# Channel Catfish

*Ictalurus punctatus, Ictalurus punctatus x Ictalurus furcatus*

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## United States

Ponds

Seafood Watch Consulting Researcher

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# Final Seafood Recommendation

## Channel catfish

*Channel catfish (Ictalurus punctatus) and channel catfish x blue catfish hybrids (Ictalurus punctatus x Ictalurus furcatus)*

**United States**

Ponds

| Criterion | Score | Rank | Critical? |
|---|---|---|---|
| C1 Data | 8.41 | GREEN | |
| C2 Effluent | 8.00 | GREEN | NO |
| C3 Habitat | 6.67 | GREEN | NO |
| C4 Chemicals | 9.00 | GREEN | NO |
| C5 Feed | 7.56 | GREEN | NO |
| C6 Escapes | 8.00 | GREEN | NO |
| C7 Disease | 8.00 | GREEN | NO |
| | | | |
| C8X Source | 0.00 | GREEN | NO |
| C9X Wildlife mortalities | –2.00 | GREEN | NO |
| C10X Secondary species escape | –0.30 | GREEN | |
| **Total** | **53.33** | | |
| **Final score (0-10)** | **7.62** | | |

OVERALL RANKING

| | |
|---|---|
| Final Score | 7.62 |
| Initial rank | GREEN |
| Red criteria | 0 |
| Interim rank | GREEN |
| Critical Criteria? | NO |

| FINAL RANK |
|---|
| **GREEN** |

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


**Summary**

The final numerical score for channel catfish grown in ponds in the United States is 7.62. This numerical score is in the Green range, and with no Red criteria, the final ranking is Green and a recommendation of "Best Choice."

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# Executive Summary

The channel catfish is a native North American freshwater fish whose original range extended from northern Mexico and the states bordering the Gulf of Mexico, up the Mississippi river and its tributaries, and west to the Rocky Mountains. This original distribution represents 20 states and about half of the total land area in the continental United States. Since the 1920s, channel catfish have been widely introduced throughout most of the rest of the United States to enhance sport fishing. Channel catfish strains currently used in culture in the U.S. were originally derived from native fish caught from local waters.

**Data.** Channel catfish farming in the United States has been extensively studied by government, the scientific community, and the industry itself. A large volume of published information is publicly available and was considered during research for this assessment. Published data were reasonably robust for all criteria, with the exception of escapes, for which minimal data exist. Direct communications with industry experts provided valuable data to supplement the primary literature; the final score for Criterion 1 – Data is 8.41 out of 10.

**Effluent.** U.S. channel catfish ponds are operated as “static” with insignificant water exchange during the production cycle. Ponds retain the same water for several production cycles before discharging any effluent. Due to the overall low volume of effluent and relatively minor contribution to cumulative impact in the receiving waterbody, catfish farming does not result in significant effluent-related environmental impacts. Any contribution to cumulative impact is well regulated and managed to be reduced to an ecologically safe level. Data show no evidence that effluent discharges cause or contribute to cumulative environmental impacts, beyond the well-regulated and enforced ecologically acceptable impacts set by federal- and state-level assessments. Thus, the final score for Criterion 2 – Effluents is 8 out of 10.

**Habitat.** Catfish ponds are sited in moderate-value habitats that were historically altered (more than 15 years ago) by activities such as agriculture, yet represent a small fraction of disturbance overall in the ecosystems they are sited in; in addition, catfish ponds provide critical habitat to a variety of taxa that would otherwise be lost as cropland, which ponds have replaced. As such, catfish ponds are said to maintain ecosystem functionality with moderate impacts. Regulations governing farm siting vary by state from absent to comprehensive, while other elements of land development and pond construction are well regulated. There are limited considerations of cumulative habitat impacts. Enforcement of these regulations is highly effective and active at the area-based scale, and the permitting, licensing, and enforcement history is transparent and accessible.

When combining the Factor 3.1 score of 7 out of 10 with the scores for Factors 3.2a (3 out of 5) and 3.2b (5 out of 5), a final score of 6.67 out of 10 is given for Criterion 3 – Habitats.

