use calculations in Factors 5.1 and 5.2, all feed sources are included in their entirety in Factor 5.3 since they represent the appropriation of primary productivity that would have otherwise remained in its respective ecosystem. Tilapia feeds in Indonesia are dominated by crop ingredients (89.7%) as no land animal products are sourced and marine ingredients inclusion is 10.3%.

Table 4: Marine, crop, and land animal inclusion in tilapia feed, and the ocean and land areas necessary to support one ton of farmed fish production.

Parameter	Data
Marine ingredients inclusion	10.3%
Crop ingredients inclusion	89.7%
Land animal ingredients inclusion	0%
Ocean area (hectares) used per ton of farmed tilapia	5.09
Land area (hectares) used per ton of farmed tilapia	0.65
Total area (hectares)	5.74
Seafood Watch Score (0-10)	8

The sum of the area appropriated for marine ingredients (5.09 hectares) and crop-derived ingredients (0.65 hectares) results in a total feed footprint of 5.74 hectares per ton of farmed tilapia. This results in a Factor 5.3 – Feed Footprint score of 8 out of 10.

The combination of Factor 5.1 – Wild Fish Use score (9 out of 10), Factor 5.2 – Net Protein Gain or Loss (3 out of 10) and Factor 5.3 – Feed Footprint (8 out of 10) result in a final score for Criterion 5 – Feed of 7.25 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations.*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		6	
C6 Escape Final Score		4.00	YELLOW
Critical?	NO		

Summary

While both PT Aquafarm Nusantara and PT Suri Tani Pemuka comply with the escape prevention measures required for ASC certification, they are not considered to be comprehensive or robust enough to mitigate the inherently-high risk of escapement from net pens. Data contained in the audits confirm that trapping devices placed between individual net pens in an array do indeed capture fish, but there is not sufficient information to determine either the number of fish captured or whether those fish are farm escapees or resident wild individuals.

There is a long history of tilapia introduction into Indonesian waterbodies, and there is evidence that resident populations have established. While tilapia introductions to ecosystems to which they are not native have often resulted in primary and secondary alterations to their structure and functionality, these impacts have not been robustly linked directly to aquaculture escapees in Indonesia. There is significant potential, however, that escapees present additional pressure on native fish already impacted by past deliberate introductions. The final score for Criterion 6 – Escapes is 4 out of 10.

Justification of Ranking

Factor 6.1a. Escape Risk

Basic Escape Risk Score

In aquaculture production, reliable information on fish escapes is often unavailable. In these cases, Seafood Watch assesses the potential risk of escape by evaluating the ‘openness’ of the production system. For tilapia production in Indonesia, net pens sited in open bodies of

lakewater present a high risk of escapement; the infrastructure points that are vulnerable to a breach of containment are many, and escapees have a direct connection to natural ecosystems. Some escape prevention measures, however, are in place at both PT Aquafarm Nusantara and PT Suri Tani Pemuka as required under ASC certification. These include appropriately-sized mesh on net pens (at PT Suri Tani Pemuka, 1-inch mesh for fish <150 g in weight and 2-inch mesh for fish >150 g in weight), regular inspections of net condition and resulting appropriate repairs (nets are inspected daily and records are kept), and the use of transport containers which have no escape path when transferring fish to and from growout pens. ASC audits confirm compliance with these requirements for both PT Aquafarm Nusantara and PT Suri Tani Pemuka (Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Frank 2015, and Sang 2015a – d). However, as is noted above, net pen production systems are inherently vulnerable to escapement at both the large scale and small scale “trickle losses”, and the few precautions required for net pen systems by the ASC tilapia standard only partially mitigate this vulnerability. The risk of escape is considered to be moderately high, and the basic, unadjusted score for Factor 6.1a – Escape Risk Factor is 2 out of 10.

Recapture and Mortality Score

The basic Escape Risk score, as detailed above, may be adjusted if some (or all) escapees are recaptured or do not survive long enough to have a negative environmental impact⁴. Per the requirements of the ASC tilapia standard, PT Aquafarm Nusantara and PT Suri Tani Pemuka have trapping devices placed between individual net pens in an array with the goal of recapturing escapees. While data contained in the audits confirm that these devices do indeed capture fish, and these captures are recorded, there is not sufficient information to determine either, *a*) the number of fish captured, or *b*) whether the fish captured are farm escapees or resident wild individuals. While it was communicated that PT Aquafarm Nusantara also make an effort to recapture escapees via gillnet fishing, the frequency of this necessity, nor its efficacy, could be determined.

