compounds, disinfectants, pesticides, and antibiotics (Rico et al. 2012, 2013) (Li, Liu et al. 2013) Li et al. 2016) (Liu et al. 2017).

A variety of regulations in China pertain, or are applicable to, the use of chemicals in aquaculture. However, it appears that these regulations are aimed at food safety (i.e., the end product) rather than regulating the primary application of chemicals and the potential risk they pose to the ecosystem if released. These include the Food Safety Law (2009, amended in 2015) (Xinhua News Agency 2015), the Law on Agricultural Product Quality Safety (2006), Special Provisions of the State Council on Strengthening the Safety Supervision of Food and Other Products (2007), Aquatic Product Safety Regulations (2003), Tracing Procedures for the Export of Aquatic Products (2004), and Regulation 5017–2002 on Pollution-Free Aquatic Products in the Fishery Drugs Application Guidelines (NALO 2014). Since 2002, more than 60 technical standards for "pollution-free" aquaculture and over 40 standards for allowable levels of drug residues have been implemented (Wang et al. 2014). Another regulation regarding chemical residues is NY5070-2002 "Fisheries Product Medicine Residual Limit Regulation Standard," which specifies MRLs (Maximum Residue Limit) to common antibiotics used in Chinese aquaculture. However, reviews of these policies have indicated that regulations specific to antibiotic use were not being followed (Broughton and Walker 2010).

There has been a growing awareness and effort to prevent overuse of antibiotics in China, as many are available over the counter (i.e., without a health professional's prescription) and are unregulated for use in aquaculture (Li et al. 2013b) (Xiao et al. 2013). In response to this growing awareness and international pressure, the Chinese government issued a national action plan in 2016 to contain antimicrobial resistance. Under this five-year plan, several of the goals include improving surveillance on antimicrobial use, and also requiring a prescription for antibiotics sold for animal husbandry, though it will only apply to half of all Chinese provinces (Litovsky 2016) (Rousseau 2016) (Xiao 2017). The results of this increased surveillance and stringency remain to be seen, since the plan is currently being implemented and will be reviewed and updated in 2020.

In general, an overview of qualitative and quantitative data on the use of the chemicals used in Chinese aquaculture is lacking in the public domain. For this reason, Rico et al. (2012) compiled country-specific information for the top seven Asian aquaculture-producing countries, based on field surveys and national reviews published since 2000. Four of the reviewed publications—(Yulin 2000) (Zheng and Xiang 2002) (Yang and Zheng 2007) and (Qi et al. 2009)—referenced chemicals and biologics used in China (Table 3). Although the chemicals were not specified regarding environment, culture system, or species, the report documented the wide variety of products used. Of these, disinfectants, pesticides, and antibiotics have been shown to be the most environmentally hazardous compounds because of their high toxicity and potential for bioaccumulation.

Guangdong Mingji Aquatic Product Co., LTD.	*Guangdong*	01/28/2016	GENTIAN VIOLET
Beihai Evergreen Aquatic Product Sci. & Tech. Co.,Ltd.	*Guangxi*	03/04/2016	SULFADIAZINE
Qingdao Seaflying Food Co., Ltd.	*Shandong*	04/07/2016	LEUCOMALACHITE GREEN
Shanwei Cathay Food Freezing and Processing Co., Ltd.	*Guangdong*	08/10/2016	SULFAMETHOXAZOLE
Huazhou Boao Aquatic Products Co., Ltd.	*Guangdong*	09/08/2016	SULFADIAZINE
Zhongshan Metro Frozen Food Co	*Yandongsheng*	11/09/2016	LEUCOMALACHITE GREEN
Huazhou Boao Aquatic Products Co., Ltd.	*Guangdong*	02/17/2017	SULFADIAZINE
Guangxi Nanning Baiyang Food Co., Ltd.	*Guangxi*	02/28/2017	SULFADIAZINE
Guangxi Nanning Baiyang Food Co., Ltd.	*Guangxi*	04/03/2017	SULFADIAZINE
Maoming Yuantian Aquatic Refrigeration Company	*Guangdong*	04/10/2018	SULFADIAZINE
Zhanjiang Evergreen Aquatic Product	*Guangdong*	03/07/2018	SULFADIAZINE

Antibiotic resistance

Antibiotic resistance has become a major research area in relation to Chinese aquaculture, and is an important consideration given the historically poor governance of antibiotic use in the sector. Various studies investigating and demonstrating the prevalence of antibiotic resistance in relation to Chinese aquaculture operations have been published in recent years. For example, while not directly implicating tilapia culture, Chen et al. (2017) have demonstrated the presence of 11 antibiotic compounds and 9 types of resistance genes (including those for tetracyclines and sulfonamides) are present near mariculture facilities in southeast China. Similar findings have been reported in freshwater aquaculture in the Yangtze River region, mainly for shrimp and crab polyculture (Song et al. 2016). Additionally, as outlined in the Seafood Watch assessment of catfish raised in ponds in China, there is overwhelming evidence to support the presence of developed resistance to several antibiotics classified as highly or critically important for human medicine: oxytetracycline, doxycycline, ampicillin, and penicillin (Seafood Watch 2017).

More specific to tilapia culture, there is evidence of resistance in *Aeromonas* (Li and Cai 2011) and *Streptococcus* (Zhang et al. 2018) bacteria, which are pathogens commonly observed in tilapia production in China (see Criterion 7 – Disease). Serotypes isolated from a *Streptococcosis* outbreak in tilapia in Guangdong Province in 2015 demonstrated resistance to penicillin and sulfonamide (Zhang et al. 2018). Interestingly, a serotype that previously had not been associated with tilapia culture (serotype IX) was also detected and it showed resistance to erythromycin. There is also some indication that antibiotic resistance genes can be more prevalent in areas where fish ponds (including tilapia) are integrated with poultry farms, though this type of integration has been decreasing in China (Zhong et al. 2018).

total area of land and ocean appropriated to produce one ton of tilapia in China is 1.25 ha. These values equate to a final score of 9 out of 10 for Factor 5.3. When combined, factors 5.1, 5.2 and 5.3 result in a final Criterion 5 – Feed score of 8.16 out of 10.

Justification of Rating

Factor 5.1. Wild fish use

Tilapias represent the second-largest fed species group of freshwater fish, and production has been increasingly based on commercial feeds (Tacon et al. 2011). The imports of fishmeal to China equate to one third of the world's production (Cao et al. 2015a) and China produces approximately 60% of global aquaculture products. Of the fishmeal that is produced domestically, approximately 40% (250,000 MT) is derived from processing wastes; however, there are large variations in domestic production annually making it a less reliant source of feeds (Chiu et al. 2013) (Cao et al. 2015a). Fishmeal is also sourced from other Asian (unspecified) fisheries, mostly from non-targeted fisheries including "trash" fish (Cao et al. 2015a).

<u>Factor 5.1a – Feed fish efficiency ratio (FFER)</u>

The level of fishmeal (FM) inclusion in tilapia feeds is low in comparison to other cultivated fed finfish species, and although inclusion levels can vary 0 to 3% (Tacon et al. 2011), 2.5% (Chiu et al. 2013), 1% (Xu and Ming 2018), an average of 1.5% is used to calculate wild fish use. The level of fish oil (FO) required in feeds is very low, and in some cases is not included as a feed ingredient (Xu and Ming 2018); however, on average, a 0.5% inclusion is reported by Tacon et al. (2011) and Chiu et al. (2013). The inclusion of by-products in domestically produced fishmeal is estimated to be approximately 40% (Cao et al. 2015a), and as domestic feed use varies but can make up approximately half of feed use in tilapia production in China (Chiu et al. 2013), an average by-product inclusion rate of 20% is used to calculate wild fish use. As there is no information regarding the use of fish oil by-products, it is not included in calculating wild fish use. There are imported feed ingredients, but the inclusion of imported by-products is unknown and therefore the inclusion rate only represents what is known of domestic by-product use. Ultimately, a ("whole fish") fishmeal inclusion of 1.2% and fish oil inclusion of 0.5% are used.

The global average of fishmeal and fish oil yield, which includes the large volume of import to China, is reported to be 22.5% and 5% respectively (Tacon and Metian 2008). However, the yields for lower quality domestically produced marine ingredients are reportedly lower, at 20% for fishmeal and 3% for fish oil (Chiu et al. 2013). As the use of domestically produced feeds can be up to half of all feed used across China (Chiu et al. 2013), these yields were averaged to give 21.25% for fishmeal and 4% for fish oil.

A review by Chiu et al. (2013) of feeds and FCRs from intensive tilapia farms in Hainan—a region producing a large proportion of tilapia in China (Zhang et al. 2015)—found an average FCR was between 1.4 and 1.6. Additionally, Cao et al. (2015a) found an average eFCR of 1.6 for intensive monoculture throughout China (Cao et al. 2015a). In 2018, a detailed review of the current status of numerous aspects of Chinese tilapia aquaculture indicated the range of typical eFCRs to be between 1.2 and 1.5 (Xu and Ming 2018). Given the range of possible values, and the most recent range being 1.2 to 1.5, a value of 1.4 is used for all calculations in this report.

Table 5. Summary of Feed Factor 5.1 Wild Fish Use data.

Parameter	Data
Fishmeal inclusion level	1.5%
Percentage of fishmeal from byproducts	20%
Fishmeal yield (from wild fish)	21.25%
Fish oil inclusion level	0.5%
Percentage of fish oil from byproducts	0%
Fish oil yield	4%
Economic Feed Conversion Ratio (eFCR)	1.4
Calculated Values	
Feed Fish Efficiency Ratio (FFER) (fishmeal)	0.08
Feed Fish Efficiency Ratio (FFER) (fish oil)	0.18
Seafood Watch FFER Score (0-10)	**9.56**

The combination of a low eFCR and low fishmeal and fish oil inclusion gives a low Feed Fish Efficiency Ratio (FEER) of 0.08 for fishmeal and 0.18 for fish oil. The higher value, 0.18 for fish oil, is used and results in an overall score for Factor 5.1a of 9.56 out of 10.

Factor 5.1b – Sustainability of the source of wild fish

To measure the sustainability of the fisheries providing fishmeal and fish oil, the origins of both imported commercial feeds and domestically produced feeds are considered. There are significant concerns over the sustainability of the sources of fishmeal and fish oil from domestic fisheries, as notable declines in catches within China's Exclusive Economic Zone (EEZ) are influencing shifts towards products from non-targeted fisheries, including trash fish (Cao et al. 2015a) (Chun 2017). Given the variable quality and quantity of domestic feeds, future supplies of high quality commercial feeds have been secured by Chinese businesses and government subsidiaries by purchasing fishing rights in the Eastern Pacific, largely from the Peruvian anchovy fishery (Cao et al. 2015a, b). Products from the Eastern Pacific fisheries can be used in Chinese aquafeeds; however, since they tend to be higher quality, they are reserved for the high-value farmed species (Chiu et al. 2013). These products can also be used for tilapia and whiteleg shrimp feeds, often in conjunction as a mixture of domestic and imported fishmeal from other Asian countries as well as the US, Russia, and New Zealand depending on price and availability (Chiu et al. 2013). Thus, fishery products for Chinese tilapia feeds likely contain material from non-targeted fisheries, including trash fish, though the proportion to products from targeted fisheries is unknown. The species composition of this fishmeal can be very broad, as indicated by Cao et al. (2015b), who identified 71 trash fish species that have been included in aquafeeds in China, a majority of which have not been assessed for sustainability, and those that have are classified as overfished or fully fished (Cao et al. 2015a).

The FishSource scores for the most widely reported source of imported fishery products, Peruvian anchovy, are all >6 which warrants a Factor 5.1b score of –4 out of –10. However, there are significant concerns over the sustainability of domestic multi-species fisheries, whose unknown composition, unassessed sustainability, or demonstrable unsustainability warrant a score of –10 out of –10. Given that domestic and imported sources each equate to roughly 50% of national feed ingredients (Cao et al. 2015a), an intermediate Factor 5.1b score of –7 out of –10 is given.