**Chemical Use.** Overall, chemical use in U.S. catfish aquaculture results in minimal environmental impacts. This finding is based on the use and limits approved by the EPA, the infrequent use due to few disease outbreaks and a high economic cost of chemical treatment, and the long residence time and microbial activity that provide both time and opportunity for dissipation of the chemical before discharge (Boyd and Hargreaves 2004). Chemical use is highly restricted and strongly regulated in U.S aquaculture. Regulation is based on thorough risk analysis, including data on residues, fate, and toxicity to target and non-target species. Survey data indicate that high-risk chemicals (i.e., antibiotics) are used infrequently across the industry, particularly in foodfish ponds, which account for the majority of the production cycle and industry acreage. In addition, it appears that chemical usage is declining based on a lower percentage of total operations using chemicals and an overall reduction in number of farms, but robust data to verify this are lacking. The impact of chemical treatments during a production cycle is mediated by high water volumes and low discharge rates (i.e., the production system does not intentionally discharge water over multiple production cycles), but as stated, fully up-to-date and detailed data on the volume of chemicals used are not available. Catfish production ponds typically discharge water once every 6 to 10 years, and medicated feeds are not normally applied during winter months when overflow effluents are most likely to occur, thereby minimizing the risk of discharging active chemicals and/or their by-products. Therefore, the environmental impacts of chemical use in channel catfish aquaculture are minimal. The final numerical score for Criterion 4 – Chemical Use is 9 out of 10.

**Feed.** Channel catfish are an omnivorous species and are fed a high-energy diet with low amounts of fishmeal and fish oil (approximately 1% each). Although figures will vary across the industry, the most representative data show the economic feed conversion ratio of channel catfish production to be 2.2. From first principles, 0.40 tons of wild fish would need to be caught to produce one ton of farmed channel catfish. With a moderate protein feed, there is also a substantial overall net loss of edible protein (–57.22%) during catfish production. Because most feed protein is sourced from edible crops, the feed footprint is estimated at 2.04 ha per ton of channel catfish production. Criterion 5 – Feed is scored 7.56 out of 10.

**Escapes.** Channel catfish are farmed in closed pond systems that either drain at harvest (nursery ponds) or do not exchange any water, even at harvest, for over 10 years on average (growout ponds). These facilities are outfitted with multiple fail-safe escape prevention devices, and the likelihood of a farmed channel catfish entering the receiving waterbody is low. This low risk of escape in conjunction with a low risk of additional competition and genetic introgression (as demonstrated by genetic studies and the nature of receiving waterbodies that were intentionally stocked with millions of domestic catfish) results in a final score of 8 out of 10 for Criterion 6 – Escapes.

**Disease.** A variety of pathogens and parasites are known to occur in catfish farming in the United States, but management practices have resulted in moderately successful mitigation of disease occurrence and losses in the industry. The ponds used to produce channel catfish are static and do not intentionally discharge water over multiple production cycles, reducing the risk of transfer of disease to wild populations. Though it is necessary to consider the potential discharge of overflow effluents (at times up to 20% of pond volume per year), such overflow generally occurs in the winter months when disease outbreaks are less common. Data from the

U.S. Fish & Wildlife Service National Wild Fish Health Survey Database suggest that on-farm pathogens and/or parasites that may be transmitted to receiving waters do not amplify those found at natural or background levels. Criterion 7 – Disease scores 8 out of 10.

**Source of Stock.** 100% of broodstock and juveniles in U.S. channel catfish aquaculture are produced in hatcheries. Therefore, there is no dependence on wild stocks and the score for Criterion 8X – Source of Stock is –0 out of –10.

**Predator and Wildlife Mortalities.** Although nonlethal predator deterrents are used extensively, lethal control is known to occur. The principal predator species on U.S. channel catfish farms is the double-crested cormorant; several government studies have shown that mortalities resulting from catfish producers are not having a population-level effect on cormorants, and the explosive population growth of double-crested cormorants can partly be attributed to the existence of catfish ponds. The federal Aquaculture Depredation Order, which authorized the take of cormorants without permits, was vacated in 2016, and is likely to result in significantly reduced lethal take of cormorants. In addition, catfish ponds are not pristine bottomland hardwood forest and are significantly less biodiverse than original habitat, but they provide considerable habitat to a wide range of taxa including reptiles, amphibians, and mammals that would otherwise not exist under previous agricultural land. The score for Factor 9X – Wildlife and Predator Mortalities is –2 out of –10.