While it is assumed that some farm escapees are recaptured, there is no data available to make a reliable estimate of reduced impact. As such, no recapture score is assigned, and the final score for Factor 6.1 – Escape Risk is 2 out of 10.

Factor 6.1b. Invasiveness

Factor 6.1b – Invasiveness is comprised of two parts: the first assesses the potential for, or degree of, ecological establishment of the farmed species in the wild (Parts A and B), while the second evaluates the direct ecological impacts of escapees in the wild (Part C).

Indonesia has a long history of tilapia introductions (Lin 1977, Welcomme 1984, Pullin 1988, Eidman 1989), likely dating to 1930 (De Silva et al. 2004), and most – if not all – lakes in Indonesia have been impacted by exotic tilapia introduction (Mozambique, *Oreochromis*

⁴ For example, if the main impact of farmed salmon escaping from sea cages occurs when they migrate into rivers, then mortality prior to reaching rivers can be included where it demonstrably leads to a reduction in the overall impact of the escapees.

mossambicus, and Nile, *O. niloticus*, tilapia) by government agencies (Sarnita 1987, Parenti and Soeroto 2004). It has been more than two decades since it was determined that tilapia have established self-sustaining populations in natural lacustrine water bodies in Indonesia (Fernando, 1991). While *O. mossambicus* is thought to be dominant in natural lakes, *O. niloticus* was first introduced to Indonesia in 1969, and is therefore typically the dominant species only in reservoirs that were built (dammed) during or after the 1970s (e.g., Jatilnuhur) (Baluyut 1999). Indeed, the ASC tilapia standard requires that all farms “demonstrate that the tilapia species cultured is established and naturally reproducing in the receiving waters of the operations on or before January 2008,” and all farm sites operated by PT Aquafarm Nusantara and PT Suri Tani Pemuka are in compliance with this requirement. As such, the score for Factor 6.1b, Part B is 2.5 out of 2.5.

While some researchers (e.g. De Silva et al. 2005, 2006) have suggested that there has been little evidence of impacts on biodiversity from commonly introduced exotic fish in Southeast Asia, there is an additional body of global evidence outlining the ecological impacts that non-native tilapia have had upon introduction (Pullin et al. 1997, Deines et al. 2016). Habitat destruction (Crutchfield 1995) and biotic and abiotic changes associated with eutrophication (Figueiredo and Giani 2005) have been linked to the establishment of feral tilapia populations, and these likely impact the fish species endemic to those ecosystems. Broadly, Deines et al. (2016) cite Canonico et al.’s (2005) conclusion that expansion of tilapia aquaculture has caused population decreases in harvestable native species, which, in turn, has led to a loss in recreational and cultural ecosystem services supported by those native species. Research has suggested that introduced tilapia have been key drivers in declines in native fish in the Philippines (Gindelberger 1981), India (Sugunan 1995, 2000), the United States (Black 1980, Varela-Romero et al. 2000), Lake Nicaragua (McKaye et al. 1995), and Lake Victoria (Ogutu-Ohwayo 1990, Mkumbo and Ligtoet 1992, Goudswaard et al. 2002). Indeed, some evidence specific to Indonesia supports the occurrence of similar ecological impact, as past fish stock enhancement conducted in some waterbodies resulted in a decline of wild resident species. The Ir. H Juanda Reservoir, for example, contained resident populations of 29 distinct species (Purnomo 1993, Purnomo et al. 1992a, 1994), but after a period of species introductions, namely tilapia, that waterbody’s species richness decreased to nine (Kartamihardja, 2004). Other research shows that, in Lake Toba, the introduction of *O. mossambicus* coincided with a decline of the endemic *Lissochilus* spp. cyprinids (Baluyut 1999, Da Silva et al. 2005), and *Neolissochilus sumatranus* (Maskur et al. 2010). However, there is a notable lack of strong, specific evidence that farm escapees or their progeny have resulted in alterations of ecological functionality in Indonesia.

While tilapia introductions to ecosystems to which they are not native have often resulted in primary and secondary alterations to their structure and functionality, these impacts have not been robustly linked to aquaculture escapees in Indonesia. It is possible, however, that escapees do contribute to such impacts, especially given the paucity of research specific to the locations in which tilapia are farmed in Indonesia (see results from Deines et al. 2016). The potential ecological impacts of tilapia production on wild populations in Indonesia are rooted mostly in competition for habitat and food resources and habitat modification. There is no

impact due to predation pressure or breeding partner competition. Tilapia has been established in the wild for reasons other than aquaculture; however, tilapia escapement from net pens is considered to present additional pressure on native fish already impacted by past deliberate introductions. This results in score for Factor 6.1b, Part C is 3.5 out of 5.