The score for Factor 5.1b (–7 out of –10), when combined with Factor 5.1a (9.56 out of 10), results in a numerical deduction of –0.25 and a final Factor 5.1 score of 9.32 out of 10.

Factor 5.2. Net protein gain or loss

The production of tilapia in China results in a net loss of edible protein. This is due to a relatively high proportion of edible protein in feeds compared to a low protein content of the harvested fillet, and although much of the by-products are utilized from tilapia, they are largely for inedible purposes (e.g., cosmetics). The protein content of grow-out feeds is low in comparison to other fed finfish species and is estimated to be 28.5% (Weimin and Mengqing 2007) (Chiu et al. 2013). Although there is some information publicly available regarding the content and source of protein in the feeds of tilapia produced in China (listed in Table 6), there is no definitive or average formula for the country, and variation in ingredients makes it difficult to accurately calculate the average edible and non-edible protein content of a diet. For example, there was a reference made to the inclusion of poultry by-product in China (Weimin and Mengqing 2007), but since this was not included as an ingredient in either the most recent survey made by Tacon et al. (2011) or in a recent publication covering common tilapia aquaculture practices in China (Xu and Ming 2018), it is not included in the current assessment calculations.

To calculate the edible protein gain or loss, the fishmeal and crop ingredient inclusions (accounting for the percentage from edible and non-edible sources), the total protein content of feeds, and the eFCR were used. The edible content of the average feed was calculated by combining the ingredients listed for each that are considered fit for human consumption according to the Seafood Watch Aquaculture Standard (e.g., corn, distiller's grains, soybean meal). The percentage of edible protein was then averaged among the reported feed types. The only non-edible sources in the cited literature is represented in the non-edible fishmeal byproducts. This resulted in an average of 7% of total feed protein derived from marine ingredients (i.e., whole-fish fishmeal, rather than by-product-derived fishmeal), and the total feed protein from non-marine ingredients was calculated to be approximately 93%, figures which are generally in line with reported feed mixes (Tacon et al. 2011) (Chiu et al. 2013) (Ng and Romano 2013).

The protein content of whole harvested tilapia is 14% (Boyd et al. 2007). The edible yield of cultivated tilapia can be between 37 and 47% (Rutten et al. 2005) (Nguyen et al. 2010) (Gjerde et al. 2012) (El-Zaeem et al. 2012); therefore, an average of 42% was used in the calculations. This results in an average of 39.9 kg of protein inputs, of which 28.07 kg (70.34%) are edible and

15.47 kg of utilized edible protein outputs (all per kg of protein per 100 kg of harvested farmed tilapia), and an overall net protein loss of –44.87%. Although there is an overall loss of edible proteins for human consumption, many of the by-products of tilapia are utilized for non-edible purposes, including leather goods, cosmetics, nutraceuticals and chemical ingredients (Hanson et al. 2011). In particular, tilapia skin is rich in collagen, and this is reused as a major ingredient in cosmetics where it is processed into high-value albumen powder (Hanson et al. 2011). Xu and Ming (2018) outline in detail the typical processes and end products for tilapia byproducts use in China (Figure 10); however, the percentages for utilization are not included. Without knowing the exact percentage of typical tilapia by-product utilization for further protein production, this value is assumed to be 50%.

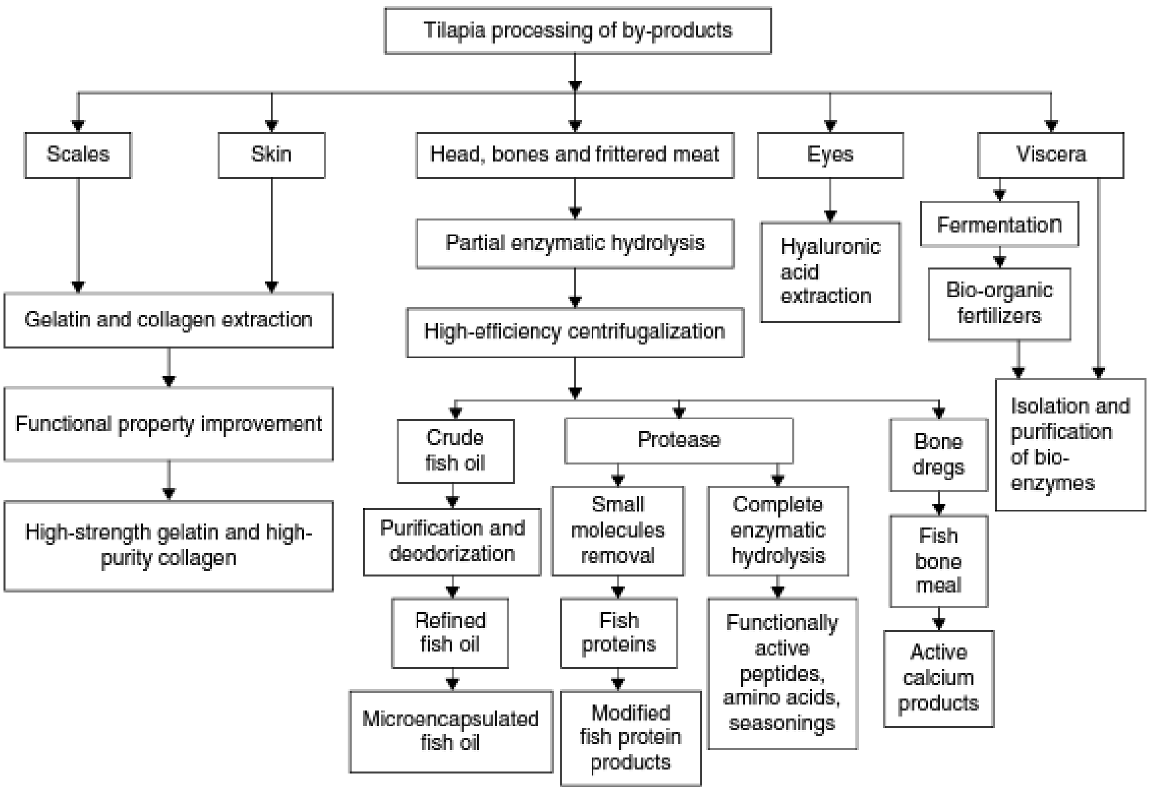

Figure 8. Production and utilization of tilapia processing byproducts (Source: Xu and Ming 2018).

Table 6. Ingredients and inclusion levels reported to be used in Chinese tilapia production. *Note:* mineral and multi-vitamin levels are not included as they are not used for calculating net protein gain or loss.

Ingredient (reference)	Inclusion Level	Edible?
(Weimin & Mengqing 2007)		
Fishmeal	4	-
Soybean meal	34	Yes
Wheat middling	30	Yes

Corn	22.1	Yes
Poultry by-product meal	6	No
Vegetable oil	0.5	Yes
(Tacon et al. 2011)		
Fishmeal	0–3	-
Soybean meal	0–25	Yes
Wheat bran	0–25	Yes
Corn	0–15	Yes
Rapeseed/canola meal	20–40	No
Cotton seed meal	0–25	No
Spirit based distillers grain	0-8	Yes
(Xu and Ming 2018)		
Fishmeal	1	-
Soybean meal	20	Yes
Peanut meal	5	Yes
Wheat	31	Yes
Barley	9.5	Yes
Rice bran	16	Yes
Soybean oil	0.5	Yes

Table 7. Summary of Feed Factor 5.2 Net protein gain or loss data.

Parameter	Data
Protein content of feed	28.5%
Percentage of protein from edible sources (whole fish FM, edible crops)	70.34%
Percentage of total protein from non-edible sources (byproducts, etc.)	29.66%
Feed Conversion Ratio	1.4
Edible protein INPUT per ton of farmed tilapia	39.90 kg
Protein content of whole harvested tilapia	14%
Edible yield of harvested tilapia	42%
Percentage of farmed tilapia byproducts utilized	50%
Utilized protein OUTPUT per ton of farmed tilapia	15.47 kg
Net protein loss	-44.87%
Seafood Watch Score (0-10)	**5**

Protein in grow-out feeds used for tilapia in China is sourced from approximately 70% from edible sources, with the remaining 30% considered to come from sources not suitable for human consumption. There is an overall net edible protein loss of 44.87%, leading to a Factor 5.2 score of 5 out of 10.

Factor 5.3. Feed footprint

The feed footprint area is an approximate measure of the global primary productivity resources required to produce feeds for tilapia in China; it is based on the global ocean and land area used to produce the feed ingredients required to grow one ton of farmed fish. The area of ocean primary production appropriated by feed ingredients per ton of farmed tilapia in China was calculated using the inclusion level of fishmeal and fish oil together at 2% and an eFCR of 1.4. The average primary production (carbon) required for aquatic feed ingredients at 69.7 tCt^{-1} and the average ocean productivity for continental shelf areas at 2.68 tCt^{-1}. Using the formula presented in the Seafood Watch Aquaculture Standard, it is calculated that Chinese tilapia feed requires 0.73 ha of ocean area for every ton of harvested fish.

In order to calculate the land area appropriated by feed ingredients of tilapia produced in China, the inclusion of both terrestrial crop and land animal ingredients in feeds are used. With no indication of land animal inclusion and minimally detailed information regarding crop ingredients, the inclusion level of marine ingredients (2%) was used to assume an inclusion rate of 98% (i.e., 100% minus 2%) for crop ingredients. Using the eFCR of 1.4, and the average yield of major feed ingredient crops 2.64 t ha^{-1}, the land area appropriated to produce one ton of tilapia in China is 0.52 ha^{-1}.

When combined, the total area of land and ocean appropriated to produce one ton of tilapia in China is 1.25 ha^{-1}. This value equates to a final score of 9 out of 10 for Factor 5.3.

Table 8. Summary of Feed Factor 5.3 Feed Footprint data.

Parameter	Data
Marine ingredients inclusion	2%
Crop ingredients inclusion	98%
Land animal ingredients inclusion	0%
Ocean area (ha) used per ton of farmed tilapia	0.73
Land area (ha) used per ton of farmed tilapia	0.52
Total area (ha)	1.25
Seafood Watch Score (0-10)	**9**

Conclusions and Final Score

The inclusion levels of FM (1.5%) and FO (0.5%) used in tilapia production in China are low in comparison to other fed finfish species. China is a significant importer of feed from South America, in particular Peru, and Peruvian anchovy stocks are generally rated as having moderate sustainability. However, a significant amount of feeds are produced domestically using unknown "trash fish" species, or products from fisheries whose sustainability is unknown or poor. Tilapia have a low fillet yield (42%) and although protein in feeds require low wild fish use, they have high inclusion rates of edible crops such as soy, wheat, and corn. Tilapia by-products can be used in cosmetic and pharmaceutical products, but it is assumed that 50% are used for further protein production. The low volumes of marine ingredients included and use of land crops for protein in feeds results in a small feed footprint of 1.25 ha to produce feed for one ton of tilapia production in China. Factors 5.1, 5.2, and 5.3 combine to result in a final Criterion 5 – Feed numerical score of 8.16 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

Escape parameters	Value	Score
F6.1 System escape risk	2	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		2
F6.2 Competitive and Genetic Interactions		0
C6 Escape Final Score (0-10)		**0**
Critical?	YES	**CRITICAL**

Brief Summary

Tilapia are considered highly invasive outside their native range and this includes the most commonly cultivated species in China (blue tilapia and Nile tilapia), which are named on the IUCN Global Invasive Species Database. Reports on tilapia escapes at the farm level in China are unavailable, therefore the risk of escapes from a pond system is measured by both the openness of the system and the vulnerability of the ponds to flooding events. Although ponds are generally only drained externally at harvest, recent literature provides evidence that tilapia cultivation occurs in regions where ponds are vulnerable to river flooding events and that escapes do indeed occur. Large areas where tilapia is cultivated are now known to have well-established (>10 years) populations (e.g., Hainan and Guangdong provinces). There are, however, still some regions in China where tilapia have not yet become established but are showing signs of developing establishment. Additionally, there are documented examples of tilapia populations vastly outcompeting local fish species for resources in Chinese waterways. Given the risk of extending the range of establishment and the invasiveness of the species, as evidenced by their competition with native species in China, the final score for Criterion 6 – Escapes is a Critical score of 0 out of 10.