**Unintentional Species Introductions.** The primary catfish hatcheries are located in Mississippi and Arkansas and supply fingerlings to the major producer states of Mississippi, Alabama, and Arkansas. The majority of fingerlings are not shipped to different waterbodies, though some (< 10%) trans-waterbody shipments may occur. The biosecurity of both fingerling production facilities and recipient growout catfish ponds is relatively high, consisting of static ponds with screened drains and no intentional water discharge. The scoring deduction for Criterion 10X – Escape of Unintentionally Introduced Species is –0.30 out of –10.

**Summary**

Overall, the final numerical score for channel catfish grown in ponds in the United States is 7.62. This numerical score is in the Green range, and with no Red criteria, the final ranking is Green and a recommendation of “Best Choice.”

# Introduction

## Scope of the analysis and ensuing recommendation

**Species**
Channel catfish *Ictalurus punctatus* and channel catfish x blue catfish hybrid *Ictalurus punctatus x Ictalurus furcatus*

**Geographic Coverage**
United States

**Species Overview**
The channel catfish is a native North American freshwater fish whose original range extended from northern Mexico and the states bordering the Gulf of Mexico, up the Mississippi River and its tributaries, and west to the Rocky Mountains. This original distribution represents 20 states and about half of the total land area in the continental United States. Since the 1920s, channel catfish have been widely introduced throughout most of the rest of the United States to enhance recreational sport fisheries. Channel catfish strains currently used in culture in the U.S. were originally derived from native fish caught from local waters. The channel catfish has been introduced to 35 countries worldwide primarily for aquaculture purposes (FAO 2016) but is only produced in exportable quantities in China.

Recent refinements in hatchery techniques and the general superiority of hybrids compared to purebreds have spurred interest in the use of hybrid catfish. The most common hybrid is produced by crossing a female channel catfish and male blue catfish *(Ictalurus furcatus)*. The blue catfish is also native to the United States, though it has a smaller native range than the channel catfish and is primarily found in the southeastern United States. Blue catfish can be distinguished from channel catfish by its more sloped head and lack of body spots, and is considerably larger than channel catfish. The resulting hybrid generally performs better than either parent species for several important production traits including survival, growth, disease resistance, and edible yield. The percentage of catfish farms that stocked channel x blue hybrid catfish increased from 2% in 2002 to 21% in 2009 (USDA NAHMS 2010a); anecdotal evidence suggests this has continued to rise, but more recent data are not available.

**Production System**
Embankment or levee ponds are the most common type of pond used in U.S. channel catfish culture and represent over 75% of all catfish ponds (USDA NAHMS 2010c). Levee ponds are constructed in flat areas by scraping soil from the pond bottom to form embankments around the pond perimeter. These ponds are filled with water pumped from shallow aquifers (principally the Mississippi River alluvial aquifer). Conversely, watershed ponds (23.5% of all catfish ponds) are built in hilly terrain by damming valleys to form reservoirs that store rainwater. Hybrid watershed-embankment ponds are built in regions with gently rolling

topography and are filled with water pumped from wells or surface water from adjacent streams. All commercial production of channel catfish in the U.S. comes from ponds.

**Production Methods**

Channel catfish aquaculture is usually practiced in four discrete phases: 1) broodfish are held in ponds at relatively low densities and allowed to freely mate each spring; 2) fertilized eggs are taken from the broodfish pond to a hatchery where they hatch under controlled conditions; 3) fry are transferred from the hatchery to a nursery pond where they are fed a manufactured feed for about 6 months until they reach between 2 and 8 inches; and, 4) fingerlings are moved from the nursery pond to foodfish production ponds where they are fed a manufactured feed until they reach 1 to 2 pounds (≈0.5–1 kg).

