Monterey Bay Aquarium
Seafood Watch®

Channel Catfish

Ictalurus punctatus

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China

Ponds and Net Pens

Aquaculture Standard Version A2

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Seafood Watch Consulting Researcher

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Final Seafood Recommendation

Channel Catfish

Ictalurus punctatus

China

Ponds and Net Pens

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.44	YELLOW	
C2 Effluent	0.00	CRITICAL	YES
C3 Habitat	2.15	RED	NO
C4 Chemicals	0.00	CRITICAL	YES
C5 Feed	6.24	YELLOW	NO
C6 Escapes	2.00	RED	NO
C7 Disease	3.00	RED	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	–6.00	YELLOW	NO
C10X Introduced species escape	–2.40	GREEN	
Total	**19.44**		
Final score	**2.43**		

OVERALL RANKING

Final Score	2.43
Initial rank	RED
Red criteria	5
Interim rank	RED
Critical Criteria?	YES

FINAL RANK

RED

Summary

Channel catfish produced in ponds and net pens in China achieves a final numerical score of 2.43 out of 10. In addition to a Red score, there are five Red criteria (Effluent, Habitat, Chemicals, Escapes, and Disease), and two of these (Effluent and Chemicals) are considered to be Critical conservation concerns. The final ranking is Red and a recommendation of "Avoid."

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

Executive Summary

Channel catfish is native to the United States but has been introduced to China several times since 1978. Chinese exports to the United States peaked in 2008 with 23.1 million pounds. Although the government has invested heavily in catfish aquaculture, there is a lack of critical information concerning predators, wildlife, feed, escapes, and animal movements, and only minimal information concerning other criteria that are vital to making an environmental assessment.

In China, channel catfish are grown in both ponds and net pens. There are increasing concerns regarding the intensification of net pen production in reservoirs and the resulting water quality deterioration. But effluents from pond culture are believed to be minimal because of low water exchange. Few studies have characterized waters receiving aquaculture effluent or have related water quality to farming activity.

Qualitative and quantitative data on the use of the chemicals used in Chinese aquaculture are currently lacking in the public domain. But field surveys and national reviews by outside scientists have identified the use of numerous disinfectants, pesticides, and antibiotics. Despite physically inspecting less than 2% of seafood products, the U.S. Food and Drug Administration refused admission of 99 shipments of Chinese channel catfish products from November 2005 until June 2013 because of noncompliance. Of these refusals, 88% were identified as containing “veterinary drug residues” and 49% were identified as containing “unsafe food additives.”

Channel catfish is omnivorous and accepts diets with low levels of animal proteins and with feedstuffs that are inedible by humans. The feed formulation used in this evaluation is based on diets used in the United States because there is no reported information from Chinese sources. Given the shortage of formulated feeds in China, the recent emphasis on culturing more carnivorous fish, and the high cost of fishmeal, it is assumed that fishmeal usage is minimal. Given low protein levels (32%) reported in literature and an estimated eFCR of 2.57 based on U.S. production figures, wild fish use and feed footprint are low, resulting in high scores for the Feed criterion.

It has been reported that channel catfish have escaped into natural waters, adapted to the natural environment, bred, and become an invasive species. It is anticipated that they compete with native populations for food and habitat. Data are unavailable on the amount of channel catfish escapes (and possible recapture) from pond and pen culture in China.

The Chinese government is making efforts to comply with global standards for environmental protection and food safety. Financial investments, new legislation, increased inspection, licensing, monitoring, and educational assistance have been initiated. But evidence suggests that initiatives begun by the central government do not easily translate to regulatory action at the provincial and local levels.

Overall, channel catfish farmed in China receives a moderate numerical score; but with five Red criteria, the final ranking is Red or “Avoid.”

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Channel catfish *(Ictalurus punctatus)*

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Production methods
Channel catfish are produced in ponds and net pens in China. Production is predominantly from polyculture in ponds with grass carp, bighead carp, and black carp, as well as monoculture in pens (Merican, 2009). Pens are used in artificial reservoirs and natural lakes.

<u>Pond production</u>
Engle (2008b) visited channel catfish pond production facilities in Jiangsu Province, a major area for pond-raised channel catfish (Yongjiang 2007). Polyculture of channel catfish with grass, silver, and bighead carps occurs in small ponds in rural areas, and products are typically marketed locally. Some ponds used for production for the export market are located in the northern part of Jiangsu Province. Land created by sediment deposition from the Yangtze River is offered tax-free to farmers for 5 years to encourage emigration from densely populated areas. The ponds belong to an owner who rents them to tenant farmers. Working capital and feed costs are split between the farmer and the landowner.

Ponds in Jiangsu Province are typically large in footprint (33 to 50 acres (12–20 ha)) and rather shallow (4.5 to 5.3 feet (1.4–1.6 m)). Fingerlings are stocked in late winter at 4,800 to 5,400 fish per surface acre (11,860 to 13,343 fish/ha). Fish are fed a sinking feed (30%–32% protein content) three to four times per day from stationary blowers. Total feed per day (approximately 88 pounds per acre per day (16 kg/ha/d)) is moderate, given the low level of aeration available. Ponds are harvested three to four times per year by large lift nets. Farmers reported no problems with off-flavor, disease, or predators (Engle 2008b).

<u>Net pen culture</u>
Engle (2008a) also visited net pen production facilities in Hubei Province. Hubei Province is a major center for pen production of channel catfish. Many of the approximately 8,000 reservoirs in the province were constructed in the 1950s and 1960s. The Chinese government does not charge for their use for pen culture. Some reservoirs that are used for pen culture also serve as the water supply for cities, so governments occasionally restrict access for aquaculture because of water quality concerns.

The net pen production facilities consist of multiple pens ranging from 1,400 to 2,150 cubic feet (40 to 61 m^3). Pens are typically stocked with large channel catfish fingerlings (around 100 pounds per 1,000 fish (45 kg/1,000 fish)) at the beginning of spring and harvested in the fall when fish reach 1.1 to 1.7 pounds (0.5 to 0.8 kg). Farmers feed a 32% or 33% protein sinking feed with reported feed conversion ratios (FCRs) around 2:1. Some farmers restock pens in the fall but report higher disease losses in this second crop.

Partly because of the small meshes used (0.5 and 0.75 in (12.7 and 19 mm)), pens are subject to fouling. Nets are changed every week during the peak of the production season by rolling the fish into another cage. The empty pen is disinfected with lime and dried on shore. Most channel catfish raised in pens are sold to processing plants for export to the U.S.

Species overview

The channel catfish is a native North American freshwater fish. The channel catfish has been introduced several times into China since 1978, as well as in an additional 35 countries (FAO Database on Introductions of Aquatic Species, http://www.fao.org/fishery/introsp/search/en). Though the primary purpose for these global introductions has been for aquaculture, China is the only country where channel catfish is produced in exportable quantities.

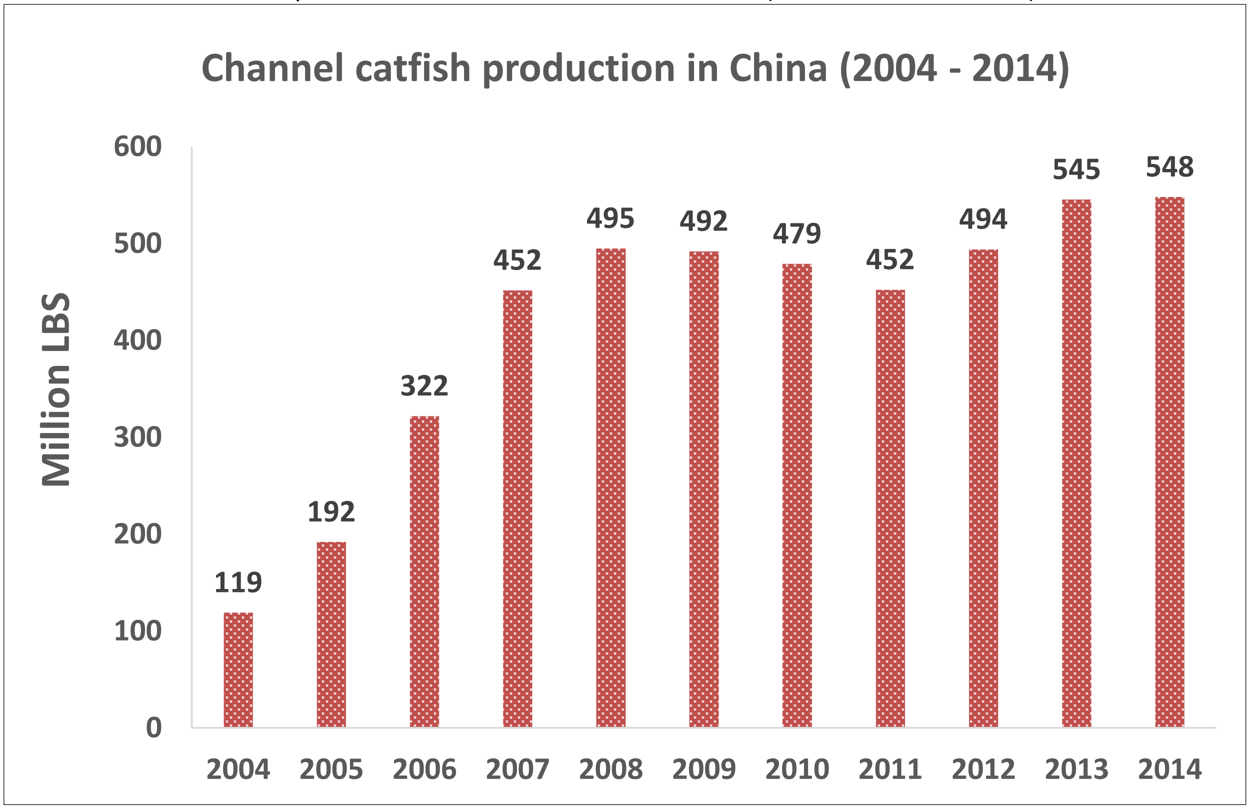
Early introductions to China were unsuccessful due to either unfavorable environmental conditions or a lack of market acceptance by the local populations (Csvas 1994). But improved feed rations and growing export opportunities have led to subsequent production attempts. Shipments of fry and/or fingerlings from Texas (1997), Arkansas (1999, 2003, 2004), and Mississippi (2001, 2007) have established identifiable broodstock populations in China (Sheng et al. 2012). An estimated 1 million eggs were imported by China from the United States as recently as 2007 (Merican 2009).