The score for Factor 6.1b – Invasiveness is 6 out of 10.

The Escape Risk score of 2 out of 10 and the Invasiveness score of 6 out of 10 result in a final score for Criterion 6 – Escapes of 4 out of 10.

Criterion 7: Disease; Pathogen and Parasite Interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

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

Summary

In Indonesia, bacterial diseases such as *Streptococcosis* and *Francisellosis* are the most frequently reported in tilapia farms. Even though there is no evidence of transmission to wild populations, the risk of disease transmission or retransmission from farmed to wild fish populations is considered to be relatively high should disease events occur due to the open nature of net pens. These systems enable the transmission of the most frequent diseases in farmed tilapia, as they can be transmitted by direct contact with infected animals, or through contaminated water. However, data contained in the ASC audit reports for PT Aquafarm Nusantara and PT Suri Tani Pemuka indicate a low incidence of disease on their farms. Therefore, the final score for Criterion 7 – Disease is 4 out of 10.

Justification of Ranking

Evidence of pathogen transmission from farmed fish to wild fish, and moreover, the population-level impact to those wild fish, is typically difficult to identify and quantify. In cases where such evidence does not exist, the Seafood Watch Disease Criterion uses on-farm disease and the openness of the production system to estimate the risk that such transmission and impact will occur.

Tilapia are susceptible to a variety of bacterial and parasitic infections, including those by *Streptococcus* spp., *Aeromonas hydrophila*, *Flavobacterium columnare*, *Edwardsiella tarda*, *Ichthyophitirius multifilllis*, *Gyrodactylus niloticus*, and *Trichodina* spp. (FAO 2005, Klesius et al. 2008, Amal and Zamri-Saad 2011). Of particular concern in tilapia aquaculture are Streptococcosis infections, caused by *S. iniae*, *S. agalactiae* (Shoemaker and Klesius 1997, Evan et al. 2006, Amal and Zamri-Saad 2011), and *Lactococcus garvieae* (Anshary et al. 2014), and its presence has been confirmed in various parts of Indonesia (Yuasa et al. 2008, Lusiastuti et al. 2009a, 2009b, 2012, 2014) and concluded to be “widely distributed” throughout the country (Anshary et al. 2014). In addition, its capability of horizontal transmission through a variety of

vectors (Shoemaker et al. 2000, Nguyen et al. 2002, Colquhoun and Duodu 2011, Anshary et al. 2014), its low host-specificity (Amal and Zamri-Saad 2011), its confirmed transmission between wild and cultured fish in the same waterbody (Colorni et al. 2002, Bromage and Owens 2002, Amal and Zamri-Saad 2011), and its potential to result in significant mortality of net pen-reared tilapia (Anshary et al. 2014) make it the most significant pathogen threat to the Indonesian ecosystems in which tilapia are farmed.

There are requirements of the ASC tilapia standard that are designed to manage on-farm disease, and certification of both PT Aquafarm Nusantara and PT Suri Tani Pemuka confirm that these requirements are being met by both companies (Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Frank 2015, Sang 2015a – d). All facilities must have site-specific health management plans in place, but without further detail, it cannot be confirmed what specific measures are taken to manage on-farm disease or its potential to be transmitted to resident wild species. Requirements also include daily removal (and recording) of mortalities, which reduce the likelihood of infections causing mortality of a fish, or the development of post-mortality infection, to persist and be transmitted throughout fish in or nearby net pens. Of additional note, as chemotherapeutant use must be recorded, audit data confirms that neither PT Aquafarm Nusantara or PT Suri Tani Pemuka have used therapeutant drugs or chemicals during the course of attaining or holding ASC certification (Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Frank 2015, Sang 2015a – d); this allows for the presumption that if diseases have been present on farms, they have not been severe or persistent enough to warrant treatment and would therefore be less likely to have been transmitted to wild fish.

However, fish grown in net pens systems are inherently vulnerable to infection by pathogens in the environment and, of most importance, have the potential to transmit disease to resident organisms. As tilapia are known to be susceptible to a variety of pathogens, including at least one that has been identified at farms throughout Indonesia and resulted in significant morbidity and mortality, this risk is notable.