To increase productivity, some farmers have modified traditional ponds by physically separating the fish-holding function from other ecological service functions (oxygen production and waste treatment) while retaining the benefits of outdoor, photosynthetic systems (Tucker and Kingsbury 2010). This "split-pond" approach has an algal growth basin of about 80% of the total area and a fish-holding area of 20%. The two components are split by an earthen levee and connected by culverts that circulate water between the water treatment area and the fish-holding area. Hybrid catfish are usually stocked in these ponds due to their increased disease resistance and aggressive feeding behavior. The advantages of this system include more efficient aeration, ease of feeding and harvest, improved feed conversion, decreased predation, and greater fish production than traditional ponds (Brune et al. 2012). The possibility of high fish production has resulted in rapid adoption of split ponds by catfish farmers, despite the economic cost of converting traditional ponds into the new system.

**Production Statistics**

Channel catfish production is the largest component of U.S. aquaculture, accounting for 63% of poundage produced and 29% of the value in 2010 (Van Vorhees and Lowther 2011). In 2003, there were 1,155 channel catfish farms operating on 181,940 acres (73,629 ha). In 2016, there were only 54,700 acres (22,136 ha) of channel catfish farms in the U.S. (USDA NASS 2016). This reduction in the United States' largest aquaculture commodity is due in part to foreign imports, high feed prices, and a prolonged sluggish economy. The import pressure is evidenced by the 127,013 tons (115,225 MT) of processed catfish (fish of the order Siluriformes) imported in 2014 compared to 75,250 tons (68,266 MT) of U.S.-processed channel catfish sold (Hanson 2015).

In 2016, foodfish were produced on 43,500 acres (17,603 ha), fingerling-producing acres totaled 7,675 (3,106 ha), and 1,575 acres (637 ha) were being used for broodfish production (USDA NASS 2016). Individual channel catfish foodfish operations average 180 acres (73 ha) in size and each foodfish pond averages 10.8 acres (4.4 ha). Well water is used as the water source for 77% of channel catfish operations while 23% of operations rely on surface water (watershed runoff, streams, or springs) (USDA NAHMS 2010b).

U.S. channel catfish growers had total sales of $361 million in 2015 (USDA NASS 2016). Foodfish sales were $345 million with 95.9% direct sales to processors. The remainder of sales were large fingerlings, commonly referred to as “stockers” ($8.9 million) and small fingerling/fry sales ($7.69 million). The top four states (Mississippi, Alabama, Arkansas, and Texas) accounted for 96% of total sales (USDA NASS 2016).

U.S. channel catfish processors processed a cumulative round weight of 301 million lbs (140,614 MT) in 2014 (Hanson 2015). Net pounds of processed channel catfish sold in 2012 totaled 161.1 million lbs (73,210 MT). Sales of fresh fish were 59.2 million lbs (26,762 MT) while frozen fish sales were 102.4 million lbs (46,448 MT). In 2012, sales of whole dressed fish represented 20% of the total fish sold, fillets accounted for 59%, and the remaining 21% were mostly steaks, nuggets, and value-added products. Whole dressed fish sales are 80% fresh and 20% frozen. Fillet sales are 28% fresh and 72% frozen. Steaks, nuggets, and value-added product sales are 17% fresh and 83% frozen (Hanson and Sites 2013).

**Import and Export Sources and Statistics**

Catfish imports for 2014 totaled 254 million lbs (115,212 MT), of which most were fillets (Hanson 2015). The largest amount of these imports was *Pangasius*, a species native to Southeast Asia, produced in cages and ponds in Vietnam and Thailand. China exported 15.2 million lbs (6,894 MT) of channel catfish to the U.S. in 2014 (Hanson 2015). Production systems for both of these species are evaluated in separate Seafood Watch reports. Additional catfish species were imported from Brazil and the Philippines.

Fresh catfish fillet exports totaled 1.2 million lbs (544 MT) in 2014, with most going to Canada. Exports of frozen catfish fillets reported for 2014 totaled 0.3 million lbs (125 MT) (Hanson 2015). Import and export data are compiled by the U.S. Census Bureau.