Production statistics

Since 1989, China has been the world's largest producer of cultured fish, recently accounting for 48% by value and about 62% by volume (FAO 2016). Aquaculture production in China in 2012 was 100.3 billion pounds (45.5 MMT). The production of channel catfish in China from 2004 to 2014 is presented in Table 1 (FAO 2016a).

The major areas of channel catfish production are Sichuan, Hunan, Hubei, Jiangxi, Anhui, Guangdong, and Jingsu Provinces (Zhong et al. 2016). In 2010, it was estimated that 70% of production was located primarily in Sichuan, Hubei, Hunan, Jiangxi, and Guangdong (Zhong et al. 2016)). These provinces are located in southcentral China (Figure 1). In Jiangsu Province, the government encouraged the development of aquaculture farms on land created by sedimentation from the Yangtze River (Engle 2008b).

Table 1. Channel catfish production in China from 2004 to 2014 (data from FAO 2016a).



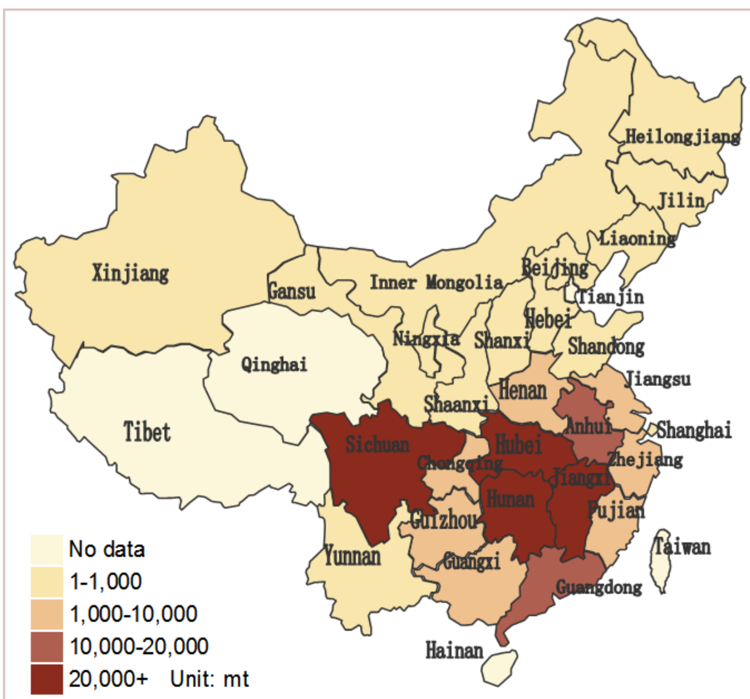
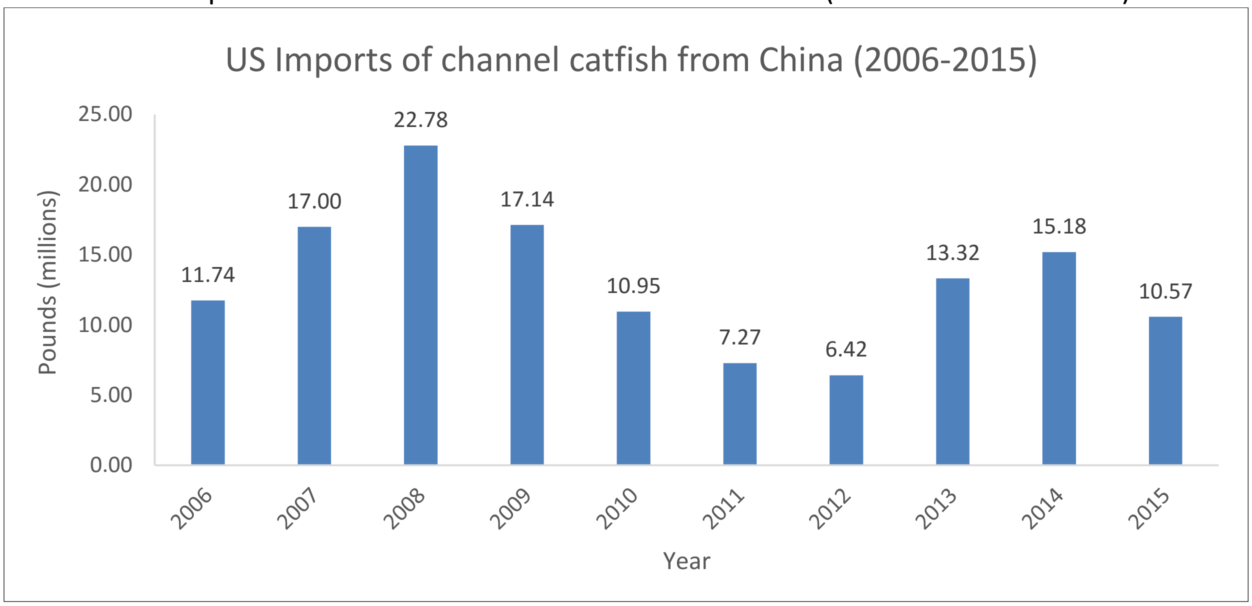


Figure 1. Production of channel catfish in China in 2011 (figure from MOA FB 2012).

Export sources and statistics

The most recent information states that the United States has historically been the second-largest importer of China's processed aquatic products, with fish fillet as the largest category in 2012 (USDA FAS 2012). U.S. imports of channel catfish from China peaked in 2008 at 22.78 million ponds but declined to 10.57 million pounds in 2015 (Table 2).

Table 2. U.S. imports of channel catfish from China 2006–2015 (data from NOAA 2016).



Common and Market Names

Scientific Name	*Ictalurus punctatus*
Common Name	Channel catfish
United States	Farm-raised catfish, channel catfish
Spanish	Bagre de canal
French	Barbue de rivière

Product forms

Fresh and frozen boneless fillets.

Analysis

Scoring guide

- With the exception of the exceptional factors (9x and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in the *Data Points and All Scoring Calculations* section at the end of this report.

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	0	0
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	5	5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**40**

C1 Data Final Score	**4.44**	**YELLOW**

Brief Summary

Most of the information pertaining to Chinese channel catfish production is not available through literature searches because of inaccessibility to Chinese journal sites. Information has been gleaned through published literature, personal communications, and proxies with similar industries. There is low availability of low quality data regarding effluent, habitat, escapes, and wildlife impacts, while varying degrees of more reliable information were obtained for the remaining criteria. The final score for Criterion 1 – Data is 4.44 out of 10.

Justification of Ranking

Sources of information concerning channel catfish production in China can be grouped into three categories. The first category consists of information provided by Chinese government agencies/officials, and research-based information from Chinese scientists. Most of this information is in Mandarin or Cantonese and published in journals that are not available through literature searches. The second source of information is based on international agencies and research institutions from outside the country. These resources provide the majority of disease and environmental monitoring research and statistics. The third category is regulatory agencies in countries that import channel catfish products.

The Chinese National Bureau of Statistics and the Ministry of Agriculture are responsible for reporting industry statistics. The UN Food and Agriculture Organization incorporates this information to make its biennial report on worldwide fishery and aquaculture production. Aquaculture trends in China are also reported by the USDA Foreign Agricultural Service. Unfortunately, the statistics behind these reports are not independently verifiable because they rely on Chinese estimates. Researchers have questioned the accuracy of China's fisheries statistics in the past (Pauly 2009). Farm-level data regarding size, location, or critical habitat do not exist other than at the province level, and this information is not publicly available.

Few studies have assessed the environmental risks posed by channel catfish production in China. Although governmental agencies have restricted access to reservoirs for cage production because of increasing concerns about water quality, no available information exists concerning effluents from pond production of channel catfish. Similarly, there is no available information regarding the habitat impacts of farm siting.

Qualitative and quantitative data on the use of the chemicals in Chinese aquaculture are currently lacking in the public domain. The only specific information concerning chemical usage is based on field surveys and national reviews conducted by researchers from other countries. Information regarding antibiotic resistance was obtained through translating Chinese abstracts on Chinese journal sites. The U.S. Food and Drug Administration (FDA) publishes import refusal data, which include information about unapproved or unsafe drugs and drug residues.

Research concerning aquaculture feed development did not begin until the 1980s. Thus, there is little available research-based information on feeds except for feed additives for fish health. The only information available concerning feed ingredients used for channel catfish production in China comes from control diets in feed additive studies and commercial research promoting the use of soybean meal. There is no available information concerning the adoption of these commercial feed sources or the formulations of locally produced feeds.

Epidemiological data are scarce, which hinders the ability to evaluate the effectiveness of disease control. Most reports of diseases are generated by Chinese fish diagnosticians or fish health researchers documenting new or emerging diseases. Scant literature exists regarding the impact of channel catfish diseases on other species.