Justification of Rating

Factor 6.1. Escape risk

Since 2014, Nile tilapia has been listed as an Alien Invasive Species in China and has specifically been listed by the government as a species that needs to be controlled to prevent the spread of invasive species. China has already had 18 provinces build specific offices/regulations to strengthen control and curb expansion of alien species (Ministry of Ecology and Environment of the People's Republic of China 2014) (Baidu Library 2015). Despite this, public reports on tilapia escape events at the farm, provincial, or national level are unavailable, and there is no information available regarding regulations for requirements to mitigate or report escapes. Therefore, the risk of escapes from a pond system is measured by both the openness of the system and the vulnerability of the ponds to flooding events.

Tilapia ponds are typically completely drained once per cycle (Liu et al. 2018). Evidence for the escape of farmed tilapia is observed across China and is thought to be primarily a result of river flooding events (Gu et al. 2014a, 2015, 2016, 2018) (Hu et al. 2015) (Xu et al. 2006), and in the Guangdong province there is evidence of the spread of Nile tilapia as a result of river flooding (Gu et al. 2014b).

Although pond culture systems for tilapia in China are typically only drained externally at harvest, there is evidence that tilapia cultivation occurs in regions where ponds are vulnerable to river flooding events and escapes do occur. Pond systems are considered a moderate-risk system; however, due to the evidence of tilapia escapes, this brings into question the robustness of the escape prevention measures implemented. Therefore, the score for Factor 6.1 is 2 out of 10.

Factor 6.2. Competitive and genetic interactions

Tilapia are considered highly invasive, and this includes the most commonly cultivated species in China (blue tilapia and Nile tilapia), which are named on the IUCN Global Invasive Species Database.[2] In China, *O. mossambicus* tilapia were first introduced in 1957 from Vietnam for aquaculture; since then, there has been an introduction of more than nine tilapia species, some specifically for aquaculture (Gu et al. 2014). Many introductions of tilapia species, however, occurred decades ago to control aquatic vegetation and stock for food in rivers, lakes and ponds. The introduction of Nile tilapia in Yunnan and Guangxi provinces are two such examples (Xu et al. 2006).

When initially introduced, it was thought that tilapia were unable to invade the temperate environments of China because they could not survive the winter temperatures, but recent evidence suggests low temperatures do not limit the year-round survival of tilapia (Gu et al. 2014) (Shuai et al. 2015), and overwintering and reproducing populations now exist in many rivers of Guangdong province, such as the Pearl, Hanjiang, Jianjiang, and Tinjiang rivers (Gu et al. 2014, 2018). There is also evidence that they have established populations in Hainan province, and there may be an emerging population in some areas of the Jiulong River in Fujian province (Xu and Ming 2018).

Since their introduction to China, tilapia have been able to establish and extend their range, which is thought to be due to both their large numbers in aquaculture and favorable biological

[2] http://www.iucngisd.org/gisd/

characteristics (Gu et al. 2016, 2018). Such characteristics have caused environmental impacts through competition with native fish for food (including invertebrates, small fish, decomposing organic matter, plants, and plankton), and their aggressive nature, which enables them to out-compete native fish species, such as mud carp (*Cirrhina molitorella*) in the rivers of South China (Canonico et al. 2005) (Martin et al. 2010) (Gu et al. 2014a, b 2015).

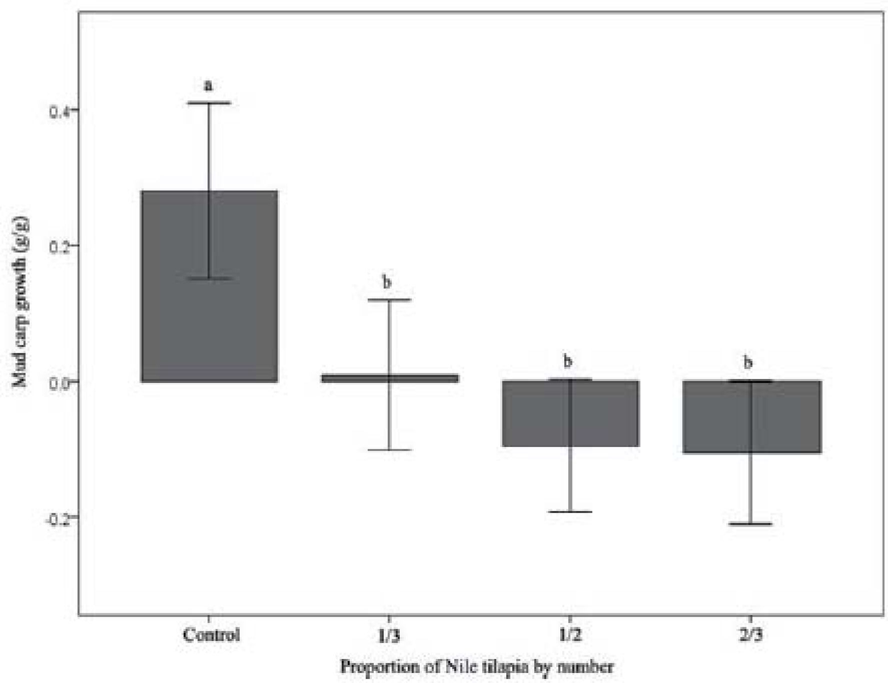

Figure 9. Native mud carp growth in the presence of Nile tilapia (Gu et al. 2017).

Tilapia biomass in rivers has also been associated with decreased water quality, primarily by increasing the total nitrogen, phosphorus, and chlorophyll levels (Gu et al. 2017). Activities like digging and nest building increase turbidity while excretions increase nutrient loading and promote phytoplankton growth. All of this leads to reduced light availability in the water column, which can modify the environment that the native species have adapted to (Gu et al. 2017) (Senanan and Bart 2010).

Although established more than 10 years ago in many areas of tilapia production, a forecast of the expansion of Nile tilapia in the Pearl River, where in some tributaries their occurrence remains rare, showed it likely to be an increasingly invasive species between 2013 and 2019 (Shuai et al. 2015). While this study represents a forecast, rather than a direct measurement, the data were based on already-established populations in this area and their likelihood to reproduce, and the resultant prediction for range expansion demonstrates the ability of tilapia to invade and establish in new areas and ecosystems, which is currently being observed in Fujian province (Xu and Ming 2018).

Despite the fact that there are still some regions in China where tilapia have not yet become established (Shuai et al. 2015) (Xu and Ming 2018), large areas where tilapia are cultivated are now known to have well-established (>10 years) populations (Gu et al. 2015, 2016, 2017). These non-native species have become fully ecologically established in the major production region of Guangdong by demonstrating survival in the winter temperatures and successful reproduction in the wild, both of which were previously not considered to be feasible for tilapia in the region. However, there is evidence that in some regions tilapia are not yet established, and given the historical and ongoing expansion of the range, this indicates a risk for continued expansion of the range.

Due to evidence of competition with mud carp in Chinese waters, the risk and ongoing expansion of the established range, and the invasiveness of tilapia, this results in a score of 0 out of 10 for Factor 6.2.

Conclusions and Final Score

There is evidence to suggest that tilapia cultivation occurs in regions where ponds are vulnerable to river flooding events, and escapes do indeed occur. Tilapia have now become fully ecologically established in the most productive region of Guangdong and Hainan; however, there still remain regions where production occurs and tilapia are not yet established. There is also evidence that populations are in the process of establishing in Fujian province. The risk of ecological impact is therefore considered to be high, and Factors 6.1 and 6.2 combine to give a final numerical score of a Critical 0 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

Disease Risk-Based Assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	3	
Critical?	NO	RED

Brief Summary

Because there is a lack of information about the impact of on-farm disease in Chinese tilapia production on wild fish, the Risk-Based Assessment is utilized. The intensification of tilapia cultivation in China has increased the risk and incidence of diseases through higher stocking densities and higher feeding rates, leading to decreased water quality and increased stress on the cultivated fish. Additionally, the GIFT strain selective breeding did not include characteristics related to disease resistance. The main diseases of tilapia in Asia include bacterial diseases caused by *Streptococcus* and *Aeromonas* species, of which *S. agalactiae* is reported as the most prevalent cause of mortalities, including in China. Other diseases are also known to be present in the industry. There are currently very few vaccines approved for aquatic use in China, few of which are relevant to the more prevalent known disease problems in the tilapia industry. The regulations for the control of disease in Chinese aquaculture are largely aimed at protecting farmed stocks from epidemics, and although these regulations may protect wild fish by reducing the prevalence of disease at the farm level, there is little detail on the enforcement measures for these regulations. In addition, there is evidence of a lack of enforcement on reporting requirements, which makes understanding current industry-wide disease incidence difficult. Pond systems are typically drained once at harvest, which reduces the risk of transmission to wild fish populations. However, there is growing evidence for disease outbreaks and resistance to treatments on farms, unknown implementation of biosecurity protocols, and little research regarding the impact this is having on wild fish populations. The final numerical score is 3 out of 10 for Criterion 7 – Disease.

Justification of Rating

As disease data quality and availability is low (i.e., Criterion 1 score of 2.5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment was utilized.

Although tilapia has long been considered a hardy and disease resistant species, the intensification of the industry has presented significant disease challenges. Intensification of tilapia cultivation in China has increased the risk of diseases through higher stocking densities and higher feeding rates that lead to decreased water quality and increased stress on the cultivated fish (Li et al. 2011, 2016) (Wang et al. 2014) (Mo et al. 2015), as well as selective breeding in GIFT strains for growth and skin color, but not for disease resistance (Wang and Lu 2015). This increased risk has resulted in disease outbreaks within the farm; however, there is currently no information regarding whether there has been amplification of disease in wild fish as a result.

The primary diseases affecting tilapia in Asia include bacterial diseases caused by *Streptococcus* and *Aeromonas* species (Li and Cai 2011) (Ye et al. 2011) (Zhao 2011a) (Li et al. 2016). The spread of *Streptococcus* bacterial infections in industries in the US, Israel, Kuwait, Brazil, Thailand, and China demonstrates its threat to the future of the industry (Ye et al. 2011). Of the *Streptococcus* species, *S. agalactiae* is reported as the most prevalent cause of mortalities in China (Li, et al. 2013) (Li et al. 2015). It was first reported in Fujian province causing 20 to 30% mortality in the summers of 2009–2010. Outbreaks spread south into Guangdong, Hainan, and Guangxi provinces with high infection rates (>50%), and of those infected, high mortality rates (>95%) in some farms (Ye et al. 2011) (Zhang et al. 2013) (Li et al. 2014). Streptococcosis mainly appears in the summer (May through September) when water temperatures are highest (25 to 37 °C) (Li et al. 2016), and there is currently no chemotherapeutic or immunological measure developed to prevent or control *Streptococcus* effectively (Zhang et al. 2013) (Wang and Lu 2015). One Chinese company has claimed it will be producing a vaccine (Liao and Ly 2017), but it is not yet available as of May 2018.

A number of less prevalent diseases are also reported in Chinese tilapia farms, which include enteritis, tail-rot (caused by *Aeromonas sobria*), fulminant hemorrhagic disease, trichodiniasis, dactylogyriasis, and obesity syndrome (Tang 2016). Enteritis has been reported in the Guangdong region, causing lethargic swimming, distended abdomen, and intestine filled with yellow mucus, as well as reports of unknown diseases that cause exopthalmia and liver enlargement (Li et al. 2016). Tail-rot disease in juvenile tilapia is caused by *Aeromonas sobria*, which has developed confirmed resistance to antimicrobial drugs commonly used in China (Li and Cai 2011). Fulminant hemorrhagic disease has been reported to cause mortalities in hybrid tilapia in Hainan (Yang et al. 2009). In addition, several novel diseases have been noted in tilapia in China. For instance, in Guangzhou, infected fish had white granulomas in the kidney, liver, heart, and spleen, thought to be the result of a *Francisella noatunesis* sub-species (Lin et al. 2016).