Despite the presence of biosecurity plans and the seemingly infrequent occurrence of disease, the openness of net pens utilized by PT Aquafarm Nusantara and PT Suri Tani Pemuka present a moderate risk of disease transmission between farm fish and their wild counterparts. The final score for Criterion 7 – Disease is 4 out of 10.

Criterion 8: Source of Stock – Independence from Wild Fisheries

Impact, unit of sustainability and principle

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

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	100	
C8 Source of stock Final Score	10.00	GREEN

Summary

Both PT Aquafarm Nusantara and PT Suri Tani Pemuka own and operate their own hatcheries and source all of their seed from these facilities. As is the case throughout the world, tilapia production in Indonesia is fully independent of wild seed use, and thus, the final score for Criterion 8 – Source of Stock is 10 out of 10.

Justification of Ranking

Tilapia production by PT Aquafarm Nusantara and PT Suri Tani Pemuka is self-sufficient in terms of broodstock and seed production. PT Suri Tani Pemuka operates one hatchery in Simalungun Regency on Sumatra, less than two hours' drive from their Lake Toba growout sites. PT Aquafarm Nusantara operates one hatchery on Sumatra (Medan Hatchery) and one on Java (Kalatin Hatchery). The ASC audits confirm the use of hatchery broodstock (Stark 2012 a-d, Stark 2013 a-c, Unger 2014, Sang 2015a – d).

The final score for Criterion 8 – Source of Stock is 10 out of 10.

Factor 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an “exceptional” factor 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.

Factor 9X Summary

Wildlife and predator mortality parameters	Score	
F9X Wildlife and predator mortality Final Score	-6.00	YELLOW
Critical?	NO	

Summary

Audit data indicate that there is no active lethal control of predators or other wildlife on PT Aquafarm Nusantara or PT Suri Tani Pemuka farm sites. Furthermore, there have been no mortalities of IUCN ‘red-listed’ species. However, there is no data to confirm that incidental mortalities of non-IUCN listed species do not occur, and as such, the impact is ultimately unknown. The final deductive score for Criterion 9X – Wildlife and Predator Mortalities is -2 out of -10.

Justification of Ranking

Aquaculture operations can directly or indirectly cause the death of predators or other wildlife that are attracted to the cultured aquatic animals and/or the infrastructure in which they are grown. Under the ASC tilapia standards, the use of lethal predator control is not permitted, nor is the mortality – intentional or incidental – of IUCN ‘red listed’ species. According to the ASC Audit Reports, there is no evidence of wildlife and/or predator mortality in PT Aquafarm Nusantara or PT Suri Tani Pemuka tilapia farms. However, it is possible that accidental mortalities do occur, and as there were no data provided to confirm their absence, the ultimate impact to wildlife populations interacting with farm sites is unknown.

The final deductive score for Criterion 9X – Wildlife and Predator Mortalities is -6 out of -10.

Factor 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

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

Factor 10X Summary

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	6.00	
C10 Escape of unintentionally introduced species Final Score	-0.00	GREEN

Summary

No international movements of tilapia occur for PT Aquafarm Nusantara or PT Suri Tani Pemuka. Furthermore, hatcheries are located merely hours’ distance from growout sites and are not considered ecologically distinct from growout sites. As such, no trans-waterbody movements occur. There is no deduction for Criterion 10X – Escape of Unintentionally Introduced Species, and the final score is -0 out of -10.

Justification of Ranking

Tilapia production by PT Aquafarm Nusantara and PT Suri Tani Pemuka is self-sufficient in terms of broodstock and seed production. Neither company is reliant on shipping broodstock internationally; PT Aquafarm Nusantara and PT Suri Tani Pemuka operate their own hatcheries within Indonesia. PT Suri Tani Pemuka operates one hatchery in Tana Jawa in Simalungun Regency on Sumatra, less than two hours’ drive from their Lake Toba growout sites. PT Aquafarm Nusantara operates one hatchery on Sumatra and one on Java. The Medan Hatchery on Sumatra is about 168 km from the Lake Toba farms. While on Java, the Kalatin Hatchery is about 70 km from the farms. The waterbodies in which net pen operations (i.e. destination) operate are not considered ecologically distinct from those which are used by hatcheries (i.e. source). As such, no trans-waterbody movements are considered to occur.

There is no deduction for Criterion 10X – Escape of Unintentionally Introduced Species, and the score is -0 out of -10.