The introduction of channel catfish to China has been well documented by the FAO Database on Introductions of Aquatic Species. Chinese officials have touted the establishment of domesticated broodstock lines in several provinces. Data regarding the numbers and associated impacts of escapes are unknown. The impact of escapes on biodiversity-related issues in China has rarely been evaluated. There is little information to evaluate the potential number of escapes or the resulting competition with other species for food or habitat.

Information regarding catfish broodstock and seed production in China is well documented and available.

There is no public domain information concerning the management of predators or the impact of these production systems on native wildlife.

Information regarding the trans-waterbody movement of live animals and the biosecurity of seed sources are minimal. The extent of known information only includes the location and market share of the China's largest hatcheries.

Criterion 2: Effluents

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary: Effluent Full Assessment

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	109.792		
F2.1b Waste discharged from farm (%)	80		
F2.1 Waste discharge score (0-10)		1	
F2.2a Content of regulations (0-5)	1		
F2.2b Enforcement of regulations (0-5)	0.75		
F2.2 Regulatory or management effectiveness score (0-10)		0.3	
C2 Effluent Final Score		**0.00**	**CRITICAL**
Critical?	YES		

Brief Summary

Channel catfish production systems in China are hydrologically connected with the surrounding waterbodies and produce continuous or intermittent wastewater discharges without relevant treatment. Depending on the system and on-farm practices, roughly 80% of waste generated on the farm is discharged into the receiving waterbody. Various levels of regulations exist to control and mitigate impacts, but effective monitoring, inspection, and enforcement at the local level are lacking. As a result, most farmers have not taken measures to adequately reduce waste discharge. Overall, waste discharge is high and regulatory structure and enforcement are weak; the final score for Criterion 2 – Effluents is 0.00 out of 10 and considered to be a Critical concern.

Justification of Ranking

With the development of intensive aquaculture, there are increasing concerns about the possible effects of aquaculture waste both on productivity inside the aquaculture system and on the surrounding aquatic ecosystem (Cao et al. 2007). Antiquated waste management technologies (excessive flushing of ponds and overfeeding of fish in pens) are still being used, and these threaten to affect aquatic biodiversity and, to some extent, to hinder the sustainable development of Chinese aquaculture (Li et al. 2011).

In 2008 (the most recent statistics available), economic losses in the aquaculture industry due to poor water quality and environmental pollution were $3.9 million (USD) (23.6 million yuan) (MOA and MEP 2009). Eutrophication has historically occurred in many reservoirs, causing mortality in both aquaculture stock and wild populations of fish (Wu 2000). Mai and Tan (2002) stated that environmentally responsible feeds should receive more research because the aquaculture environment is deteriorating rapidly. Increasing concerns over water quality have resulted in some restrictions in access to reservoirs for net pen production (Merican 2009). There are concerns regarding the water quality of these reservoirs because many also provide drinking water for cities (Engle 2008a).

Channel catfish production systems (freshwater inland pens and ponds) in China are hydrologically connected with the surrounding water bodies and produce continuous or intermittent wastewater discharges (Zhang et al. 2015) (Cai et al. 2013). As a result, considerable amounts of the chemicals and biological products used in these systems are released into the surrounding aquatic ecosystems, potentially damaging the natural structure and functioning of these ecosystems (GESAMP 1997) (Boyd and Massaut 1999) (Graslund and Bengtsson 2001). Few studies have characterized waters receiving aquaculture effluent and waters used by the farms or have related water quality to farming activity (Zhang et al. 2015) (Yu et al. 2008). This is due to 1) the rapid expansion and intensification of the aquaculture sector; 2) a weakness in the environmental regulatory frameworks; and 3) a lack of scientific and economic resources. Therefore, the risk-based assessment of effluent discharge impacts is used.

Factor 2.1 – Waste discharge

The economic feed conversion ratio (eFCR) required for calculations used in this report is the total amount of catfish feed delivered to foodfish growout facilities divided by the total pounds of foodfish sold to processors. There is no available research-based information related to eFCR of channel catfish produced in China. Based on a 5-year average reported by the USDA National Agriculture Statistics Service Feed Delivery and Catfish Processing reports, the eFCR for U.S.-produced channel catfish is 2.61 (USDA NASS 2013a/b). Because this is the only documented eFCR for channel catfish, it was used in these calculations.

On average, a typical commercial diet is a 28%–32% protein sinking feed, which sources protein primarily from plant ingredients such as soybean meal and cottonseed meal (Zhao et al. 2016a/b) (Li and Robinson, 2013). Regarding nitrogen output, the harvested fish have a protein content of 14.9%, equating to 23.84 kg nitrogen (N) per ton of fish produced. Therefore, the waste production per ton of harvested fish (109.8 kg N) is relatively high. Channel catfish are raised in both net pens and ponds, which have different waste discharge potential based on the water exchange rates and feeding methods. Zhang et al. (2015) compiled data across the Chinese aquaculture industry and determined the nutrient use efficiency (NUE), or the nutrient input retained within the aquaculture system, for fish raised in both ponds and net pens.

Although there is a wide range due to the variability in production systems, species, and operation, the authors found the nitrogen NUE of fish ponds to be 22.9% and fish pens to be 24.7%; this equates to discharge percentage of 78.1% and 75.3%, respectively (Zhang et al. 2015). A value of 80% (the Seafood Watch standard for pen production) is used because there is wide variability in the Zhang et al. (2015) figures, and there is not any information available to help determine the proportion of pens versus ponds in the industry. A total value of 87.83 kg N per ton of channel catfish is estimated to be discharged to the environment, and the resulting Factor 2.1 – Waste Discharge score is 1 out of 10.

Factor 2.2 Content/Enforcement of regulations

Factor 2.2a Content of Effluent Management Measures

Water quality regulations and effluent management are principally established and addressed by a number of national aquaculture-related laws in China (Chen et al. 2011) (Hanson et al. 2011) (Table 3 from Zou and Huang 2015).

Table 3. Effluent-relevant regulations in China; adapted from Zou and Huang, 2015.

General areas	Specific regulations
Basic legislation	The Fisheries Law (1986, amended in 2000 and 2004)
	Regulation for the implementation of the fisheries Law (1987)
Accessibility legislation	The Water Law (1988, as amended in 2002)
	The Sea Area Use Management Law (2002)
Environment influence assessment	The Environmental Protection Law (1989)
	The law on the prevention and control of water pollution (1984)
	The marine environment protection law (1982)
	The environmental impact assessment law (2002)
Water and wastewater	The rules for implementation of the law on the prevention and control of water pollution (2000)
	The Regulations on the prevention of pollution damage to the marine environment by land-sourced pollutants (1990)
	Water quality standards for fisheries (1989)
	Production Area Environment Condition of Freshwater Aquaculture for “Pollution-Free” Aquaculture Food (NY 5361-2010)
	Production Area Environment Condition of Seawater Aquaculture for “Pollution-Free” Aquaculture Food (NY 5362-2010)
National Agriculture Specialized Standards	Water Discharge Criteria for Freshwater Farmed Ponds (SC/T9101-2007)

The most basic of these regulations includes The Fisheries Law (2004), which addresses the legal framework for both wild capture and aquaculture fisheries. The Water Law (2002) is administered by the Ministry of Water Resources and regulates the development, utilization, allocation, and management of water resources. The Environmental Protection Law (1989) gives provisions on environmental impact assessment (EIA) requirements; according to this law, appropriate departments of the Environmental Protection Administration of the Peoples' Government at or above the county level make investigations and assessments of the environment within their jurisdiction. Environmental impact assessments of construction projects, including large-scale aquaculture operations, must assess the risk of potential pollution and describe preventative measures undertaken (NALO 2012). This statute works in conjunction with The Law on the Prevention and Control of Water Pollution (1984), which aims to prevent and control pollution of water bodies. This law contains provisions requiring that aquaculture development should contain a risk assessment on the likely pollution hazards, their impacts, and preventative measures, while mandating that a pollution discharge report be written and submitted to the local EPA body before licensing is approved.

Provinces, autonomous regions, and municipalities may establish their own local standards for items that are not specific in national standards, such as nitrogen and phosphorus discharge limits (NALO 2012). Despite these local and national regulations, there is a lack of effective monitoring, inspection, and enforcement; as a result, most farmers have not taken measures to adequately manage waste discharges to comply with regulations (Zhu and Dong 2013) (Cao et al. 2007). The Chinese government has attempted to upgrade national regulations concerning aquaculture effluents in order to better manage and enforce standards, and introduced the Water Discharge Criteria for Freshwater Farmed Ponds (SC/T9101-2007) in 2007; in spite of this, some authors have concluded that more specific regulations regarding aquaculture effluents are needed to mitigate the environmental impacts (Zhu and Dong 2013) (Cao et al. 2007). Therefore, a score of 1 out of 5 is given for Factor 2.2a – Content of Effluent Management Measures.

Factor 2.2b Enforcement of Effluent Management Measures

As mentioned, enforcement of effluent management measures occurs on a local level through local departments of national agencies. The agency that coordinates fisheries and aquaculture enforcement is The Bureau of Fisheries, and it works under the guidance of the Ministry of Agriculture; within this Bureau, enforcement is carried out by The Fisheries Law Enforcement Command of China. In 2013, a reported 2,949 law enforcement agencies existed in provinces across China and employed over 35,000 staff (Zou and Huang 2015). Because the majority of aquaculture in China occurs in rural regions, the sector has become an important component to regional economic growth. When considering this in conjunction with weak regulations that are largely guidelines that lack defined limits, legal repercussions are often foregone in favor of continued economic growth of the sector (Zou and Huang 2015) (Cao et al. 2007).