While it is not yet publicly reported in mainland China, another disease of global concern, Tilapia Lake Virus (TiLV), has affected tilapia farms and wild stocks on at least three continents and there is a notable global threat for its spread, as outlined by FAO and OIE (FAO 2017) (OIE 2017) (Intrafish 2017) (Kramer 2017). There has been confirmation of TiLV in Chinese Taipei, and mainland China was listed as a high risk for TiLV spread due to destinations of fry from Thai hatcheries where TiLV has been confirmed (Dong et al. 2017). The investigation into the destinations for tilapia fry from TiLV-affected Thai hatcheries did not indicate volumes or any further distinctions, so the frequency of shipments is unknown, neither the precise destination of potentially affected fry. Although China is reportedly monitoring for the disease, there has not been a confirmed case reported (Intrafish 2017) (Kramer 2017). Since TiLV has not been confirmed in China it does not currently impact the score for Criterion 7 – Disease, but monitoring should be prioritized.

Fishborne trematodes have been identified in tilapia farms of Guangdong province, but low prevalence was generally observed with highest rates in nursery monoculture ponds (6.2% prevalence) as opposed to nursery polyculture systems (1.1%), and rates much lower in monoculture and polyculture grow-out ponds at 0% and 0.5% respectively (Liet al. 2013a). However, regarding the impact this disease might have on wild fish, the results of this study indicate that on-farm amplification and to-the-wild transmission are mitigated by biosecurity measures taken by farmers, since the prevalence on-farm was significantly lower in comparison to the prevalence in local wild-caught fish from the surrounding areas.

Regulations on the control of disease in Chinese aquaculture are largely aimed at protecting farmed stocks from large-scale industry epidemics rather than the health of wild fish in the vicinity of farm sites. The Law on Animal Diseases (1997, amended in 2007, 2013) outlines the general requirements for quarantine measures that are administered primarily at the central and provincial government levels and these requirements do specifically include aquaculture (Central Government of the People's Republic of China 2013). This law also describes the procedures required for controlling the spread of animal disease, such as reporting large disease incidents, removing diseased animals after consulting a veterinarian for proper disposal, sanitizing associated equipment, and ensuring personnel working with diseased animals are not granted access to unaffected areas of the farm. The local veterinary department is responsible for enacting the first response to potential epidemics, by delineating the epidemic sites and identifying further threats for the potential to spread. Article 18 of the Fisheries Law (2004), outlines that administrative departments for fisheries at or above the county level will provide technical guidance for aquaculture in the prevention and treatment of diseases.

The Law on Animal Diseases (amended 2013) also states that the veterinary department is responsible for designing and implementing a mandatory immunization program; however, this does not appear to be implemented for aquaculture (pers. comm., F. Chen 2018) (China Aquaculture Network 2014). This is primarily due to the limited number of aquatic vaccines approved for use in China (Sohu 2017) (Table 9). Vaccines to prevent infection from several strains of *Vibrio*, *Edwardsiella*, *Aeromonas*, as well as grass carp hemorrhagic disease are the only aquatic vaccines produced and approved for use in China. Currently, the validity on the approval for vaccine for *Aeromonas* is expired (Sohu 2017).

Table 9. Vaccines produced domestically in China for aquatic use.

Vaccine (Chinese)	Vaccine (English)	Company
牙鲆鱼溶藻弧菌、鳗弧菌、迟缓爱德华菌病多联抗独特型抗体疫苗	*Vibrio alginolyticus, Vibrio anguillarum, Edwardsiella tarda* multi-antibody vaccine	Xi'an Skade Biological Products Co., Ltd.
大菱鲆迟钝爱德华氏菌病活疫苗（EIBAV1株）	*Edwardsiella tarda* live vaccine (EIBAV1 strain)	Zhejiang Nuoweiwei Biotechnology Co., Ltd.
草鱼出血病活疫苗（GCHV-892株）	Grass carp hemorrhagic disease live vaccine (GCHV-892 strain)	Zhaoqing Dahuanong Biological Pharmaceutical Co., Ltd.
嗜水气单胞菌败血症灭活疫苗	*Aeromonas hydrophila sepsis* inactivated vaccine	Guangzhou Purin Biological Products Co., Ltd.

Source: Sohu 2017

These regulations aim to reduce the prevalence of disease at the farm level and therefore theoretically reduce the potential discharge of pathogens to the environment; they include enforceable metrics in the form of quarantine protocols, mandated reporting and lists of mandatory immunizations. Nonetheless, there is little detail on the enforcement measures for these regulations and there appears to be no enforcement on reporting requirements for incidence of disease at the farm level. Additionally, there is a lack of investigation into transmission of diseases between farm and wild species; therefore, this report relies on incidence of on-farm pathogens and production system details.

Conclusions and Final Score

There is currently no available research into the impacts of on-farm diseases in Chinese tilapia on wild fish; thus, the Risk-Based Assessment was used for this criterion. There have been reported mass mortality events in Chinese tilapia pond cultivation systems. These have largely been the result of *Streptococcus* bacterial infections, and there has been some demonstrated resistance to antimicrobial drugs used to treat them. Also, new and emerging diseases are being reported in major production regions in China, and though disease control regulations are in place from the central government, there is no information on their enforcement or further implementation at lower levels of government. Thus, there is a risk posed to wild fish through the amplification of diseases from infected farmed fish. Pond systems are typically drained once at harvest (see Criterion 2 – Effluent), which reduces the risk of transmission to wild fish populations, but there is evidence of high infection and mortality rates on farms and the implementation and efficacy of biosecurity measures are currently unknown. Therefore, the final score is 3 out of 10 for Criterion 7 – Disease.

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

Brief Summary

Seed production of tilapia in China can occur by collecting seedlings from grow-out ponds; however, the predominant method is via large-scale hatchery production. The development of Genetically Improved Farmed Tilapia (GIFT) seed has helped overcome inconsistencies in traditional seed collection from grow-out ponds, increase growth rates, and increase cold and salinity tolerance. There are >200 hatcheries/nurseries nationwide, which includes five national seed hatcheries and >10 tilapia seed brands. Recent literature confirms that (domestic) hatchery production is more than 100 billion fingerlings annually, which is sufficient to meet industry demand. Because this is a closed, domesticated life cycle and 0% of the farmed tilapia stock is dependent on wild broodstock or wild fisheries, the final numerical score for Criterion 8X – Source of Stock is 0 out of –10.

Justification of Rating

There are two methods for seed production of tilapia in China: either by collecting seedlings from grow-out ponds or from large-scale hatchery production (Qiuming and Yi 2004). The production of seedlings (i.e., those fish to be stocked for grow-out) by collecting them from grow-out ponds after natural spawning is less efficient at producing males for grow-out due to impure parent genotype segregation; it is more labor intensive and less dependable (Qiuming and Yi 2004) (Xu and Ming 2018). The collection method for seed production has not been as prevalent in recent years, and large-scale hatchery production is utilized in some of the main producing provinces (Guangdong, Hainan, Guangxi). Primarily in these hatcheries, the collective production of tilapia fingerlings was sufficient to meet the needs of the tilapia industry, based on numbers of approximately 103 billion in 2013 (Xu and Ming 2018). As of 2014, there has been an estimated >200 hatcheries/nurseries, which includes five national seed hatcheries and >10 tilapia seed brands, which are located in Guangdong (100 hatcheries/nurseries), Hainan (40 hatcheries/nurseries) and Guangxi (10 hatcheries/nurseries) (Zhang 2014).

Genetically Improved Farmed Tilapia (GIFT) seedlings were developed to help overcome inconsistency in traditional seedling collection from grow-out ponds, increase the growth of production, and increase cold tolerance (Zhang et al. 2015) (Xu and Ming 2018). Many of the tilapia strains currently being bred in the large hatcheries are hybrids, which are also being selected to produce a large number of males, which primarily improves the growth rate (Xu and Ming 2018).

Because Chinese tilapia production, like that of the industry globally, operates with a closed, domesticated life cycle, and none of the farmed tilapia stock is dependent on wild broodstock or wild fisheries, the final numerical score for Criterion 8X – Source of Stock is 0 out of –10.

Conclusions and Final Score

Because no tilapia farm stock in China is dependent on wild broodstock or wild fisheries, the final numerical score for Criterion 8X – Source of Stock is 0 out of –10.

Criterion 9X: Predator and wildlife mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: 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

Predator and wildlife mortality parameters	Score	
C9X Predator and wildlife mortality Final Score (0–10)	**–3**	
Critical?	NO	**GREEN**

Brief Summary

Pond cultivation of tilapia is considered to attract a variety of predators and other wildlife: reptiles, birds, and small mammals. However, data on mortalities that occur as a result of this interaction in China are not available. Water birds in Chinese tilapia growing regions have been shown to be closely associated with aquaculture ponds. Despite this documented interaction, there is no information regarding whether control methods are taken by farmers against migratory birds. There is also a lack of research on wildlife interactions with tilapia ponds in China, and current literature suggests there is potential for migratory water birds to utilize ponds for foraging and resting. Chinese law does contain protections for rare and endangered species, yet the level of implementation for these regulations, as well as the specificity for aquaculture activities is unclear. Due to unknown interactions, evidence of the presence of wildlife on the farms, the presence of legal protections yet unclear implementation, and the possibility of migrating birds utilizing ponds for foraging and resting, the score for Criterion 9X – Predator and Wildlife Mortalities is –3 out of –10.

Justification of Rating

Pond cultivation of tilapia is considered to attract a variety of predators, such as reptiles, birds and small mammals (El-Sayed 2006) (Lucas and Southgate 2012). However, data on mortalities that occur as a result of this interaction in China are not available.

There is a lack of research on wildlife interactions with tilapia ponds in China, and current literature suggests the potential for migratory water birds to utilize ponds for foraging and resting (Choi et al. 2013). Many species of water birds in Chinese tilapia growing regions have been shown to be closely associated with aquaculture ponds (Ma et al. 2004, 2009) (Ke et al. 2011) (Choi et al. 2013) (Bai et al. 2015), ranging from the endangered red-crowned crane (*Grus japonensis*) (Ke et al. 2011) to more common dunlin shorebirds (*Calidris alpine*) (Choi et al. 2013). These interactions suggest that ponds can be used for foraging and resting (Choi et al. 2013) throughout the year or during migrations.

Within Chinese regulations, both terrestrial and aquatic wildlife is considered a state resource. The Wildlife Protection Law of the People's Republic of China specifically covers terrestrial and aquatic species that are "rare or near extinction" and terrestrial species that are "of important ecological, scientific, and social value" (Central Government of the People's Republic of China 1988, revised 2016). The list of wildlife that is considered rare or vulnerable in the context of the law is available online.[3] Further protections specifically for wild aquatic animals are covered in the Regulations of the People's Republic of China for the Implementation of Wild Aquatic Animal Protection (1993).

Both regulations require permits for capturing wild animals that are not under special protection and also prohibit the capture or extermination of a wild animal that is considered rare or vulnerable. Nonetheless, the law does indicate that a special permit for hunting some species protected by the Wildlife Protection Law can be granted in special circumstances, though it doesn't indicate what those circumstances would be. Because both of these regulations are not specific to aquaculture, it is unknown to what extent (if any) these special provisions are utilized specifically for the tilapia industry. Additionally, though these regulations do protect the rare and endangered species, it is unclear how the regulations are implemented at a local level.

Despite the known interaction of birds with fish ponds, there is no information regarding whether control methods are, in fact, taken by farmers against migratory birds. Laws are in place protecting rare and endangered species; however, the level of implementation and enforcement is unknown.

Conclusions and Final Score

Tilapia ponds can attract or interact with many species of reptiles, mammals, and water birds, yet there is no information regarding the prevalence of wildlife mortalities and what impact they might have on the populations. Additionally, there is evidence to suggest tilapia ponds can provide sufficient habitat for migrating birds. Chinese law does contain protections for rare and endangered species, but the level of implementation for these regulations, as well as the specificity for aquaculture activities is unclear. Due to unknown interactions, evidence of the presence of wildlife on the farms, the presence of legal protections, yet unclear implementation, and the possibility of migrating birds utilizing ponds for foraging and resting, the score for Criterion 9X – Predator and Wildlife Mortalities is –3 out of –10.