**Common and Market Names**

| | |
|---|---|
| Scientific Name | *Ictalurus punctatus, Ictalurus punctatus x Ictalurus furcatus* |
| Common Name | Channel catfish, channel catfish x blue catfish hybrid |
| United States | Farm-raised catfish, channel catfish, hybrid catfish |
| Spanish | Bagre, siluro |
| French | barbue de rivière, poisson-chat |

**Product Forms**

Channel catfish is available fresh and frozen. Whole, dressed fish have been headed, eviscerated, and skinned. Steaks are cross-section cuts from larger dressed fish. Boneless fillets are available with the belly section attached (regular) or removed (shank). The boneless pieces cut from the belly section of the fillet are referred to as nuggets. Smaller pieces cut from the fillets are called strips or fingers. Channel catfish is also available in prepared forms including breaded, marinated, and *pâté*.

# Analysis

## Scoring guide

- With the exception of the exceptional criteria (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 Appendix 1.

# Criterion 1: Data quality and availability

***Impact, unit of sustainability and principle***

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

**Criterion 1 Summary**

| Data Category | Data Quality | Score (0-10) |
|---|---|---|
| Industry or production statistics | 10 | 10 |
| Management | 10 | 10 |
| Effluent | 10 | 10 |
| Habitat | 7.5 | 7.5 |
| Chemical use | 7.5 | 7.5 |
| Feed | 7.5 | 7.5 |
| Escapes | 5 | 5 |
| Disease | 7.5 | 7.5 |
| Source of stock | 10 | 10 |
| Predators and wildlife | 7.5 | 7.5 |
| Introduced species | 10 | 10 |
| Other – (e.g. GHG emissions) | Not Applicable | n/a |
| **Total** | | **92.5** |

| | | |
|---|---|---|
| **C1 Data Final Score (0-10)** | **8.41** | **GREEN** |

**Brief Summary**

Channel catfish farming in the United States has been extensively studied by the government, the scientific community, and the industry itself. A large volume of published information is publicly available and was considered during research for this assessment. The Criterion 1 – Data score is 8.18 out of 10.

**Justification of Ranking**

As the largest component of U.S. aquaculture, channel catfish production is of considerable interest to federal and state agencies as well as the scientific community. Other than perhaps rainbow trout, more is known of the biology and culture of channel catfish than any other aquaculture species grown in the U.S. Moreover, environmental management of catfish farming has been more thoroughly studied than for any other species.

There is a large volume of data related to U.S. channel catfish farming. The principle sources are federal government agencies, state agencies, and universities. Federal government agencies generate data through surveys, regulation, and research/extension. State agencies have a regulatory mandate and may act as a permit authority. University faculty conduct research and develop books, peer-reviewed articles, websites, and extension materials.

The United States Department of Agriculture (USDA) reports foodsize and stocker (by size class), fingerling, and broodfish catfish production volume by state twice annually; number of operations; and the water surface acres in production, those taken out of production, and those undergoing or scheduled for renovation and new construction (1988–present). "Catfish Processing" reports are issued monthly and contain information on round weight purchased, prices paid, inventory, quantity sold, price, imports, and exports (1993–2014). The "Census of Aquaculture" is conducted every 5–8 years (most recently conducted in 2013) and covers aquaculture practices, operation size, production, sales, sources of water, marketing channels, and aquaculture for restoration and conservation purposes; these data are also available through the USDA-APHIS-NAHMS surveys, most recently published in 2010 with a 2020 update underway. A score of 10 out of 10 for data quality is given for industry/production statistics.

Data regarding catfish aquaculture management and regulations are all publicly available on a federal level (e.g., U.S. Environmental Protection Agency) and state level (e.g., Mississippi Department of Environmental Quality) by each agency on their respective websites. A score of 10 out of 10 for data quality is given for management and regulations.

Effluent regulatory control is stringent and enforcement is strict. Data regarding effluent discharge are available through the literature and provide information regarding typical ponds under various environmental conditions (rain, drought, etc.). The impact of effluent discharges from catfish ponds is well studied and understood; comprehensive regional-scale studies specific to watersheds where catfish farming occurs in the U.S. have been completed, and state regulatory agencies monitor and report public water quality as well as identify causes of impairment, though neither is specific to catfish farm effluent impact. A score of 10 out of 10 for data quality is given for effluent.