In 2011, the Chinese Ministry of Agriculture (MoA) released the 12th Five-year (2011–2015) Plan, which placed importance on environment improvement and emphasized improving law enforcement (Zou and Huang 2015). Despite this, well-defined enforcement measures are not publicly reported, which prevents appropriate assessment of enforcement effectiveness. Enforcement agencies appear regionally fragmented, and there is little public evidence of monitoring or compliance data. Therefore, a score of 0.75 out of 5 is given for Factor 2.2b – Enforcement of Effluent Management Measures.

Conclusions and Final Score

Overall, waste discharge is high and regulatory structure and enforcement is weak. Combining Factors 2.2a and 2.2b results in a score of 0.3 out of 10 for Factor 2.2 – Management of farm-level and cumulative impacts. Given the Factor 2.1 – Waste Discharge score of 1 out of 10, the final score for Factor 2 – Effluents is 0 out of 10. This score is considered to represent a Critical concern for effluent-related impact.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		3.00	
F3.2a Content of habitat regulations	1.50		
F3.2b Enforcement of habitat regulations	0.75		
F3.2 Regulatory or management effectiveness score		0.45	
C3 Habitat Final Score		**2.15**	**RED**
Critical?	NO		

Brief Summary

Channel catfish acreage in China continues to grow, albeit more slowly, in sensitive habitats such as freshwater wetlands, lakes, and reservoirs. But there is no documented evidence that channel catfish production has altered ecosystem services. Regulations that address the siting of new farms are unclear, because many fall under regulations that are unspecific to the aquaculture sector and/or are based not on ecological principles but on maximized economic benefit. Clarity on enforcement measures is lacking and there is no clear evidence of punitive measures or documented action against farms out of compliance. The final score for Criterion 3 – Habitat is 2.15 out of 10.

Justification of Ranking

Overall, aquaculture production area in China has grown consistently since the early 1980s, with aquaculture pond acreage in particular increasing since the early 1990s while net pen culture (in reservoirs and lakes) has slightly declined over the same period (Wang et al. 2014). Production volume has increased dramatically in both systems, especially in ponds (eight times that of the early 1990s), indicating increased intensification (Wang et al. 2014). The increases in both aquaculture production area and volume suggest that habitat impacts are likely.

Freshwater pond aquaculture acreage grew from 2.11 million hectares to 2.45 million hectares (15.9%) between 2008 and 2011, while net pen (reservoir and lake) acreage grew from 2.51 million hectares to 2.87 million hectares (14.5%) over the same period; however, the rate of growth declined each year (USDA FAS 2012/2010). Data specifically regarding acreage in channel catfish production were not available. The main provinces where catfish production occurs are Sichuan, Hubei, Hunan, Jiangxi, and Guangdong (Zhong et al. 2016). The most recent available data indicate that Hubei increased aquaculture area by 66,000 hectares in 2009, but no information for other provinces is available; industry experts suggest that this level of expansion is not sustainable because of limited water resources and subsequent environmental degradation (USDA FAS 2010). Accordingly, the growth of aquaculture acreage is slowing, with a growth rate of 3.0% from 2010–2011 compared to 9.1% from 2008–2009 (USDA FAS, 2012).

Factor 3.1. Habitat conversion and function

There is no documented evidence that channel catfish production has altered ecosystem services. But the majority of channel catfish production occurs in provinces in southcentral China; the predominant habitats used in these regions are freshwater wetlands and lakes (i.e., high value habitat). Over half of the pond acreage in southcentral China was built in former croplands during the 1990s (Hu et al. 2015) (Li and Yeh 2004) and there is evidence of habitat fragmentation in these areas (Lang et al. 2009) (Ke et al. 2011). There is ongoing expansion (though at a declining rate) of aquaculture area within lakes and reservoirs, yet there is no distinction between artificial and natural reservoirs (USDA FAS 2012/2010). There has been a mainly historic loss (more than 10 years before today) of high-value habitat (i.e., freshwater wetlands, warranting a score of 4 out of 10), as well as some ongoing loss of both moderate and high value habitat (i.e., natural and artificial freshwater lakes and/or reservoirs, warranting scores of 0 and 2 out of 10, respectively); therefore, a score of 3 out of 10 is given for Factor 3.1 – Habitat conversion and function.

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

To manage the impacts of land conversion in high value habitats, such as freshwater wetlands and lakes, regulatory measures must be appropriate to the scale of the industry, be based on ecological principles, and take into account the cumulative impacts of farms sited within these habitats.

On a national scale in China, aquaculture licenses are given by the Ministry of Agriculture (MoA). Given the predominance of rural, small-scale aquaculture farms across China, it remains difficult for the MoA to license each farm (Zou and Huang 2015). Although the 12th Five-Year Fishery Development Plan aimed to license 100% of aquaculture operations by 2015, the most recent statistics show that 79% were licensed through 2011 (USDA FAS 2012). Despite the Fishery Development Plan's goal for licensing, there remains no specific law or legislation on aquaculture site selection; rather, provisions for management dealing with aquaculture and the environment are included in a number of more general laws and regulations (Zhu and Dong 2013).

The appropriate use of terrestrial and freshwater aquatic environments is regulated by three main laws: The Fisheries Law (2004), The Water Law (2002), and The Environmental Impact Assessment Law (2002) (Zou and Huang 2015) (NALO 2012). Because all land and aquatic areas are state-owned, they fall under local functional zoning schemes, which apply in channel catfish producing provinces (Zhu and Dong 2013). The schemes manage the integration of conservation areas and industry, including aquaculture (NALO 2012). Although there is a requirement for the environmental impact assessment (EIA) of new construction in various laws unspecific to aquaculture, there is no information that indicates a standardized process for assessing risk at an aquaculture farm site before it is licensed. The Environmental Protection Law (1989) gives the responsibility for conducting EIAs to appropriate departments of the Environmental Protection Administration of the Peoples' Government at or above the county level (NALO 2012). As a result, there is large variability from one area to another. Factor 3.2a – Regulatory or management effectiveness is scored 1.5 out of 5.

Enforcement of these regulations is divided among many government departments, such as the Bureau of Fisheries (NALO 2012). In 2013, a reported 2,949 law enforcement agencies existed in provinces across China and employed over 35,000 staff (Zou and Huang 2015). There is no center for information on punitive measures or any documented action against farms that do not comply. Enforcement agencies appear regionally fragmented, and there is little public evidence of monitoring or compliance data. Often, economic development takes precedence over compliance with environmental regulation (Zhu and Dong 2013). Factor 3.2b – Siting regulatory or management enforcement is scored 0.75 out of 5.

Conclusions and Final Score

Regulations that address the siting of new farms are unclear, because many fall under regulations that are unspecific to the aquaculture sector and/or are based not on ecological principles but on maximized economic benefit. Clarity on enforcement measures is lacking and there is no clear evidence of punitive measures or documented action against farms out of compliance. When combining Factor 3.2a and Factor 3.2b, a score of 0.45 is given to Factor 3.2 – Habitat Management. In conjunction with Factor 3.1 – Habitat conversion and function, which scored 3 out of 10, the final score for Criterion 3 – Habitat is 2.15 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

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

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**0**	
C4 Chemical Use Final Score	**0**	**CRITICAL**
Critical?	YES	

Brief Summary

Chinese regulations aim to restrict the use of chemicals, though this has not translated to regulatory action at the provincial and local level. The FDA continues to refuse imports of China channel catfish because of unsafe levels of authorized and unauthorized antibiotics. Importantly, there is documented evidence of the ongoing use of banned chemicals, as well as documented antibiotic resistance to highly and critically important antimicrobials for human medicine. The final score for Criterion 4 – Chemicals is Critical (0 out of 10).

Justification of Ranking

As aquaculture practices have intensified, the Chinese aquaculture industry has been overwhelmed by several aquatic animal health problems (Li et al. 2011). The proliferation of viral, bacterial, and fungal infections as well as parasitic pests has resulted in large economic losses (Li et al. 2011) (see Criterion 7 – Disease). Consequently, channel catfish farmers have relied on a variety of chemical treatments to prevent and treat disease outbreaks and to improve the environmental conditions of the production systems. These include water and soil treatment compounds, disinfectants, pesticides, and antibiotics (Rico et al. 2012).

In general, an overview of qualitative and quantitative data on the use of the chemicals used in Chinese aquaculture is currently 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 4). 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 to nontarget organisms and potential for bioaccumulation.

Many water and sediment treatment compounds are relatively innocuous inorganic substances with a short environmental life and are not expected to result in toxic effects to aquatic organisms when applied according to recommendations (Boyd and Massaut 1999). But they are likely to alter (at least temporarily) water quality parameters of the ecosystems, such as alkalinity and pH.

Table 4. Chemicals used in Chinese aquaculture (data from Rico et al. 2012).

Antibiotics	*Water and sediment treatments*
Gentamycin	Calcium oxide
Streptomycin	EDTA
Ampicillin	Sodium chloride
Penicillin	Zeolite
Erythromycin	*Disinfectants*
Furazolidone[1]	Benzalkonium chloride
Ciprofloxacin	Calcium hypochlorite
Enrofloxacin	Calcium peroxide
Norfloxacin	Chlorine
Oxolinic acid	Chlorine dioxide
Sulfamethazine	Copper chloride
Sulfamethoxazole	Copper complex solution
Chlortetracyclin	Formaldehyde
Doxycycline	Iodine
Oxytetracycline	Potassium permanganate
Chloramphenicol[1]	Providone iodine
Rifampicin	Sodium dichloroisocyanurate
Pesticides	Trichloroisocynuric acid
Copper sulfate	*Other*
Malachite green[1]	Amino acids
Methylene blue	Local herbs
Nystatin	Polysaccharides
Trichlorfon	Probiotics

[1] Currently banned for use in most countries.