[3] http://www.fao.org/fishery/shared/faolextrans.jsp?xp_FAOLEX=LEX-FAOC006515&xp_faoLexLang=E&xp_lang=en

Criterion 10X: Escape of Secondary Species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- 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	
F10Xa International or trans-waterbody live animal shipments (%)	0	
F10Xb Biosecurity of source/destination	4	
C10X Escape of unintentionally introduced species Final Score (0–10)	**–6.00**	**YELLOW**

Brief Summary

Trans-waterbody movement between ecologically distinct environments risks introducing non-native pathogens, parasites, and non-target species, and the risk is driven by the reliance of production on such movements. In China, international imports of tilapia species for aquaculture breeding programs have occurred historically; however, there is currently a national program for seed production. In this program, seed is produced nationally and distributed locally to farmers of all production scales, which is likely to include trans-waterbody movements, resulting in a factor 10Xa score of 0 out of 10. The biosecurity of the source (hatchery) is presumed to be higher than that at the destination (farm), due to the developed industrial hatchery system and the inherent risks of culture for young life stages, resulting in a moderate score of 4 out of 10 for factor 10Xb. Although Chinese tilapia is self-sufficient in domestic seed production, the dissemination of tilapia broodstock and seed is reliant on trans-waterbody movements. Combining the scores for factors 10Xa and 10Xb results in the final numerical score for Criterion 10X – Escape of Secondary Species of –6 out of –10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

Mass movements of animals for aquaculture without appropriate management procedures can lead to the simultaneous unintentional introduction of accompanying animals (Naylor et al.

2001). Trans-waterbody movement between ecologically distinct environments risks introducing non-native pathogens, parasites, and non-target species, and the risk is driven by the reliance of production on such movements.

In China, international imports of species for aquaculture breeding programs have occurred in the past, and this includes the import of tilapia from several Southeast Asian countries, Egypt, Sudan, and the US since the 1940s (Yan et al. 2001) (Xu and Ming 2018). Since the introduction of the Genetically Improved Farmed Tilapia (GIFT) strain to China in the early 2000s, there is now a heavily government-supported infrastructure in place to produce GIFT seed domestically (Xu and Ming 2018) (Kumar and Engle 2016). In the past there have been small-scale imports of tilapia for seed production, including base GIFT populations from Vietnam in 2004 (Thodesen et al. 2011, 2013) and from Taiwan to Fujian province (Jiang et al. 2013). Additionally, Dong et al. (2017) identified China as a destination of fry from Thai hatcheries, but this report did not indicate volumes or destinations, so it is unknown whether this is a common occurrence for tilapia breeding programs in China or a one-time import for research purposes.

As demonstrated by the Fujian provincial government, there has been significant investment in the development of more industrialized seedling production systems (Jiang et al. 2013), and domestic broodstock that are adapted for different production systems in China are maintained domestically (Thodesen et al. 2011, 2013). GIFT seed is produced in provincial hatcheries and distributed to farmers of all production scales across China, which includes trans-waterbody movements (Honglang 2007) (Jiang et al. 2013). In Figure 10, the general framework for the tilapia breeding system in China is outlined, showing the centralized organization and potential for trans-waterbody movement as breeds and strains are disseminated throughout the country.

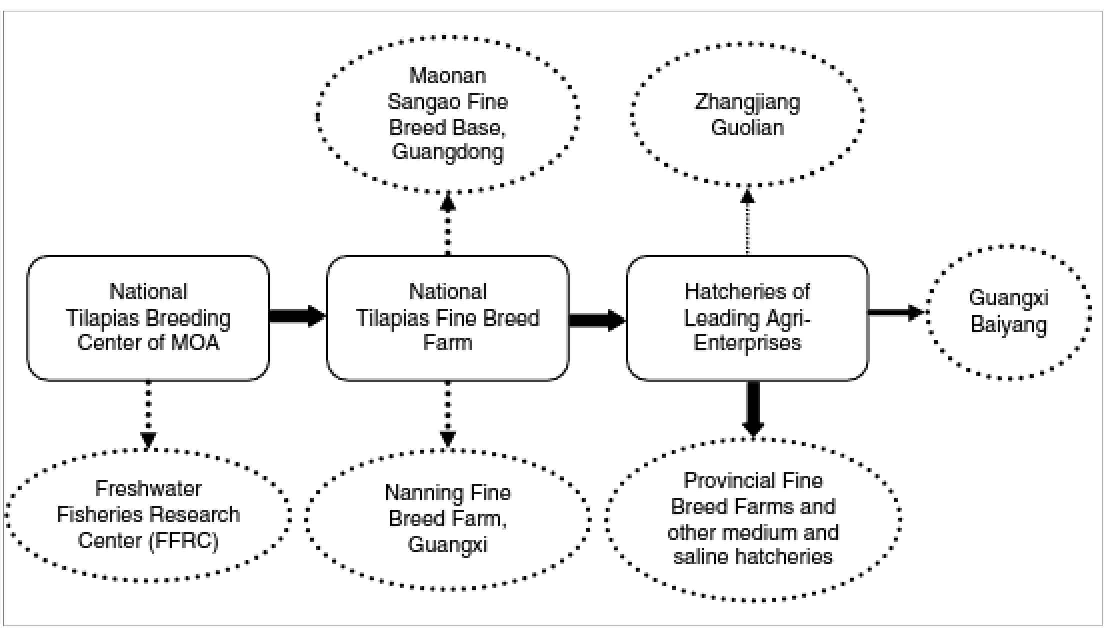

Figure 10. Framework for tilapia breeding systems in China (Xu and Ming 2018).

Although the production of tilapia in China does not rely on international waterbody movement, it does rely on trans-waterbody movement among provinces. Without specific data on the percentage of Chinese tilapia production that is reliant on trans-waterbody movements, based on the aforementioned national breeding systems, it must be assumed that nearly all production is reliant on such movements; therefore, the score for Factor 10Xa is 0 out of 10.

Factor 10Xb Biosecurity of source/destination

The biosecurity of hatcheries, or the source of animal movements, is reportedly high, and assumed to be higher than growout farms due to the sensitivity of eggs and larvae (Thodesen et al. 2011) (Jiang et al. 2013). Hatchery facilities are likely comprised of a combination of systems for different stages of the fish, most notably flow-through tanks or raceways (Xu and Ming 2018). Additionally, biosecurity is inherent in the quality demands and highly controlled environment of large-scale, industrialized hatchery production in China (Xu and Ming 2018) (Jiang 2013). Broodstock are also maintained in research institutes that have strict biosecurity management measures in place (Thodesen et al. 2011) (Jiang et al. 2013). The biosecurity risk for source of animal movements is moderate and scores 4 out of 10.

The biosecurity risk of the destination (farm) is likely variable. Ponds are believed to typically operate as harvest-exchange (Liu et al. 2018), whereby water is drained from the ponds at harvest. However, given the unknown adoption of best-management practices regarding escapes prevention and biosecurity in ponds, the precautionary principle is applied and a biosecurity risk score of 2 out of 10 is given.

As the higher of the two scores, the hatchery biosecurity score of 4 out of 10 is used for Factor 10Xb – Biosecurity of source/destination.

Conclusions and Final Score

Although Chinese tilapia is self-sufficient in domestic seed production, the dissemination of tilapia seed is reliant on trans-waterbody movements. The biosecurity of the source (hatchery) is presumed to be higher than that at the destination (farm), resulting in a moderate score of 4 out of 10. Combining the scores for Factors 10Xa (0 out of 10) and 10Xb (4 out of 10) results in the final numerical score for Criterion 10X – Escape of Secondary Species of –6 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 rating is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

- **Best Choice** = Final Score ≥6.661 **and** ≤10, and no Red Criteria, **and** no Critical scores
- **Good Alternative** = Final score ≥3.331 and ≤6.66, **and** no more than one Red Criterion, **and** no Critical scores.
- **Red** = Final Score ≥0 and ≤3.33, **or** two or more Red Criteria, **or** one or more Critical scores.

Criterion	**Score**	**Rank**	**Critical?**
C1 Data	3.64	YELLOW	
C2 Effluent	5.00	YELLOW	NO
C3 Habitat	2.93	RED	NO
C4 Chemicals	0.00	CRITICAL	YES
C5 Feed	8.16	GREEN	NO
C6 Escapes	0.00	CRITICAL	YES
C7 Disease	3.00	RED	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-3.00	GREEN	NO
C10X Secondary species escape	-6.00	YELLOW	
Total	**13.73**		
Final score (0-10)	**1.96**		

OVERALL RANKING

Final Score	1.96
Rank	RED
Red criteria	3
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

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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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References

Agricultural Products Futures Network (2016) WHere should cage fishermen withdraw from the historical stage? Retrieved September 10 2017 from http://finance.sina.com.cn/money/future/agri/2016-12-12/doc-ifxypizk0260437.shtml In Chinese.

Bai Q, Chen J, Chen Z, Dong G, Dong J, Dong W, Fu VWK, Han Y, Lu G, Li J, Liu Y, Lin Z, Meng D, Martinez J, Ni G, Shan K, Sun R, Tian S, Wang F, Xu Z, Yu Y, Yang J, Yang Z, Zhang L, Zhang M, Zeng X (2015) Identification of coastal wetlands of international importance for waterbirds: a review of China Coastal Waterbird Surveys 2005–2013. Avian Res 6:12

Baidu Library (2015). The regulation to prevent alien invasive species. (n.d.). Retrieved September 5, 2017, from https://wenku.baidu.com/view/f0baf73d1a37f111f0855b5e.html

Baidu Library (2017a)What documents and procedures do you need to open an aquaculture farm? Retrieved September 5, 2017, from https://zhidao.baidu.com/question/455743634392808125.html.

Baidu Library (2017b) DB33/ 453-2006 Zhejiang Province Aquaculture discharge effluent regulations. (n.d.). Retrieved September 5, 2017, from https://wenku.baidu.com/view/5c2fa759ee06eff9aff80752.html

Beveridge CM, McAndrew BJ (2000) Tilapias : Biology and Exploitation. Fish Fish Ser 25

Boyd CE, Tucker C, Mcnevin A, Bostick K, Clay J (2007) Indicators of Resource Use Efficiency and Environmental Performance in Fish and Crustacean Aquaculture.