Regulatory control of habitat conversion is moderate and enforcement is strict. The areas where catfish farming primarily occurs in the U.S. have completed habitat assessments (nonspecific to catfish farm construction) and these are available in the literature. Data regarding site locations and their history is available through the National Resources Conservation Service (NRCS) and U.S. Army Corps of Engineers mapping. Data on the impact of habitat loss specifically due to catfish farm construction are limited, though this is due to the "secondary" conversion nature of their construction (catfish ponds are almost exclusively sited in retired cropland, created up to 200 years ago). Data quality for habitat receives a score of 7.5 out of 10.

Data regarding chemical use are well documented, though the most recent information was published by the USDA National Animal Health Monitoring System (NAHMS) in 2010. Chemicals legal for use in the U.S. go through a scientifically rigorous authorization by the U.S. Food and Drug Administration, which assesses the environmental and human health impact of the expected use and discharge of chemicals; these are publicly available and fairly comprehensive. Impacts of chemical discharges are also fairly well understood and documented in the literature. Data quality on chemicals is assigned a score of 7.5 out of 10.

Feed formulations used in this report are largely based on peer-reviewed research on catfish feeds and personal communications with specialists. The sustainability of the source of wild fish used in the formulation of catfish feed was assessed using peer-reviewed literature and FishSource, a widely-used indicator of fish stock health and vulnerability. The amount of protein recovered (i.e., harvested) was assessed using USDA data regarding processing totals and feed deliveries, as well as peer-reviewed literature. Although feed formulations vary by manufacturer and through time, the feed composition used here is considered a very good approximation of industry operation and results in a data score of 7.5 out of 10.

Data regarding escapes are limited. No data exist to quantify the number of escapes or the number of recaptures, though estimates for post-escape mortality are obtained from USDA NAHMS statistics. The ecological impacts of escapees are estimated using literature examining the impact of intentionally released fish for recreation, as well as USDA information regarding genetically improved farmed lines and their performance relative to native, wild fish. Data on biosecurity protocols and movements of animals are well documented. Together, these result in a data score of 5 out of 10 for escapes.

Estimates of disease occurrence and mortality on channel catfish farms are from peer-reviewed literature, government reports, and personal communication with experts. These are considered reasonably robust, but estimates quantify the percentage of farms experiencing mortality due to diseases (pathogen-specific) and do not quantify the actual loss of catfish. Information regarding pathogen type, transmission, and treatment is well documented, and biosecurity management measures are robust and well documented. The U.S. Fish & Wildlife Service National Wild Fish Health Survey Database provides comprehensive data on pathogen occurrence in wild fish in waters throughout the United States. However, there appears to be a lack of research regarding the transmission from diseases on-farm to the surrounding environment. Data on diseases is scored 7.5 out of 10.

Information on source of stock is well documented and peer-reviewed literature confirms that all stock is sourced from hatcheries. Source of stock data is therefore scored 10 out of 10.

Information on the efforts and strategies used to manage predator and wildlife interactions was obtained from published literature. Catfish producers require depredation permits in order to use lethal means to dispatch nuisance wildlife and quantitative information on these interactions is available. Lethal take of the double-crested cormorant, the primary predator affecting catfish farms, was historically covered under a federal depredation order, yet is now illegal without a permit, and its population status is monitored/managed and well documented. A data quality score of 7.5 out of 10 is given.

Information regarding the trans-waterbody movement of live animals is estimated from personal communication with experts and industry white papers. The biosecurity of both sources and destinations of live animals is well documented. A data score of 10 out of 10 is given.

The overall score for data quality and availability is 8.41 out of 10.