Pesticides are used to treat fungal and parasitic infections in the cultured species, to kill unwanted organisms entering the system within the inflow water, and to kill pests and predators when ponds cannot be drained completely before stocking. The main fungicides mentioned in the reviewed publications were malachite green, copper sulfate, methylene blue, and trifluralin (Table 4). Malachite green is also used as a powerful bactericide (Hernando et al.

2007), but its use in food-producing activities has been banned in many countries because of its attributed carcinogenic properties (Yang et al. 2007) (Perez-Estrada et al. 2008).

A wide range of disinfectants are used in hatcheries and grow-out ponds to disinfect facilities and often to treat bacterial disease outbreaks. The most commonly used disinfectants are formaldehyde, potassium permanganate, chlorine and chlorine-containing compounds, and iodine.

Antibiotics used in aquaculture are routinely applied in bath treatments or mixed with feed to prevent or treat bacterial infections. Tetracycline and quinolone antibiotics are the most commonly used antibiotic groups, together with sulfonamides. Oxytetracycline and chloramphenicol were used in all seven countries; however, chloramphenicol has recently been banned for use in aquaculture in most countries.

Food Safety Regulation

In China, many government agencies are involved in enforcing food safety regulations. These include the Ministry of Agriculture (MoA); the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ); the Ministry of Health (MoH); the Food and Drug Administration; the Administration for Industry and Commerce; and the Standardization Administration (Broughton and Walker 2010).

The MoA is responsible for regulating quality and safety standards for farm products and their inputs (Tam and Yang 2005). The agency has called for more technology transfer, protection of water resources, and reconstruction of ponds for repairing the ecosystem (USDA FAS 2010).

The AQSIQ is responsible for control of importation and export of food products. Rapid development of transportation infrastructure in the major production areas allows the connection of small aquaculture farms to distant markets, thus contributing to difficulties in tracing aquaculture products (Ellis and Turner 2008). AQSIQ reports that, in 2006, less than half of all domestic food suppliers had proper licenses to sell products for human consumption (AQSIQ 2007).

The Food Hygiene Law gives responsibility to the MoH for monitoring, inspecting, and giving technical assistance for food hygiene as well as investigating food contamination and food poisoning incidents. But strong local government protectionism of local producers may decrease the effectiveness of the inspection process (Ellis and Turner 2008). Punishments for breaches of Food Safety Laws at the local level are generally minor and are often not implemented, allowing producers to continue in business despite dangerous production practices (Ming 2006).

Though the central Chinese government appears to understand the importance of complying with global standards for food safety, evidence suggests that this does not translate to regulatory action at the provincial and local levels (Thompson and Ying 2007). The Chinese regulatory system does not consider the early stages of aquaculture production, so there can be significant use of banned pharmaceutical agents and other inputs (Zhong et al. 2016) (Thompson and Ying 2007).

As part of its regulation of aquaculture imports, the U.S. Food and Drug Administration (FDA) requires all producers exporting to the U.S. to use a Hazard Analysis and Critical Control Points (HACCP) plan. This system identifies potential danger points in the production process and defines management and monitoring systems to ensure that only safe products enter the human food market (USDA Food Safety Research Information Office 2008). But the development and implementation of the plan requires a financial investment that few small farmers in China can afford (Zhong et al. 2016) (Sun and Collins 2013). It has also proved difficult to overcome daunting bureaucratic hurdles. Applications for the HACCP Verification Certificate must pass through government agencies from county to prefecture to province to national levels in order to eventually reach the State Administration for Entry-Exit Inspection and Quarantine. Currently, only a few of the leading large-scale aquaculture companies have been able to overcome these bureaucratic hurdles (Zhong et al. 2016) (Sun and Collins 2013).

This fragmentary nature of enforcement has resulted in a system that operates at far less than optimal efficiency and effectiveness. To address this fragmentation, the Chinese government has attempted to introduce reforms. The central government pledged 1.2 billion dollars to improve food and drug safety in 2007 (Ellis and Turner 2008). The MoA also announced in early 2008 that 30,000 extra inspectors had been sent to help improve regulatory compliance at aquatic food production facilities (Barboza 2008). The Food Safety Law, passed in February 2009, calls for the formation of a state-level food safety commission to oversee the entire food monitoring system. It also defines harsher punishments, including significant fines and compensatory awards to victims, for businesses producing or selling substandard food products. These reforms have yet to result in dramatic changes in exported channel catfish food safety; in 2014, 19 shipments of Chinese channel catfish were refused entry to the United States, with 95% testing positive for “veterinary drug residues” (Table 5).

FDA Inspection
The U.S. Food and Drug Administration (FDA) is authorized to detain a regulated import product that appears to be out of compliance with U.S. food safety law. If the owner of the product fails to submit evidence that the product is in compliance or cannot bring the product into compliance, the FDA refuses admission of the product. From November 2005 until July 2015, there were 99 refusals of shipments labeled as channel catfish and/or *Ictalurus puctatus* from China (Table 5). Of these shipment refusals, 88% were identified as containing “veterinary drug residues” and 49% were identified as containing “unsafe food additives” (FDA Import Refusals, 2015). In May 2007, the Mississippi Department of Agriculture and Commerce issued a “Stop-Sale Order” after testing confirmed the presence of the unapproved antibiotics ciprofloxacin and enrofloxacin in 11 of 16 samples of channel catfish from China (Anonymous 2007).

The improper use of antibiotics or chemicals in aquaculture, especially those unapproved by the FDA, raises significant public health concerns. Improper use can result in the development of antibiotic resistance in bacteria as well as residues in the edible portion of the aquaculture product. Exposure to unapproved chemicals such as nitrofurans, malachite green, and gentian violet can have a carcinogenic effect. Because the FDA has not approved these products, their residues are considered to be either “unsafe new animal drugs/veterinary drug residues” or “unsafe food additives” that render the aquaculture products “adulterated.”

The FDA has several existing import alerts related to unapproved drugs in seafood dating to November 2001. This led to increased monitoring of imported aquaculture seafood. During an 8-month period in 2006 and 2007, 25% of samples of catfish, basa, shrimp, dace, and eel imported from China were found to contain drug residues. The residues detected in catfish included malachite green, gentian violet, and fluoroquinolones (FDA Import Alert 16-131 2013).

Although the use of nitrofurans and malachite green in aquaculture has been prohibited by Chinese authorities since 2002, FDA continues to find residues of these and other animal drugs in shipments of aquaculture seafood products from China (FDA Import Alert 16-131 2013). Furthermore, Chinese authorities have acknowledged permitting the use of fluoroquinolones in aquaculture. The apparent continued use of banned chemicals is of significant concern to Seafood Watch.

Table 5. FDA refusals of channel catfish products from China for 2005 to June 2015 (data from USDA FDA Import Refusals, 2015).

		Refusal Charges					
Year	**# of Shipments Refused**	**Salmonella**	**Mislabeled (Company)**	**Mislabeled (Nutrition)**	**Falsely Categorized**	**Unsafe Food Additive**	**Veterinary Drug Residues**
2005	6				6		
2006	4				2		4
2007	19	1	1	1	4	2	19
2008	4					4	4
2010	5				2		3
2011	10					9	10
2012	15					12	14
2013	14					11	13
2014	19					9	18
2015	3					2	3
Total/Charge	99	1	1	1	14	49	88
% of Total		1	1	1	14	49	88

Developed Resistance

As can be expected from widespread overuse of antibiotic treatments, antibiotic resistance to several highly and critically important antimicrobials for human medicine, as defined by the World Health Organization (WHO), has been found in pathogenic bacteria sampled from

Chinese channel catfish operations. A review of recent literature reveals evidence of abundant developed resistance to oxytetracycline (highly important), doxycycline (highly important), ampicillin (critically important), and penicillin (critically important) in *Aeromonad* bacteria causing disease and mortality in farmed channel catfish (Chuah et al. 2016) (Peng et al. 2014) (Zhao et al. 2014) (Zhao et al. 2013) (Tong et al. 2009). This is of critical concern to Seafood Watch.

Conclusions and Final Score

A variety of chemical products are known to be used in channel catfish aquaculture in China. Of greatest concern is the use of antibiotics, because there is evidence of developed resistance to highly and critically important antimicrobials for human medicine, as defined by the World Health Organization, as well as evidence of ongoing use of banned/illegal chemicals. The final score for Criterion 4 – Chemicals is Critical, 0 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

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

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	0.65	8.37	
F5.1b Source fishery sustainability score		–6.00	
F5.1: Wild Fish Use		7.98	
F5.2a Protein IN	62.01		
F5.2b Protein OUT	10.80		
F5.2: Net Protein Gain or Loss (%)	–82.58	1	
F5.3: Feed Footprint (hectares)	5.65	8	
C5 Feed Final Score		**6.24**	**YELLOW**
Critical?	NO		

Brief Summary

Feed for channel catfish production in China uses fewer fish in the feed than are produced (FIFO value of 0.65 and score of 8.37 for Factor 5.1a). These fish are sourced from fisheries with some management concerns (score of –6 for Factor 5.1b and 7.98 out of 10 for Factor 5.1). Because of the high use of crop ingredients considered to be edible for humans, the overall protein lost by feeding channel catfish is estimated at 82.6% (score of 1 out of 10 for Factor 5.2), and the area required to support the primary productivity that produces channel catfish feed is 5.65 ha per ton (score of 8 out of 10 for Factor 5.3). Together, these contribute to a final score of 6.24 out of 10 for Criterion 5 – Feed.