Broughton EI, Walker DG (2010) Policies and practices for aquaculture food safety in China. Food Policy 35:471–478

Canonico GC, Arthington A, Mccrary JK, Thieme ML (2005) The effects of introduced tilapias on native biodiversity. Aquat Conserv Mar Freshw Ecosyst 15:463–483

Cao L, Chen Y, Dong S, Hanson A, Huang B, Leadbitter D, Little DC, Pikitch EK, Qiu Y, Sadovy de Mitcheson Y, Sumaila UR, Williams M, Xue G, Ye Y, Zhang W, Zhou Y, Zhuang P, Naylor RL (2017) Opportunity for marine fisheries reform in China. Proc Natl Acad Sci 114:435–442

Cao L, Naylor R, Henriksson P, Leadbitter D, Metian M, Troell M, Zhang W (2015a) China's aquaculture and the world's wild fisheries. Science (80-) 347:133–135

Cao L, Naylor R, Henriksson P, Leadbitter D, Metian M, Troell M, Zhang W (2015b) China's aquaculture and the world's wild fisheries- supplimentary information. Science (80-) 347:133–135

Cao L, Wang W, Yang Y, Yang C, Yuan Z, Xiong S, Diana J (2007) Environmental impact of aquaculture and countermeasures to aquaculture pollution in China. Environ Sci Pollut Res Int 14:452–462

Central Government of the People's Republic of China (1988). WIldlife Protection Law. Retrieved from https://www.chinalawtranslate.com/2016wildlifeprotection/?lang=en

Central Government of the People's Republic of China (1993). Regulations of the People's Republic of China for the Implementation of Wild Aquatic Animal Protection. Retrieved September 18 2018 from https://www.unodc.org/res/cld/document/regulations-of-the-peoples-republic-of-china-for-the-implementation-of-wild-aquatic-animal-protection_html/China-regulations-aquatic.pdf

Central Government of the People's Republic of China (2013). Animal epidemic prevention law

of the People's Republic of China. Retrieved September 5, 2017, from http://www.gov.cn/ziliao/flfg/2007-08/31/content_732590.htm.
Chang, J. (2014). The new Environmental Protection Law: the most stringent in history but the hardest to implement. Chinese Institute of Law. Retrieved 11 July 2018 from http://www.iolaw.org.cn/showArticle.aspx?id=4013
Chen DC. (2005). Protection and Management Countermeasures for Mangrove Resource in Guangdong Province. Central South Forest Inventory and Planning, 22(2), 35-38.
Chen, L, Wang, W, Zhang, Y, Lin, G. (2009). Recent progress in mangrove conservation, restoration and research in China. Journal of Plant Ecology 2(2): 45-54
China Aquaculture Network (2014). Main trends and treatment methods of aquaculture in 2014. Retrieved Septemebr 18, 2019 from http://www.shuichan.cc/article_view-25941.html
China Aquaculture Network (2016a). The Hainan farmed Tilapia under new GCoP is on harvest. (n.d.). Retrieved September 3, 2017, from http://www.shuichan.cc/news_view-307040.html.
China Aquaculture Network (2016b). Zhejiang Zhoushan fisheries technology extension station conducted Mari-culture water quality monitoring works. Retrieved September 3, 2017, from http://www.shuichan.cc/news_view-280007.html
China Fishery News (2017) Why are "banned drugs" banned in aquatic products? Retrieved September 4, 2017, from http://www.fishfirst.cn/article-87628-1.html .
China Fishery Information Network (2017)Tianjin city enforcing aquaculture discharge effluent investigation and monitoring. Retrieved September 4, 2017, from http://shuichan.jinnong.cn/n/2017/06/10/153300342319.shtml
China Law Translate (2016). 2016 Wildlife Protection Law. Published online July 2, 2016. Retrieved September 18, 2018 from https://www.chinalawtranslate.com/2016wildlifeprotection/?lang=en
Chiu A, Li L, Guo S, Bai J, Fedor C, Naylor RL (2013) Feed and fishmeal use in the production of carp and tilapia in China. Aquaculture 414–415:127–134
Choi C, Gan X, Hua N, Wang Y, Ma Z (2013) The habitat use and home range analysis of dunlin (Calidris alpina) in Chongming Dongtan, China and their conservation implications. Wetlands:1–12
Chun, Z. (2017) Chinese aquaculture is driving fisheries to the brink. *China Dialogue* published online August 17, 2017. Retrieved September 18, 2018 from https://www.chinadialogue.net/article/show/single/en/9990-Chinese-aquaculture-is-driving-fisheries-to-the-brink
Dey MM (2000) The impact of genetically improved farmed Nile tilapia in Asia. Aquac Econ Manag 4:107–124
Dey M, Bimbao G, Yong L, Regaspi P, Kohinoor AHM, Pongthana N, Paraguas F (2000) Current status of production and consumption of tilapia in selected Asian countries. Aquac Econ Manag 4:13–31
Diana J (2012) Some principles of pond fertilization for Nile tilapia using organic and inorganic inputs. Aquac Pond Fertil Impacts Nutr Input Prod Edited
Dong, HT, Ataguba, GA, Khunrae, P, Rattanarojpong, T, Senapin, S (2017). Evidence of TiLV infection in tilapia hatcheries from 20120-2017 reveals probable global spread of the

disease. *Aquaculture* 479: 579-583.
Donya SM, Farghaly AA, Abo-Zeid MA, Aly HF, Ali SA, Hamed MA, El-Rigal NS (2012) Malachite green induces genotoxic effect and biochemical disturbances in mice. Eur Rev Med Pharmacol Sci 16:469–482
El-Sayed A-FM (2006) Tilapia culture.
El-Zaeem SY, Ahmed MMM, Salama MES, El-Kader WNA (2012) Phylogenetic differentiation of wild and cultured Nile tilapia (Oreochromis niloticus) populations based on phenotype and genotype analysis. African J Agric Reseearch 7:2946–2954Environmental Protection agency of Guangdong Province (2016) The P.R.C. Environmental impact assessment law, effected at 2016-09-01. Retrieved September 5, 2017, from http://www.gdep.gov.cn/zcfg/falv/201609/t20160907_214959.html.
FAO (2006) Cultured aquatic species information programme. Oreochromis niloticus. FAO Fish Aquac Dep [online]
FAO (2014) The State of World Fisheries and Aquaculture 2014.
FAO (2018) Fishery and Aquaculture Statistics. Global aquaculture production 1950-2016 (FishstatJ). In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2018. www.fao.org/fishery/statistics/software/fishstatj/enFAO (2017). Outbreaks of Tilapia lake virus (TiLV) threaten the livelihoods and food security of millions of people dependent on tilapia farming. In: Special Alert (Global)
No. 388, (26 May 2017).
Fitzsimmons K, Watanabe WO (2010) Tilapia (Family: Cichlidae). Finfish Aquac Diversif:374
Funge-Smith S, Briggs M, Miao W (2012) Regional overview of fisheries and aquaculture in Asia and the Pacific 2012. RAP Publ Asia-Pacif
Fuzhou Customs District of the People's Republic of China (2017) The inspection procedure for import aquatic animal. (n.d.). Retrieved September 4, 2017, from http://www.fjciq.gov.cn/jyj/233706/233730/300855/267752/330441/index.html.
Gjerde B, Mengistu SB, Ødegård J, Johansen H, Altamirano DS (2012) Quantitative genetics of body weight, fillet weight and fillet yield in Nile tilapia (Oreochromis niloticus). Aquaculture 342–343:117–124
Godfrey M. (2016). Massive aquaculture shut-down in central China as government gets tough on pollution. Seafood Source. December 19, 2016. Retrieved September 10, 2018 from https://www.seafoodsource.com/features/massive-aquaculture-shut-down-in-central-china-as-government-gets-tough-on-pollution
Godfrey M. (2018a). Chinese aquaculture polution tax enforcement begins with mixed results. Seafood Source February 2, 2018. Retrieved September 10, 2018 from https://www.seafoodsource.com/news/aquaculture/chinese-aquaculture-pollution-tax-enforcement-begins-with-mixed-results
Godfrey M. (2018b). Costs mounting from China's aquaculture clean-up program. Seafood Source May 16, 2018. Retrieved September 10, 2018 from https://www.seafoodsource.com/features/costs-mounting-from-china-s-aquaculture-clean-up-program
Gu DE, Luo D, Xu M, Ma GM, Mu XD, Luo JR, Hu YC (2014a) Species diversity defends against the invasion of Nile tilapia (Oreochromis niloticus). Knowl Manag Aquat Ecosyst:7
Gu DE, Ma GM, Zhu YJ, Xu M, Luo D, Li YY, Wei H, Mu XD, Luo JR, Hu YC (2015) The impacts of

invasive Nile tilapia (Oreochromis niloticus) on the fisheries in the main rivers of Guangdong Province, China. Biochem Syst Ecol 59:1–7
Gu DE, Mu XD, Song HM, Luo D, Xu M, Luo JR, Hu YC (2014b) Genetic diversity of invasive Oreochromis spp. (tilapia) populations in Guangdong province of China using microsatellite markers. Biochem Syst Ecol 55:198–204
Gu DE, Mu XD, Xu M, Luo D, Wei H, Li YY, Zhu YJ, Luo JR, Hu YC (2016) Identification of wild tilapia species in the main rivers of south China using mitochondrial control region sequence and morphology. Biochem Syst Ecol 65:100–107
Gu DE, Hu Y, Wei H, Zhu Y, Mu Y, Luo D, Xu M, Yang Y. (2017) Chapter 22: Nile Tilapia *Oreocrhomis niloticus* (L.) *Biological Invasions and its Management in China Volume 2*. Edited by Wan F, Jiang M, Zhan A. Springer Nature Singapore. pp 77-89
Gu DE, Hu YC, Xu M, Wei H, Luo D, Yang YX, Yu FD, Mu XD (2018). Fish invasion in the river systems of Guangdong Province, South China: Possible indicators of their success. Fish Manag Ecol. 25:44-53.
Guangdong Maoming News. Maoming Binhai District implemented Aquaculture special law enforcement inspection. Retrieved September 5, 2017, from http://www.mgs.gov.cn/kjjhj/gzdt/2016/0409/6176.html
Gupta M V, Acosta BO (2004) A review of global tilapia farming practices. Aquac Asia IX No. 1:7–12
Hang L, xu YB, Xu JX, Ling JY, Chen JL, Zhou JL, Zheng L, du QP (2017). Chemosphere 168:1107-1114.
Hanson A, Cui H, Zou L, Clarcke S, Muldoon G, Potts J, Zhang H (2011) Greening China’ s Fish and Fish Products Market Supply Chains. Int Inst Sustain Dev:38pp
Hanson AJ, Cui H, Zou L, Clarke S, Muldoon G, Potts J, Zhang H (2011) Greening China’s Fish and Fish Products Market Supply Chains. Int Inst Sustain Dev:151
Herbeck LS, Unger D, Wu Y, Jennerjahn TC (2013) Effluent, nutrient and organic matter export from shrimp and fish ponds causing eutrophication in coastal and back-reef waters of NE hainan, tropical China. Cont Shelf Res 57:92–104
Honglang H (2007) 7.5 Freshwater fish seed resources in China. Assess Freshw Fish Seed Resour Sustain Aquac:185
Hu, Y. C., Gu, D. E., & Mu, X. D. (2015). *The Common Alien Aquatic Species in China*. Beijing, China: Science Press. (in Chinese).
Intrafish media (2017). Contagious disease hits tilapia farmers on three continents. published May 29, 2017. Accessed online http://www.intrafish.com/aquaculture/1268773/contagious-disease-hits-tilapia-farmers-on-three-continents
Jia M, Wang Z, Li L, Song K, Ren C, Liu B, Mao D (2014) Mapping China’s mangroves based on an object-oriented classification of Landsat imagery. Wetlands 34:277–283
Jiangsu Guangdianron Media News Center (2016).The YNNR aquaculture size dramatically narrowed which farmer appeal to proper redistribution. Retrieved September 5, 2017, from http://news.jstv.com/a/20161221/1482301822194.shtml.
Jiang G, Sun F, Li Q, Zhong Q (2013) Current Development Situation, Problem and Countermeasures on Tilapia Seed Industry in Fujian Province. Asian Agric Res 5:32–35
Ke CQ, Zhang D, Wang FQ, Chen SX, Schmullius C, Boerner WM, Wang H (2011) Analyzing