# Criterion 2: Effluent

***Impact, unit of sustainability and principle***

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: 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 Evidence-Based Assessment

| | | |
|---|---|---|
| **C2 Effluent Final Score** | **8.00** | **GREEN** |

**Brief Summary**

U.S. channel catfish ponds are operated as "static" with insignificant water exchange during the production cycle. Ponds retain the same water for several production cycles before discharging any effluent. Due to the overall low volume of effluent and relatively minor contribution to cumulative impact in the receiving waterbody, catfish farming does not result in significant effluent related environmental impacts. Any contribution to cumulative impact is well regulated and managed to be reduced to an ecologically safe level. Data show no evidence that effluent discharges cause or contribute to cumulative environmental impacts, beyond the well-regulated and enforced ecologically acceptable impacts set by federal and state-level assessments. The final score for Criterion 2 – Effluents is 8 out of 10.

**Justification of Ranking**

Due to the large amount of effluent data available from peer-reviewed literature and government led assessments, the Effluent category score in Criterion 1 – Data was good (i.e., 10 out of 10), so the evidence-based assessment method was used.

A major component of the federal government's role in effluent management is promulgated in the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (33 U.S.C. §§ 1251–1387 and 40 C.F.R. Parts 104–424). The CWA mandates that a state designate specific uses of its waterbodies—such as aquatic life, fishing, and swimming—and assign site-specific water quality standards that will maintain those uses (CWA Section 303). If the water quality of a given waterbody is not meeting quality standards, the waterbody must be designated as "water quality limited" and specific total maximum daily loads (TMDL) are put in place in order to restore water quality to a level that achieves state water quality standards (CWA Section 303(d)). TMDLs are plans that provide a calculation of the maximum amount of a pollutant, such as nitrogen or phosphorus, that a waterbody can receive without exceeding state water quality standards. Maximum pollutant levels are established and major water-user industries, such as aquaculture, are given allocations that specify how much each pollutant source may discharge to the waterbody.

The Environmental Protection Agency (EPA) regulates aquaculture pollutant discharges from point sources and non-point sources under the Clean Water Act via permitting through the National Pollutant Discharge Elimination System (NPDES) (CWA Section 402). In 2002, the EPA developed effluent limitations guidelines and standards for the concentrated aquatic animal production (CAAP) point source category (USEPA 2002). The EPA conducted a comprehensive literature review and consulted with experts to assess the environmental impacts of aquatic animal production, including “pollutants causing environmental impacts, water quality and ecological impacts from these pollutants, nonnative species impacts, and other potential impacts” (USEPA 2002). The aquaculture effluent limitation guideline was published with a complete description of the applicable legal authorities, environmental requirements, and rationale for the final rule (Federal Register 2004). The technology-based regulation applies to CAAP facilities with annual production of 100,000 pounds (45,454 kg) or more. Closed ponds that discharge only during periods of excess runoff, or facilities that produce less than 100,000 pounds (45,454 kg) per year, are not defined as CAAP facilities due to the low risk of environmental impact associated with little discharge or little waste production. Therefore, the EPA has determined that channel catfish ponds are exempt from CAAP regulations, and they are considered non-point sources in TMDL listings. As a result, there are no commercial channel catfish farms with approved wasteload allocations; instead, they are included in the non-point source total allocation.

Prior to approximately 1985, catfish farmers believed that "flushing" the pond would substantially improve growing conditions in the pond. Subsequent research (McGee and Boyd 1983) and practical experience have demonstrated that "flushing" at rates possible in commercial culture ponds (less than 5% of total pond volume per day) is generally not beneficial. All catfish ponds are now managed as "static" systems with insignificant water exchange except during periods of unusually high precipitation; 41.9% of operations drain once every 6 to 10 years, with a significant portion (39.4%) draining once every 11 to 16+ years (USDA NAHMS 2010a).

Long residence times in channel catfish ponds result in a variety of natural physical, chemical, and biological processes that would otherwise not occur if a higher water discharge rate were used. This water retention allows for as much as 90% of the waste organic matter, nitrogen, and phosphorus produced during culture to be broken down by microbial activity and volatilization prior to discharge (Tucker et al. 1996). The large size of catfish ponds (average of 10.8 acres per pond) is the result of the pond functioning both as a waste treatment facility and a fish confinement area (USDA NAHMS 2010a); Brune et al. (2003) estimated that more than 95% of the total area of a channel catfish pond functions as a photosynthetic waste treatment lagoon while less than 5% of the pond serves to hold catfish.