Justification of Ranking

Factor 5.1. Wild Fish Use

5.1a Fish in:fish out ratio (FI:FO)
The fish in to fish out ratio (FI:FO) for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of fish used in feeds, and the source of the marine ingredients (i.e., does the fishmeal and fish oil come from processing by-products or whole fish targeted by wild capture fisheries?). FCR is the ratio of feed given to an animal per weight gained, measured in mass (e.g., FCR of 1.4:1 means that 1.4 kg of feed is required to produce 1 kg of fish). It can be reported as either biological FCR, which is the straightforward comparison of feed given to weight gained, or economic FCR (eFCR) which is the amount of feed given per weight harvested (accounting for mortalities, escapes, and other losses of otherwise-gained harvestable fish).

The use of a single eFCR value to represent an entire industry is challenging. The difficulty is rooted in the differences in fish genetics, feed formulations, farm practices, occurrence of disease and more. Although eFCRs ranging from 1.53 to 2.02 (average 1.8) have been observed in Chinese and American catfish research ponds and laboratories, the average U.S. farm-level eFCR over a 5-year period was found to be 2.61 (Robinson and Li 2015) (Chang 2012) (Jin 2011) (Li and Robinson 2012) (Li et al. 2008) (Wu et al. 2004) (USDA NASS 2016). This apparent loss in efficiency is primarily due to unaccounted mortalities, wasted feed, and delayed harvest (Robinson and Li 2015). This is currently the best approximation of the eFCR that can be expected for the aquaculture of channel catfish in China.

The only information available concerning feed ingredients used for channel catfish production in China comes from either commercial research (i.e., American Soybean Association International Marketing, http://www.soyaqua.org/search/node/China) or university research on feed additives for fish health management. Considering the participation of Chinese feed manufacturers in these studies, it is assumed that the compositions of control diets are suitable proxies for commercial diets.

On average, a typical commercial diet is a 28%–32% protein sinking feed, which sources protein primarily from plant ingredients such as soybean meal and cottonseed meal (Zhao et al. 2016a/b) (Li and Robinson 2013). Diets have not changed significantly in the past decade; Engel (2008a) reported that farmers using cages in Hubei Province were feeding 32%–33% protein sinking feed with a reported 2:1 feed conversion ratio. Pond producers reported using 30% to 32% protein sinking feed (Engle 2008b).

Channel catfish can accept diets with low levels of animal proteins and feedstuffs that are inedible for humans. Fishmeal inclusions are kept to a minimum due to its high cost and the edibility of suitable alternatives, and ranges between 1% and 6% in Chinese channel catfish feeds (FAO 2016) (Zhao et al. 2016a/b) (Li and Robinson 2013). It has been reported that several of the native carps are polycultured with channel catfish; however, no reports on harvest yields or stocking rates for these species could be found. Therefore, no protein or waste assimilation credits could be assigned to the production of these species.

As mentioned, fishmeal inclusion for Chinese catfish production is between 1% and 6% (FAO 2016) (Zhao et al. 2016a/b) (Li and Robinson 2013). In general, fishmeal is still regarded as the best animal protein source for aquaculture feeds, though it is used in small quantities due to both its high cost and the suitability of plant-based diets (FAO 2016) (USDA FAS 2010). Fish oil is only used as a supplement—applied as a spray at inclusion rates of 0%–2% to reduce feed dust and provide additional energy and fatty acids (Zhao et al. 2016a/b) (Li and Robinson 2013). But because of the paucity of available data, this report assesses the feed sustainability of a catfish feed with 6% fishmeal and 1% fish oil inclusions.

The use of by-products in Chinese catfish feeds is difficult to estimate due to the lack of information regarding the composition of feeds. It is especially difficult to determine the precise inclusion of domestic or imported fishmeals and fish oils, because most feed producers formulate feeds based on market prices and availability. A review of data regarding domestically produced and imported fishmeal indicates that approximately 6.5% of the fishmeal in China is sourced from by-products (Cao et al. 2015b) (Jackson and Shepherd 2012) (USDA FAS 2012). A statement from the International Fishmeal and Fish Oil Organisation (IFFO) in response to the Cao et al. (2015) paper suggests that "processing by-products make up around 40% of fishmeal production" in China, though no data could be obtained to confirm this (IFFO 2015). No information could be obtained regarding the percentage of the fish oil in China sourced from by-products, and it is assumed to be 0%.

Table 6: Wild fish products in Chinese channel catfish feeds.

Parameter	**Data**
Fishmeal inclusion level	6%
Percentage of fishmeal from byproducts	6.5%
Fishmeal yield (from wild fish)	22.50%[1]
Fish oil inclusion level	1%
Percentage of fish oil from byproducts	0%
Fish oil yield	5.00%[2]
Economic Feed Conversion Ratio (eFCR)	2.57
Calculated Values	
Fish Feed Efficiency Ratio (fishmeal)	0.65
Fish Feed Efficiency Ratio (fish oil)	0.52
Seafood Watch FIFO Score (0–10)	**8.37**

[1] 22.5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fishmeal from typical forage fisheries. Yield estimated by Tacon and Metian (2008).
[2] 5% is a fixed value from the Seafood Watch Criteria based on global values of the yield of fish oil from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

As a result of the fishmeal and fish oil inclusion rates, the eFCR, and the by-product use, the FI:FO value for Chinese catfish production is calculated to be 0.65 (based on the fishmeal inclusion). This means that 0.65 tons of wild fish would need to be caught to produce 1 ton of farmed catfish. This equates to a score of 8.37 out of 10 for Factor 5.1a.

5.1b. Sustainability of Wild Fish Source

The specific source of fishmeal and fish oil used in channel catfish feeds is variable and subject to change depending on market price and availability. Fishmeal imports (1.08 million MT in 2012) dominate domestic production (0.3–0.4 million MT in 2012) (Cao et al. 2015b) (USDA FAS 2012). The top three foreign sources of fishmeal in China in 2012 were Peru, the United States, and Chile, with 636,283 MT, 136,778 MT, and 116,776 MT, respectively, and these represent 82% of Chinese fishmeal imports (USDA FAS 2012).

Table 7. Summary of imported fishmeal and related source fisheries (Data from (USDA FAS 2012) (Peron et al. 2010) (FishSource)).

				FishSource Scores							
				Management Quality			Stock				
	Species	**Landings (Peron et al. 2010)**	**% of landings**	**Precautionary?**	**Scientific?**	**Comply?**	**Healthy?**	**Future?**	**Chinese imports (MT)**	**% of imports**	**By-product**
	Peruvian anchovy	7,200,000	95%	>6	9.7	>6	>6	>6			
Peru	Chilean jack mackerel	274,000	4%	>6	10	9.1	5.3	8.6	636,283	58.7%	2%
	Chub mackerel	87,000	1%	<6	n/a	n/a	n/a	n/a			
	Gulf menhaden	479,000	53%	>6	>8	>6	8.8	10			
	Atlantic menhaden	212,000	23%	>6	>6	10	7.6	10			
U.S.	Atlantic herring	96,000	11%	>8	10	9.7	7.1	9.9	136,778	12.6%	25%
	Pacific herring	37,000	4%	n/a	n/a	n/a	n/a	n/a			
	California sardine	85,000	9%	>6	>6	>6	>6	8			
	Peruvian anchovy	1,268,000	40%	>6	>6	>6	6.1	3.2			
Chile	Chilean jack mackerel	1,475,000	47%	>6	10	9.1	5.3	8.6	116,776	10.8%	14%
	Chub mackerel	418,000	13%	<6	n/a	n/a	n/a	n/a			

The composition of imported fishmeal is dominated by Peruvian anchoveta, Chilean jack mackerel, and menhaden (Table 7; (Peron et al. 2010)). Domestically, the primary targeted reduction fisheries are Japanese anchovy, jack mackerel, and Pacific herring (Cao et al. 2015b). To aid in the assessment of sustainability of wild fish sources, the FishSource[3] database was used. According to FishSource, two fisheries from Peru have one score < 6, each of the fisheries from Chile has one score < 6, while every fishery from the United States scores > 6 (Table 7). There are no scores regarding the sustainability of domestic fishmeal and fish oil sources in China. Together, source fisheries of domestic and imported fishmeals and fish oil result in a score of –6 out of 10 for Factor 5.1b – Source Fishery Sustainability.

When Factor 5.1a and 5.1b are combined, the final score for Factor 5.1 – Wild Fish Use is 8.37 out of 10.

Factor 5.2. Net Protein Gain or Loss

In commercial aquaculture, there is potential for a net protein loss when aquaculture systems produce less protein than they consume (Naylor et al. 2000). This is determined by the amount of protein fed to the farmed fish and the amount of protein harvested in the final fish product.

Protein content of commercial catfish feeds in China range from 30% to 32%, with recent trends toward 32% (Zhao et al. 2016a/b) (Engle 2008a/b). The protein in these diets is primarily sourced from plant ingredients, such as soybean meal, rapeseed meal, cottonseed meal, and wheat middlings (Zhao et al. 2016a/b) (FAO 2016) (Li and Robinson 2013). Because fishmeal is approximately 66.5% protein (FAO 2016c) and fishmeal is 6% of total feed composition (see Factor 5.1), then protein from fishmeal accounts for 12.4% of total feed protein; the remaining 87.6% of total feed protein comes from edible crop sources. This corroborates with the representative feed formulation found in Zhao et al. (2016a/b), and feed ingredient composition can be seen in Table 8.