coastal wetland change in the Yancheng National Nature Reserve, China. Reg Environ Chang 11:161–173
Koch JF, Rawles SD, Webster CD, Cummins V, Kobayashi Y, Thompson KR, Gannam AL, Twibell RG, Hyde NM (2016) Optimizing fish meal-free commercial diets for Nile tilapia, Oreochromis niloticus. Aquaculture 452:357–366
Kumar G, Engle CR (2016) Technological Advances that Led to Growth of Shrimp, Salmon, and Tilapia Farming. Rev Fish Sci Aquac 24:136–152
Kramer, Lauren (2017). Sizing up TiLV and its potential impact on tilapia production. Global Aquaculture Alliance Advocate. Accessed online https://www.aquaculturealliance.org/advocate/27041/
Lai Q, Yang Y (2004) Tilapia Culture in Mainland China. 6th Int Symp Tilapia Aquac ISTA 6:18–29
Li Y, Cai SH (2011) Identification and pathogenicity of Aeromonas sobria on Tail-rot disease in Juvenile Tilapia Oreochromis niloticus. Curr Microbiol 62:623–627
Li K, Clausen JH, Murrell KD, Liu L, Dalsgaard A (2013a) Risks for fishborne zoonotic trematodes in Tilapia production systems in Guangdong province, China. Vet Parasitol 198:223–229
Li X, Li J, Wang Y, Fu L, Fu Y, Li B, Jiao B (2011) Aquaculture Industry in China: Current State, Challenges, and Outlook. Rev Fish Sci 19:187–200
Li K, Liu L, Clausen JH, Dalsgaard A (2013b) Diseases and treatment reported by shrimp and tilapia farmers in Guangdong Province, China. Asian-Pacific Aquac
Li K, Liu L, Clausen JH, Lu M, Dalsgaard A (2016) Management measures to control diseases reported by tilapia (Oreochromis spp.) and whiteleg shrimp (Litopenaeus vannamei) farmers in Guangdong, China. Aquaculture 457:91–99
Li YW, Liu L, Huang PR, Fang W, Luo ZP, Peng HL, Wang YX, Li AX (2014) Chronic streptococcosis in Nile tilapia, Oreochromis niloticus (L.), caused by Streptococcus agalactiae. J Fish Dis 37:757–763
Li L, Wang R, Liang W, Gan X, Huang T, Huang Y, Li J, Shi Y, Chen M, Luo H (2013) Rare serotype occurrence and PFGE genotypic diversity of Streptococcus agalactiae isolated from tilapia in China. Vet Microbiol 167:719–724
Li LP, Wang R, Liang WW, Huang T, Huang Y, Luo FG, Lei AY, Chen M, Gan X (2015) Development of live attenuated Streptococcus agalactiae vaccine for tilapia via continuous passage in vitro. Fish Shellfish Immunol 45:955–63
Li X, Yeh AG-O (2004) Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS. Landsc Urban Plan 69:335–354
Liao CX, Wu DH, You WZ, Huang ZZ (1992). The effect of diet added with mixed vitamin on the growth of tilapia nilotica. Freshwater Fisheries, 1, 13-16.
Liao J,Lv HD. (2017). The pioneer process by Yongshun Company on develop innovative vaccine on tilapia disease. Journal of Marine and Fisheries (2), 33-35. http://210.37.0.26/KCMS/detail/detail.aspx?filename=HYUY201702020&dbcode=CJFD&dbname=CJFD2017
Library of Congress (2016) China: New Wildlife Protection Law. Global Legal Monitor published online August 5, 2016. Retrieved September 18, 2018 from http://www.loc.gov/law/foreign-news/article/china-new-wildlife-protection-law/
Lin ZD, Liu HM. (2003). The Current Situation and Development Measure of Mangrove in GuangDong Province. Forestry Science and Technology of Guangdong Province, 21(3), 75-

78.
Lin Q, Li N, Fu X, Hu Q, Chang O, Liu L, Zhang D, Wang G, San G, Wu S (2016) An outbreak of granulomatous inflammation associated with Francisella noatunensis subsp. orientalis in farmed tilapia (Oreochromis niloticus O. aureus) in China. Chinese J Oceanol Limnol 34:460–466
Lin CK, Yi Y (2003) Minimizing environmental impacts of freshwater aquaculture and reuse of pond effluents and mud. Aquaculture 226:57–68
Liping L, Fitzsimmons K (2011) Better science, better fish, better life- Proceedings of the ninth International Symposium on Tilapia in Aquaculture. AquaFish Collaborative Research Support Program
Litovsky, A (2016). Antibiotic waste is polluting India and China's rivers; big pharma must act. *The Guardian* published online October 25, 2016. Retrieved July 18 2018 from https://www.theguardian.com/sustainable-business/2016/oct/25/antibiotic-waste-pollution-india-china-rivers-big-pharma-superbugs-resistance
Liu X, Steele JC, Meng XZ (2017). Usage, residue and human health risk of antibiotics in Chinese aquaculture: A review. Environmental Pollution 223:161-169.
Liu XG, Xu H, Liu C (2018). Ecological Engineering Technologies for Optimizing Freshwater Pond Aquaculture. *Aquaculture in China: Success Stories and Modern Trends* edited by Gui JF, Tang Q, Li Z, Liu J, De Silva SS. Wiley Blackwell Publishing. pp 555-576.
Lucas JS, Southgate PC (2012) Aquaculture: Farming Aquatic Animals and Plants. Wiley-Blackwell
Lv CX. (1998). The Chinese Mangrove Ecosystem Conservation Situation, existed problems, and solutions. Marine development and management, (3), 41-43.
Lv J. (2013) The influence cause by pond aquaculture to Mangrove ecosystem. China Environmental Science Academic annual meeting thesis collection (Volume 6).
Ma Z, Li B, Zhao B, Jing K, Tang S, Chen J (2004) Are artificial wetlands good alternatives to natural wetlands for waterbirds? - A case study on Chongming Island, China. Biodivers Conserv 13:333–350
Ma Z, Wang Y, Gan X, Li B, Cai Y, Chen J (2009) Waterbird population changes in the wetlands at chongming dongtan in the yangtze river estuary, China. Environ Manage 43:1187–1200
Mao LJ. (2011). Assessment of Changes in Mangrove Forest Patterns from Multitemporal Remotely Sensed Imagery over Zhanjiang City Guangdong Province. (Doctoral dissertation, Nanjing: Nanjing Forestry University)
Macintosh DJ (2008) Risks Associated with Using Methyl Testosterone in Tilapia Farming. Sustain Fish Partnersh December 3:1–12
Mair GC, Abucay JS, Abella TA, Beardmore JA, Skibinski DOF (1997) Genetic manipulation of sex ratio for the large-scale production of all-male tilapia Oreochromis niloticus. Can J Fish Aquat Sci 54:396–404
Martin CW, Valentine MM, Valentine JF (2010) Competitive interactions between invasive nile tilapia and native fish: The potential for altered trophic exchange and modification of food webs. PLoS One 5:57–59
Meador MM, Xinping W (2012) Peoples Republic of China Fishery Product Annual. USDA Foreign Agric Serv GAIN Rep
Ministry of Agricultural and Rural Affairs of the People’s Republic of China (2011a). The China

12th Five-Year Plan in Fisheries Industry development. (n.d.). Retrieved September 4, 2017, from http://www.moa.gov.cn/govpublic/YYJ/201111/t20111114_2408578.htm.
Ministry of Agricultural and Rural Affairs of the People's Republic of China (2011b)The MoA office reported the going on national aquaculture permit registration process. Retrieved September 5, 2017, from http://www.moa.gov.cn/zwllm/tzgg/tfw/201108/t20110802_2101070.htm.
Ministry of Agriculture (2013) Regulation for the implementation of the fisheries Law. . Retrieved September 5, 2017, from http://www.moa.gov.cn/fwllm/zxbs/xzxk/spyj/201706/t20170606_5662357.htm.
Ministry of Agriculture (2014). China Fisheries Law,. Retrieved September 5, 2017, from http://www.moa.gov.cn/fwllm/zxbs/xzxk/bszl/201405/t20140528_3919077.htm
Ministry of Ecology and Environment of the People's Republic of China (2014).The alien invasive species in China (3rd volume). Retrieved September 4, 2017, from http://www.zhb.gov.cn/gkml/hbb/bgg/201408/t20140828_288367.htm.
Ministry of Ecology and Environment of the People's Republic of China (2015). EIA application on different construction projects. Retrieved September 5, 2017, from http://www.zhb.gov.cn/gkml/hbb/bl/201504/t20150420_299283.htm
Ministry of Ecology and Environment of the People's Republic of China (2016) The New Water Law. Retrieved September 5, 2017, from http://www.zhb.gov.cn/gzfw_13107/zcfg/fg/xzfg/201610/t20161008_365107.shtml
Ministry of Ecology and Environment of the People's Republic of China (2017) The Amendment decision regard to the Law on the prevention and control of water pollution. Retrieved September 5, 2017, from http://www.zhb.gov.cn/xxgk/hjyw/201706/t20170628_416809.shtml.
Mjoun Kamal, Kurt.A, Brown Michael L. (2010) Tilapia : Environmental Biology and Nutritional Requirements. Fs963-02:7
Mo WY, Chen Z, Leung HM, Leung AOW (2015) Application of veterinary antibiotics in China's aquaculture industry and their potential human health risks. Environ Sci Pollut Res:1–12
NALO (2004) National Aquaculture Legislation Overview. China. National Aquaculture Legislation Overview (NALO) Fact Sheets. Text by Spreij, M. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 3 May 2004.
Naylor RL, Williams SL, Strong DR (2001) Ecology. Aquaculture--a gateway for exotic species. Science 294:1655–6
NBSO (2010) An overview of China's aquaculture. Netherlands Bus Support Off Dalian:1–24
Ng WK, Romano N (2013) A review of the nutrition and feeding management of farmed tilapia throughout the culture cycle. Rev Aquac 5:220–254
Nguyen NH, Ponzoni RW, Abu-Bakar KR, Hamzah A, Khaw HL, Yee HY (2010) Correlated response in fillet weight and yield to selection for increased harvest weight in genetically improved farmed tilapia (GIFT strain), Oreochromis niloticus. Aquaculture 305:1–5
NOAA (2016) US China Tilapia Imports. Commer Fish Stat
OIE (2017b). Tilapia Lake Virus Disease, Chinese Taipei. Immediate Notification. Available at. http://www.oie.int/wahis_2/public/wahid.php/Reviewreport/Review?reportid=24033.
Primavera JH (2005) Mangroves, fishponds, and the quest for sustainability. Science (80-)

310:57–59
The P.R.C. Environmental Protection Law. (2014). Retrieved September 5, 2017, from http://zfs.mep.gov.cn/fl/201404/t20140425_271040.htm.
The P.R.C. Marine Environment Protection Law. (2017). Retrieved September 5, 2017, from http://www.soa.gov.cn/zwgk/fwjgwywj/shfl/201705/t20170517_56111.html.
Qi Z, Zhang X, Boon N, Bossier P (2009). Probiotics in aquaculture in China – current state, problems and prospect. Aquaculture 290:15–21.Qiuming L, Yi Y (2004) Tilapia culture in mainland China. Proc 6th Int Symp Tilapia Aquac:18–29
Rico A, Satapornvanit K, Haque MM, Min J, Nguyen PT, Telfer TC, van den Brink PJ. (2012). Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture 4:75–93.
Rico A, Phu TM, Satapornvanit K, Min J, Shahabuddin AM, Henriksson PJG, Murray FJ, Little DC, Dalsgaard A, Brink PJ Van den (2013) Use of veterinary medicines, feed additives and probiotics in four major internationally traded aquaculture species farmed in Asia. Aquaculture 412–413:231–243
Ross LG, Telfer TC, Falconer L, Soto D, Aguilar-Manjarrez J (2013) Site selection and carrying capacities for inland and coastal aquaculture. accessed online http://www.fao.org/docrep/017/i3099e/i3099e00.htm
Rousseau, O. (2016) Chinese authorities split over antibiotic overuse. G*lobal Meat News* published online Feb 26 2016. Retrieved July 18 2018 from https://www.globalmeatnews.com/Article/2016/02/26/Chinese-authorities-split-over-antibiotic-overuse
Rutten MJM, Bovenhuis H, Komen H (2005) Genetic parameters for fillet traits and body measurements in Nile tilapia (Oreochromis niloticus L.). Aquaculture 246:125–132
Seafood Watch Consulting Researchers (2017). Monterey Bay Aquarium Seafood Watch Report for Channel Catfish (*Ictalurus punctatus*) raised in ponds and net pens in China. Retrieved July 18 2018 from http://www.seafoodwatch.org/-/m/sfw/pdf/reports/c/mba_seafoodwatch_channelcatfish_chinaponds_report.pdf
Senanan W, Bart AN (2010) The Potential Risks from Farm Escaped Tilapias. Sustain Fish Partnersh http://med
SFP (2012) Chinese Sustainable Tilapia Initiative May 2012. Sustain Fish Partnersh
SFP (2016) Chinese Tilapia Aquaculture Improvement Project. January 2016 https://ww
Shuai F, Li X, Li Y, Jie L, Jiping Y, Lek S (2015) Forecasting the invasive potential of Nile tilapia (Oreochromis niloticus) in a large subtropical river using a univariate approach. Fundam Appl Limnol / Arch für Hydrobiol 187:165–176
Song C, Zhang C, Fan L, Qiu L, Wu W, Meng S, Hu G, Kamira B, Chen J (2016). Occurrence of antibiotics and their impacts to primary productivity in fishponds around Tai Lake, Chin. Chemosphere 161:127-135.
Sohu News (2016) Zhejiang fishermen get penalty up to 10,000 RMB for used illegal fish drug. Retrieved September 5, 2017, from http://www.sohu.com/a/168643950_178379.
Sohu News (2017) Current status of fish vaccines in China. Published onnline August 4, 2017. Retrieved September 18, 2018 from https://www.sohu.com/a/162369594_299363
Srivastava S, Sinha R, Roy D (2004) Toxicological effects of malachite green. Aquat Toxicol 66:319–329

Tacon AGJ, Hasan MR, Metian M (2011) Demand and supply of feed ingredients for farmed fish and crustaceans : Trends and prospects.