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

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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	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	5	5
Predators and wildlife	Yes	5	5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			37.5

C1 Data Final Score	4.2	YELLOW
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Criterion 2: Effluent

Factor 2.1a–Biological waste production score

Protein content of feed (%)	32
eFCR	1.9
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)	97.28
N in each ton of fish harvested (kg)	22.4
Waste N produced per ton of fish (kg)	74.88

Factor 2.1b–Production System discharge score

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	0.8

2.2 – Management of farm-level and cumulative impacts and appropriateness to the scale of the industry

Factor 2.2a–Regulatory or management effectiveness

Question	Scoring	Score
1–Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2–Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Mostly	0.75
3–Do the control measures address or relate to the cumulative impacts of multiple farms?	Partly	0.25
4–Are the limits considered scientifically robust and set according to the ecological status of the receiving waterbody?	Partly	0.25
5–Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Moderately	0.5
		2.75

Factor 2.2b–Enforcement level of effluent regulations or management

Question	Scoring	Score
1–Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Yes	1
2–Does monitoring data or other available information demonstrate active enforcement of the control measures?	Yes	1
3–Does enforcement cover the entire production cycle (i.e., are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Mostly	0.75
4–Does enforcement demonstrably result in compliance with set limits?	Yes	1
5–Is there evidence of robust penalties for infringements?	Yes	1
		4.75

F2.2 Score (2.2a*2.2b/2.5)	5.3
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C2 Effluent Final Score	5.00	YELLOW
	Critical?	NO

Criterion 3: Habitat**3.1. Habitat conversion and function**

F3.1 Score	8
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3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)**Factor 3.2a–Regulatory or management effectiveness**

Question	Scoring	Score
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1–Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Mostly	0.75
2–Is the industry’s total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	No	0
3 – Is the industry’s ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Partly	0.25
4–Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5–Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		2.5

Factor 3.2b–Siting regulatory or management enforcement

Question	Scoring	Score
1–Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2–Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Yes	1
3–Does the farm siting or permitting process take account of other farms and their cumulative impacts?	No	0
4–Is the enforcement process transparent–e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc,?	Yes	1
5–Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Yes	1
		4

F3.2 Score (2.2a*2.2b/2.5)	4.00
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C3 Habitat Final Score	6.67	GREEN
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	8.00	
C4 Chemical Use Final Score	8.00	YELLOW
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a–Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	8.8
Fishmeal from byproducts (%)	50
% FM	4.4
Fish oil inclusion level (%)	1.5
Fish oil from byproducts (%)	50
% FO	0.75
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.9
FIFO fishmeal	0.37
FIFO fish oil	0.29
Greater of the 2 FIFO scores	0.37
FIFO Score	9.07

Factor 5.1b–Sustainability of the Source of Wild Fish (SSWF)

SSWF	-2
SSWF Factor	-0.074311111

F5.1 Wild Fish Use Score	9.00
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5.2. Net protein Gain or Loss

Protein INPUTS		
Protein content of feed	32	
eFCR	1.9	
Feed protein from Nonedible sources (%)	18	
Feed protein from EDIBLE CROP sources (%)	82	
Protein OUTPUTS		
Protein content of whole harvested fish (%)	14	
Edible yield of harvested fish (%)	37	
Non-edible byproducts from harvested fish used for other food production	95	
Protein IN	35.60	
Protein OUT	13.559	
Net protein gain or loss (%)	-61.9099084	
	Critical?	NO
F5.2 Net Protein Score	3.00	

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	10.3
eFCR	1.9
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	69.7
Average ocean productivity for continental shelf areas (ton C/ha)	2.68
Ocean area appropriated (ha/ton fish)	5.09

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	89.7
Inclusion level of land animal products (%)	7.7
Conversion ratio of crop ingredients to land animal products	2.88
eFCR	1.9
Average yield of major feed ingredient crops (t/ha)	2.64
Land area appropriated (ha per ton of fish)	0.81

Value (Ocean + Land Area)	5.89
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F5.3 Feed Footprint Score	8.00
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Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	2
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Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	2

6.1b. Invasiveness

Part A – Native species

Score	0
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Part B – Non-Native species

Score	2.5
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Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g., by feeding, foraging, settlement or other)?	To some extent
Do escapees have some other impact on other native species or habitats?	To some extent
	3.5

F 6.1b Score	6
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Final C6 Score	4.00	YELLOW
	Critical?	NO

Criterion 7: Diseases

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

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	100	
C8 Source of stock Final Score	10	GREEN

Exceptional Factor 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
F9X Wildlife and Predator Final Score	-6.00	YELLOW
Critical?	NO	

Exceptional Factor 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	6.00	
F10X Escape of unintentionally introduced species Final Score	0.00	GREEN