The protein content of whole catfish is 14.9% (Boyd 2007), with edible yield (fillet + nugget, which is the belly meat and other edible trimmings not large enough to be fillets) estimated to be 45% (Bosworth 2012) (Li et al. 2008) (Li et al. 2004) (Argue et al. 2003). Without industry-specific data, it is assumed that 50% of harvesting by-products (e.g., head, rack, viscera) are further utilized. These calculations show that channel catfish farming results in a net protein loss of 82.58% and the final score for Factor 5.2 – Net Protein Gain or Loss is 1 out of 10.

Table 8: Net protein transformation calculations.

Parameter	Data
Protein content of feed	32%
Percentage of total protein from non-edible sources (i.e. byproducts)	0.81%
Percentage of protein from edible sources (i.e. edible marine and crop)	98.79%

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[3] www.fishsource.org

Feed Conversion Ratio	2.61
Protein INPUT per 100 kg of farmed channel catfish	62.01 kg
Protein content of whole harvested channel catfish	14.9%
Edible yield of harvested channel catfish	45%
Percentage of farmed trout byproducts utilized	50%
Utilized **protein OUTPUT** per ton of farmed channel catfish	10.80 kg
Net protein gain or loss	–82.58%
Seafood Watch Score (0-10)	**1.00**

Factor 5.3. Feed Footprint

Because of the omnivorous nature of channel catfish, inclusions of aquatic and land animal resources are low while relying primarily on crop feed ingredients. Using the feed formulation described above, it is estimated that a typical channel catfish feed contains approximately 7% marine ingredients (fishmeal and fish oil), 91% crop ingredients, and 0% land animal ingredients; the remaining 2% of feed is attributed to supplementary vitamins and minerals. Based on the average primary productivity of ocean and land ecosystems, this feed requires 4.75 ha of ocean area and 0.90 ha of land area per ton of channel catfish produced.

Table 9. Ocean area of primary productivity and land area appropriated by feed ingredients.

Parameter	Data
Marine ingredients inclusion	7%
Crop ingredients inclusion	97%
Land animal ingredients inclusion	0%
Ocean area (hectares) used per ton of farmed channel catfish	4.75
Land area (hectares) used per ton of farmed channel catfish	0.90
Total area (hectares)	5.65
Seafood Watch Score (0-10)	**8**

The total feed footprint is 5.65 ha per ton of channel catfish production, and results in a final score of 8 out of 10 for Factor 5.3 – Feed Footprint.

Conclusions and Final Score

Feed for channel catfish production in China uses fewer fish in the feed than are produced (FIFO value of 0.65 and score of 8.37 for Factor 5.1a). These fish are sourced from fisheries with some management concerns (score of –6 for Factor 5.1b and 7.98 out of 10 for Factor 5.1). Because of the high use of crop ingredients that are considered to be edible to humans, the overall protein lost by feeding channel catfish is estimated at 82.6% (score 1 out of 10 for Factor 5.2), and the area required to support the primary productivity that produces channel catfish feed is 5.65 ha per ton (score of 8 out of 10 for Factor 5.3). Together, these contribute to a final score of 6.24 out of 10 for Criterion 5 – Feed.

Criterion 6: Escapes

Impact, unit of sustainability and principle

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

Criterion 6 Summary

Escape parameters	Value	Score	
F6.1 Escape Risk		1.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		4	
C6 Escape Final Score		**2.00**	**RED**
Critical?	NO		

Brief Summary

Channel catfish is a non-native species in China. The risk of escape in both cages and ponds is high, though no information is available regarding actual numbers of escapes. It is anticipated that any escapees would compete with native populations for food and habitat, as well as pose additional predation and disease vector threats; again, there is no information available that is specific to the impacts of Chinese channel catfish escapes. The final score for Criterion 6 – Escapes is 2 out of 10.

Justification of Ranking

In China, the impact of alien species in aquaculture and their resulting effects on biodiversity-related issues have not been well evaluated, though invasive aquatic species have been documented for some time (Lin et al. 2015) (Xiong et al. 2015) (Xu et al. 2006).

The channel catfish has been introduced several times into China since 1978 (FAO Database on Introductions of Aquatic Species, http://www.fao.org/fishery/introsp/search/en). Subsequent shipments from Texas (1997), Arkansas (1999, 2003, 2004), and Mississippi (2001, 2007) have established identifiable broodstock populations (Zhong et al. 2016) (Sheng et al. 2012). An estimated 1 million eggs were imported as recently as 2007 (Merican 2009).

Laws and regulations associated with alien species include the Law of Sanitation Epidemic Prevention, Law of Animal Epidemic Prevention, and the Law of Wild Animal Protection. Unfortunately, there is no regulation specific to the prevention, introduction, or control of invasive alien species. Existing laws stipulate the management of unintentional introduction of invasive alien species and control of epidemics (Xu et al. 2006). But organisms subject to quarantine are those posing risks to agriculture, forestry, animal husbandry, and fisheries. Targeted organisms do not include those that threaten the environment or biodiversity (Xu et al. 2003).

Factor 6.1a. Escape risk

Evidence concerning the number of channel catfish escapes (and possible recapture) from pond and pen culture in China is unavailable.

Escape risk is directly related to the degree of connection to the natural ecosystem (Hill 2008). Net pens are considered high escape-risk systems unless best-management practices are in place, in which case they are considered moderate to high. As reported by Engle (2008a), channel catfish produced in pens are transferred to new pens throughout the growing season, so that pen structures can be cleaned and disinfected. This transfer can lead to increased opportunity for escapes if best-management practices are not used. In ponds, the risk of escape is dependent on water exchange rates, vulnerability to flooding, and implementation of best-management practices to prevent escapes (Tucker et al. 2008). There is a distinct lack of information in regard to the percentage of industry that is pen versus pond farm, as well as the adoption of best-management practices in both production systems. Therefore, Seafood Watch applies the precautionary principle and assigns a worst-case scenario score of 1 out of 10 for Factor 6.1a – Escape Risk.

Because there is no evidence of recapture of escaped fish or direct mortality at the escape site, no adjustment is applied and the Factor 6.1a score remains 1 out of 10.

Factor 6.1b. Invasiveness

Channel catfish is a non-native species in China. It is anticipated that it would compete with native populations for food and habitat, because this has been documented in other regions where channel catfish are invasive, though no information is available to indicate that this is occurring in China (Pool 2007). As a cavity spawner, channel catfish may compete with other native cavity spawners and may affect habitat by creating cavities when suitable habitat is not available (Pool 2007). Escaped channel catfish may also pose additional predation risk to indigenous species because of its omnivorous diet (Pool 2007). A pathogen that was once endemic to U.S. channel catfish was found (not necessarily caused by escaped catfish) in native yellow catfish after several mass mortalities occurred, indicating a disease risk posed by potential escapees (Xiong et al. 2015). Xu et al. (2006) reported that channel catfish have escaped into Chinese waters, adapted to the natural environment, bred naturally, and have become invasive species, though a larger body of literature suggests catfish are considered “non-native” simply by their presence in aquaculture operations and do not provide evidence of establishment in watersheds (Jiawen and Chen 2012) (Lin et al. 2015) (Yu et al. 2011) (Xiong et al. 2015).

When considering both the uncertain invasive status in the wild and the potential invasive impact that has been documented in areas with greater data availability, a score of 4 out of 10 is given for Factor 6.1b – Invasiveness.

Conclusions and Final Score

The inherent risk of escape from net pen systems without robust BMPs for escape management is high, and in the absence of robust data showing the respective percentages of production accounted for by pen and pond systems, the score for Factor 6.1a is 1 out of 10. Channel catfish is non-native in China; although country-specific data on whether it has an impact on natural ecosystems are lacking, it has been demonstrated to negatively affect ecosystems in other regions where it has been introduced; this results in a score of 4 out of 10 for Factor 6.1b. The scores for Factors 6.1a and 6.1b combine to give a final numerical score of 2 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: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	3	
C7 Disease; pathogen and parasite Final Score	**3**	**RED**
Critical?	**NO**	

Brief Summary

Diseases have become a serious problem in channel catfish production in China. Scientific literature has documented several emerging diseases and the transfer of disease from channel catfish stock to other species. The biosecurity of catfish pens and ponds is low, so they pose a significant risk of disease transfer into the surrounding waterbodies. The final score for Criterion 7 – Disease is 3 out of 10.

Justification of Ranking

The intensification of aquaculture in China has led to deterioration in environmental and fish health conditions (Zou and Huang 2015) (Wang et al. 2014) (Li et al. 2011). Chinese aquaculture has been plagued by disease outbreaks caused by viral, bacterial, fungal, and parasitic pathogens, and the associated mortality has caused substantial economic losses (Li et al. 2011). In 2010, aquaculture in China suffered production losses of 295,000 MT caused by diseases (FAO 2012). Epidemiology data are scarce, which hinders the development of effective strategies for disease control. Because most farms are small and located in remote regions, technical support—such as disease diagnosis and training—is often lacking at the farm level. As Chinese aquaculture continues to grow, the prevalence and spread of diseases will unavoidably increase (Tan et al. 2006).

Diseases have become a serious problem in channel catfish production in China. Scientific literature has documented several emerging diseases, including channel catfish virus, enteric septicemia of catfish, columnaris diseases, and intestinal intussusceptions, sometimes with losses of 50% of the stock (Merican 2009). *Streptococcus iniae* causes mortality in many species of fish and has been proved to cause mortality in channel catfish in China (Chen et al. 2011). A reovirus, designated as CCRV-730, has been isolated from channel catfish fingerlings in Hubei Province (Xu et al. 2013). Recently, two new species of gill parasites were found in channel catfish in China (Tang et al. 2012). *Edwardsiella ictaluri* began causing losses of channel catfish fry and foodfish in Gaungxi Province in 2005 (Liang et al. 2007).