Tacon AGJ, Metian M (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285:146–158

Tang JL. (2016). The common disease and method of control on tilapia farm. How Fisheries Make You Rich, (1), 57-59.

Thodesen J, Rye M, Wang YX, Li SJ, Bentsen HB, Yazdi MH, Gjedrem T (2013) Genetic improvement of tilapias in China: Genetic parameters and selection responses in growth, survival and external color traits of red tilapia (Oreochromis spp.) after four generations of multi-trait selection. Aquaculture 416–417:354–366

Thodesen J, Rye M, Wang Y, Yang K, Bensten HB, Gjedrem T (2011) Genetic improvement of tilapias in China: Genetic parameters and selection responses in growth of Nile tilapia (*Oreochromis niloticus*) after six generations of multi-trait selection for growth and fillet yield. Aquaculture 322-323:51-64

Tveterås R, Nystoyl R, Jory DE (2017) GOAL 2017: Global finfish production review and forecast. Global Aquaculture Alliance Advocate. 20 November 2017, accessed online https://www.aquaculturealliance.org/advocate/goal-2017-finfish-production-survey/

USDA (2018) Aquaculture Data. Economic Research Service. http://www.ers.usda.gov/data/Aquaculture/

USDA FAS. 2012. USDA Foreign Agricultural Service Global Agriculture Information Network (GAIN) Report: Peoples Republic of China. Gain Report Number: CH12073. Release date 12/28/2012.

Walters BB, Rönnbäck P, Kovacs JM, Crona B, Hussain SA, Badola R, Primavera JH, Barbier E, Dahdouh-Guebas F (2008) Ethnobiology, socio-economics and management of mangrove forests: A review. Aquat Bot 89:220–236

Wang Q, Cheng L, Liu J, Li Z, Xie S, Silva SS De (2014) Freshwater aquaculture in PR China: Trends and prospects. Rev Aquac 7:283–302

Wang JN, Jiang HQ, Liu NL. (2015). Strategic ideas on the 13th Five-Year Plan of National Environmental Protection. Chinese Journal of Environmental Management 7 (2) 1-7.

Wang M, Lu M (2015) Tilapia polyculture: a global review. Aquac Res:1–12

Webster CD, Lim C (Eds.). (2006) Tilapia: biology, culture, and nutrition. CRC Press.

Weimin M, Mengqing L (2007) Analysis of feeds and fertilizers for sustainable aquaculture development in China. In: In M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon (eds). Study and analysis of feeds and fertilizers for sustainable aquaculture development.p 141–190

World Bank (2013) FISH TO 2030 Prospects for Fisheries and Aquaculture FISH TO 2030 Prospects for Fisheries and Aquaculture. Rep Number 83177-GLB

World Health Organization (2017). Critically important antimicrobials for human medicine-5th rev. Geneva. Licence CC BY-NC-SA 3.0 IGO.

Xia, J. (2014) Breakthroughs and dilemmas of the new environmental protection law. New York Times China. Retrieved on July 11 2018 from https://cn.nytimes.com/china/20140508/cc08xiajun/

Xiao Y, Zhang J, Zheng B, Zhao L, Li S, Li L. (2013). Changes in Chinese Policies to Promote the Rational Use of Antibiotics. PLoS Med 10 (11): e2001556. Retrieved July 18 2018 from

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3833832/pdf/pmed.1001556.pdf
Xiao Y. (2017) A National Action Plan to Contain Antimicrobial Resistance in China: Contents, Actions and Expectations. *AMR Control* Published online 24 Spetember 2017. Retrieved July 18 2018 from http://resistancecontrol.info/2017/a-national-action-plan-to-contain-antimicrobial-resistance-in-china-contents-actions-and-expectations/
Xinhua News Agency (2015) The PRC Food safety law (President Command No.21). Retrieved September 4, 2017, from http://www.gov.cn/zhengce/2015-04/25/content_2853643.htm.
Xu H, Qiang S, Han Z, Guo J, Huang Z, Sun H, He S, Ding H, Wu H, Wan F (2006) The status and causes of alien species invasion in China. Biodivers Conserv 15:2893–2904
Xu P, Ming J. (2018) Status and Trends of the Tilapia Farming Industry Development. *Aquaculture in China: Success Stories and Modern Trends* edited by Gui JF, Tang Q, Li Z, Liu J, De Silva SS. Wiley Blackwell Publishing. pp 404-420.
Yan X, Zhenyu L, Gregg WP, Dianmo L (2001) Invasive species in China—an overview. Biodivers Conserv 10:1317–1341
Yang N, Xie Z, Huang J, Zhou Y (2009) Isolation and Identification of Bacterial Pathogen of Fulminant Haemorrhagic Disease in Hybrid Tilapia (T. niloticus♂× T. aureus♀) in Hainan. Nat Sci J Hainan Univ 1:10
Yang XL, Zheng ZL. (2007). The application status and strategy of fishery medicine in China. Journal of Shanghai Fisheries University 16:374–380 (in Chinese).
Ye X, Li J, Lu M, Deng G, Jiang X, Tian Y, Quan Y, Jian Q (2011) Identification and molecular typing of Streptococcus agalactiae isolated from pond-cultured tilapia in China. Fish Sci 77:623–632
Yulin J. (2000). The use of chemicals in aquaculture in the People's Republic of China. In: Arthur JR, Lavilla-Pitogo CR, Subasinghe RP (eds) Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia, pp. 141–153. Southeast Asian Fisheries Development Centre, Tigbauan.
Zhang, J.S. (2017). Present Research Status of Mangrove Conservation in China Based on Bibliometric Analysis. Chinese Journal of Tropical Agriculture, 37(4), 102-106.
Zhang D, Li A, Guo Y, Zhang Q, Chen X, Gong X (2013) Molecular characterization of Streptococcus agalactiae in diseased farmed tilapia in China. Aquaculture 412–413:64–69
Zhang W (2014) Sustaining export-oriented value chains of farmed seafood in China. PhD Thesis- Univ Stirling
Zhang W, Murray FJ, Liu L, Little DC (2015) A comparative analysis of four internationally traded farmed seafood commodities in China: Domestic and international markets as key drivers. Rev Aquac 0:1–22
Zhang Z, Lan J, Li Y, Hu M, Yu M, Zhang J, Wei S (2018). The pathogenic and antimicrobial characteristics of an emerging *Streptococcus agalactiae* serotype IX in Tilapia. Microbial Pathogenesis. Accepted manuscript 29 May 2018.
Zhao HJ, Yang BB, He Y, Chen RY, Li RH. etc. (2008). The actualities and countermeasures of export tilapia in China. Journal of Food Safety and Quality, (12), 5100-5106.
Zhao J (2011a) Tilapia germplasm in China: chance and challenge. Better Sci Better Fish, Better Life Proc Ninth Int Symp Tilapia Aquac AquaFish C:6pp
Zhao J (2011b) Tilapia germplasm in China: chance and challenge. In: Better science, better fish, better life. Proceedings of the Ninth International Symposium on Tilapia in Aquaculture,

Shanghai, China, 22-24 April 2011. AQUAFISH Collaborative Research Support Program, p 217–221
Zhao W, Shen, H (2016) A statistical analysis of China's fisheries in the 12th five-year period. Aquac Fish 1:41–49
Zheng, ZL and Xiang L. (2002). Status of drug use in fisheries in China. Aquaculture (Chinese Journal) 4:36–39 (in Chinese).
Zhong y, Chen ZF, Dai X, Liu SS, Zheng G, Zhu X, Liu s, Liu G, Cai z (2018). Investigation of the interaction between the fate of antibiotics in aquafarms and their level in the environment. Journal of Environmental Management 207:219-229
Zhu, YF. (2013). The investigation of fishery drugs usage in Fujian. (Master dissertation, Nanjing: Jimei University)
Zhu C, Dong S (2013) Aquaculture site selection and carrying capacity management in the People's Republic of China. Site Sel Carr Capacit Inl Coast Aquac:219
Zou L, Huang S (2015) Chinese aquaculture in light of green growth. Aquac Reports 2:46–49

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.

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Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[4] 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

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

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

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

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

Appendix 1 - Data points and all scoring calculations

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	2.5
Management	2.5
Effluent	2.5
Habitats	2.5
Chemical use	2.5
Feed	5
Escapes	2.5
Disease	2.5
Source of stock	10
Predators and wildlife	2.5
Unintentional introduction	5
Other – (e.g., GHG emissions)	n/a
Total	**40**

C1 Data Final Score (0-10)	**3.636363636**	**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	1.4
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)	63.84
N in each ton of fish harvested (kg)	22.4
Waste N produced per ton of fish (kg)	**41.44**

Factor 2.1b - Production System discharge

Basic production system score	0.34
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0

Discharge (Factor 2.1b) score (0-1)	**0.34**

\# % 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)	14.09
Waste discharge score (0-10)	**8**

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

2.2a Content of effluent management measure	2
2.2b Enforcement of effluent management measures	1
2.2 Effluent management effectiveness	**0.8**

C2 Effluent Final Score (0-10)	**5.00**	**YELLOW**
Critical?	NO	

Criterion 3: Habitat

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	4

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

3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	**0.8**

C3 Habitat Final Score (0-10)	**3**	**RED**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	**Score**
C4 Chemical Use Score (0-10)	**Critical**

C4 Chemical Use Final Score (0-10)	Critical	RED
Critical?	YES	

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	1.5
Fishmeal from by-products (%)	20
% FM	1.2
Fish oil inclusion level (%)	0.5
Fish oil from by-products (%)	0
% FO	0.5
Fishmeal yield (%)	21.25
Fish oil yield (%)	4
eFCR	1.4
FIFO fishmeal	0.08
FIFO fish oil	0.18
FIFO Score (0-10)	**9.56**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	–7
Calculated sustainability adjustment	–0.25
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**9.32**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	28.5
eFCR	1.4
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	70.34
Feed protein from NON-EDIBLE sources (%)	29.66
Protein OUTPUTS	
Protein content of whole harvested fish (%)	14
Edible yield of harvested fish (%)	42
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	39.9

Edible protein IN kg/100kg fish	28.07
Utilized protein OUT kg/100kg fish	15.47
Net protein gain or loss (%)	–44.87
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 (%)	2
eFCR	1.4
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)	0.73
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	98
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.4
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.52
Total area (Ocean + Land Area) (ha)	1.25
F5.3 Feed Footprint Score (0-10)	9

Feed Final Score

C5 Feed Final Score (0-10)	**8.16**	**GREEN**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	2	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape Risk Score (0-10)	**2**	
6.2. Invasiveness score (0-10)	**0**	
C6 Escapes Final Score (0-10)	**0**	**RED**
Critical?	**YES**	

Criterion 7: Diseases

Disease Evidence-based assessment (0-10)	

Disease Risk-based assessment (0-10)	3	
C7 Disease Final Score (0-10)	3	RED
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)	**–3**	
C9X Wildlife and Predator Final Score (0-10)	**–3**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

F10Xa live animal shipments score (0-10)	0.00	
F10Xb Biosecurity of source/destination score (0-10)	4.00	
C10X Escape of unintentionally introduced species Final Score (0-10)	**–6.00**	**YELLOW**
Critical?	n/a	