Of growing concern are reports of human bacterial pathogens being diagnosed in channel catfish. In Sichuan Province, the bacterial pathogen *Stenotrophomonas maltophilia* resulted in a widespread epidemic (Geng 2010) (Du et al. 2011), causing huge economic losses and proving quite difficult to control. This bacterium is resistant to most currently available broad-spectrum antibiotics and causes a variety of serious diseases in humans. *Aeromonas veronii*, a common pathogen in both humans and animals, was confirmed as the causative agent in deaths of channel catfish in China in April 2009 (Huang et al. 2010); of significant concern is the developed resistance in *A. veronii* to antibiotic treatments, such as oxytetracycline and doxycycline (Zhao et al. 2014) (Zhao et al., 2013). *Acinetobacter baumannii*, also associated with human clinical infections, was isolated from diseased channel catfish from Anhui Province in 2007 (Xia et al. 2008).

The data regarding channel catfish disease impacts on wild fish, shellfish, or other populations are poor. There is evidence of the transfer of *Edwardsiella ictaluri* to native yellow catfish aquaculture operations, which resulted in great losses of > 50% of farmed stock (Xiong et al. 2015).

Conclusions and Final Score

It is likely that pathogens are being amplified on the farm by stocking density and stress (FAO channel catfish, 2004) and, given the open nature of net pens and ponds exchanging water multiple times per production cycle, it is likely that these pathogens are entering the environment. Regulations such as the Law on Animal Diseases exist with the intention of controlling and stopping animal diseases (NALO 2012), though enforcement is unknown. As a result, the final score for Criterion 7 – Disease is 3 out of 10.

Criterion 8. Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

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

Criterion 8 Summary

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

Brief Summary

Chinese catfish farming is completely independent of wild populations, so the score for Criterion 8 – Source of Stock is 10 out of 10.

Justification of Ranking

Channel catfish hatcheries and fingerling suppliers are well established in many provinces in China (Zhong et al. 2016). All channel catfish stock is sourced from hatchery-raised broodstock, so the score for Criterion 8 – Source of Stock is 10 out of 10.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife. This is an "exceptional" factor that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**–6**	**YELLOW**
Critical?	NO	

Brief Summary
Although there is no information available, it is expected that some mortalities of wildlife species occur on channel catfish farms in China; however, the population-level impacts of these mortalities are unknown. Thus, the final score for Criterion 9X – Wildlife and Predator Mortalities is –6 out of –10.

Justification of Ranking
The concentration of potential prey items in open aquaculture ponds provides foraging opportunities for both mammalian and avian predators. Wildlife can also be attracted to aquaculture ponds when regional wetlands are in decline. Ma et al. (2004, 2009) found that water birds were closely associated with aquaculture ponds in China. This can directly or indirectly lead to the death of predators or other wildlife. Though there is no information available, it is expected that some mortalities of wildlife species occur; however, the population-level impacts of these mortalities are unknown. Thus, the final score for Criterion 9X – Wildlife and Predator Mortalities is –6 out of –10.

Criterion 10X: Escape of unintentionally introduced species

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

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

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	6.00	
C10Xb Biosecurity of source/destination	4.00	
C106 Escape of unintentionally introduced species Final Score	**–2.40**	**GREEN**

Brief Summary
The majority (75%–80%) of catfish seed is produced from two hatchery centers in China. There is no international movement of live animals, though channel catfish is produced in 20 provinces across China, so some trans-waterbody movement occurs. The biosecurity of both source and destination are unknown, though they are scored based on the production system risk. The final score for Criterion 10X – Escape of unintentionally introduced species is –2.4 out of 10.

Justification of Ranking

Factor 10Xa International or trans-waterbody animal shipments
Channel catfish eggs, fry, and fingerlings were imported from the U.S. from 1997 until 2007 (Sheng et al. 2012) (Merican 2009). Currently, there are hundreds of hatcheries throughout catfish-producing provinces in China that cater specifically to local markets (Zhong et al. 2016). Most of these hatcheries are small-scale and produce low quality seed; in 2013, the government established two large breeding centers by integrating hundreds of hatcheries in the primary producing provinces of Hubei and Sichuan in order to standardize production (Zhong et al. 2016). These hatcheries now produce 75%–80% of the catfish seed in China. Because catfish production occurs in over 20 provinces throughout China, there is some trans-waterbody movement of live animals (Zhong et al. 2016). It is estimated that roughly 30%–40% of the industry relies on trans-waterbody movement of live animals, and Factor 10Xa – International or Trans-waterbody live animal shipments is scored 6 out of 10.

Factor 10Xb Biosecurity of source and destination
The biosecurity of broodstock farms, or the source of animal movements, is unknown, though assumed to be higher than growout farms due to the sensitivity of eggs and larvae; the biosecurity risk for source of animal movements is moderate and scores 4 out of 10. The biosecurity risk of the destination (farm) is variable, given the unknown adoption of best-

management practices in regard to water exchange and preventing escapes in both ponds and cages. Therefore, the precautionary principle is applied and a biosecurity risk score of 2 out of 10 is given. The score for Factor 10Xb – Biosecurity of source and destination is 4 out of 10.

Conclusions and Final Score

An estimated 30%–40% of Chinese channel catfish production is reliant on trans-waterbody animal movements, and though the biosecurity of growout sites is likely low, hatchery biosecurity is likely moderate. Combining the scores for Factors 10Xa and 10Xb results in a final Criterion 10X – Escape of unintentionally introduced species score of –2.4 out of –10.

Overall Recommendation

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

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

Channel Catfish
Ictalurus punctatus

China
Ponds and cages

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.44	YELLOW	
C2 Effluent	0.00	CRITICAL	YES
C3 Habitat	2.15	RED	NO
C4 Chemicals	0.00	CRITICAL	YES
C5 Feed	6.24	YELLOW	NO
C6 Escapes	2.00	RED	NO
C7 Disease	3.00	RED	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	–6.00	YELLOW	NO
C10X Introduced species escape	–2.40	GREEN	
Total	**19.44**		
Final score	**2.43**		

OVERALL RANKING

Final Score	2.43
Initial rank	RED
Red criteria	5
Interm 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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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

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

- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

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

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

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

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

Appendix 1. Data Points and All Scoring Calculations

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

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	0	0
Chemical use	Yes	5	5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	5	5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**40**

C1 Data Final Score	4.4	YELLOW

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	32
eFCR	2.61
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	14.9
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	133.632
N in each ton of fish harvested (kg)	23.84
Waste N produced per ton of fish (kg)	**109.792**

Factor 2.1b - Production System discharge score

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

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

80 % of the waste produced by the fish is discharged from the farm

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

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Partly	0.25
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Partly	0.25
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Partly	0.25
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	No	0
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	Partly	0.25
		1

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Partly	0.25
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	Partly	0.25
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	Partly	0.25
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	No	0
		0.75

F2.2 Score (2.2a*2.2b/2.5)	**0.3**

C2 Effluent Final Score	**0.00**	**RED**
	Critical?	YES

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**3**

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

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Partly	0.25
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Moderately	0.5
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	No	0
		1.5

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	No	0
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	No	0
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	No	0
		0.75

F3.2 Score (2.2a*2.2b/2.5)	**0.45**

C3 Habitat Final Score	**2.15**	**RED**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	CRITICAL	
C4 Chemical Use Final Score	**CRITICAL**	**RED**
Critical?	YES	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a - Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	6
Fishmeal from by-products (%)	6.5
% FM	5.61
Fish oil inclusion level (%)	1
Fish oil from by-products (%)	0
% FO	1
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	2.61
FIFO fishmeal	0.65
FIFO fish oil	0.52
Greater of the 2 FIFO scores	0.65
FIFO Score	**8.37**

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

SSWF	-6
SSWF Factor	-0.390456

F5.1 Wild Fish Use Score	**7.98**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	32
eFCR	2.61
Feed protein from NON-EDIBLE sources (%)	0.81

Feed protein from EDIBLE CROP soruces (%)	87.2
Protein OUTPUTS	
Protein content of whole harvested fish (%)	14.9
Edible yield of harvested fish (%)	45
Non-edible by-products from harvested fish used for other food production	50
Protein IN	62.01
Protein OUT	10.8025
Net protein gain or loss (%)	-82.5806
Critical?	NO
F5.2 Net protein Score	**1.00**

5.3. Feed Footprint

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

Inclusion level of aquatic feed ingredients (%)	7
eFCR	2.61
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	4.75

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

Inclusion level of crop feed ingredients (%)	91
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingedients to land animal products	*2.88*
eFCR	2.61
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.90

Value (Ocean + Land Area)	**5.65**

F5.3 Feed Footprint Score	**8.00**

C5 Feed Final Score	**6.24**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**1**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**1**

6.1b. Invasiveness

Part A – Native species

Score	0

Part B – Non-Native species

Score	**1.5**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	To some extent
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some extent
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	To some extent
Do escapees have some other impact on other native species or habitats?	To some extent
	2.5

F 6.1b Score	**4**

Final C6 Score	**2.00**	**RED**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parameters	Score	
C7 Biosecurity	3.00	
C7 Disease; pathogen and parasite Final Score	**3.00**	**RED**
Critical?	NO	

Criterion 8: Source of Stock

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

Criterion 9X: Wildlife and predator mortalities

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

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	6.00	
F10Xb Biosecurity of source/destination	4.00	
C10X Escape of unintentionally introduced species Final Score	**-2.40**	**GREEN**