U.S. channel catfish ponds have two types of effluents. The first is overflow effluent, which occurs when rainfall exceeds pond storage capacity. The second type of effluent occurs much more infrequently, when ponds are drained roughly once every decade. These effluents differ in quality, volume, and discharge frequency, but most of the discharge occurs as overflow in the winter and spring due to increased rainfall (Tucker and Hargreaves 2003).

In embankment ponds, the volume of overflow effluent depends on the storage capacity of the pond. Storage capacity is the volume of rainfall that can be captured in the pond. In general, most catfish ponds are maintained with at least 7.5 to 10 cm (3 to 4 inches) of storage capacity as recommended by published best management practices (Tucker 1999) (Romaire 2012) (Boyd and Hulcher 2001). During a year of normal precipitation in northwest Mississippi, overflow from ponds managed with 6 inches (15 cm) of storage capacity is about 13 inches (33 cm) (Tucker et al. 1996). For ponds managed with 6 to 18 inches (15 to 46 cm) of storage capacity, overflow ranged from 8 to 15 inches (20 to 38 cm) (Tucker et al. 1996) (Hargreaves et al. 2001). Overflow from watershed ponds can range from 93 to 150 inches (235 to 380 cm) due to discharge of excess rainfall accumulation (Boyd et al. 2000). Most overflow occurs from fall to mid-spring, which represents the wetter, cooler part of the year when rainfall exceeds losses from evaporation and seepage. Very little overflow occurs during the dry summer months.

During overflow events due to rainfall, active water exchange is usually low because the pond volume is large compared to the amount of rainfall; considering that most ponds are 4 to 6 feet deep, overflow is often < 20% of pond capacity (USDA NAHMS 2010a). The quality of most overflow effluents is similar to or dilute compared with water in the pond prior to the rainfall (Tables 1a, 1b) (Tucker et al. 2008a) (Silapajarn et al. 2004) (Tucker and Hargreaves 2003) (Boyd et al. 2000). Solids in the overflow effluent are principally phytoplankton, phytoplankton-derived detritus, and clay particles from pond bank and watershed erosion (Tucker et al. 2008a).

**Table 1a.** Concentrations of selected water quality variables (means and ranges, in mg/L) in potential overflow effluents from 20 commercial channel catfish ponds in northwest Mississippi sampled over 2 years (Tucker and Hargreaves 2003).

| Variable | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Total suspended solids | 129 (46–289) | 122 (40–225) | 87 (22–175) | 101 (39–194) |
| Total nitrogen | 4.9 (1.5–7.9) | 6.6 (2.6–14.1) | 6.5 (2.9–10.8) | 5.3 (0.6–8.8) |
| Total phosphorus | 0.34 (0.15–0.58) | 0.53 (0.23–1.24) | 0.30 (0.14–0.62) | 0.34 (0.13–0.62) |
| 5-day BOD | 14.9 (8.2–27.1) | 23.6 (10.5–41.2) | 11.0 (1.9–34.0) | 12.8 (4.8–29.7) |

Adapted from Tucker et al. (1996).

**Table 1b.** Mean concentrations of water quality variables of samples collected from the surface of 25 commercial channel catfish ponds in central and west-central Alabama over the course of an entire year (Boyd et al., 2000).

| Variable | Range | Mean ± SD |
|---|---|---|
| 5-d biochemical oxygen demand (mg/L) | 1.28–35.54 | 9.42 ± 4.75 |
| Settleable solids (mL/L) | 0.00–1.80 | 0.08 ± 0.13 |
| Total suspended solids (mg/L) | 0.7–329 | 69.4 ± 49.0 |
| Total volatile solids (mg/L) | 0.2–208 | 27.8 ± 30.5 |
| Total phosphorus (mg/L) | 0.05–1.48 | 0.25 ± 0.18 |
| Soluble reactive phosphorus (mg/L) | 0.001–0.017 | 0.010 ± 0.012 |
| Total nitrogen (mg/L) | 0.58–14.04 | 5.19 ± 1.68 |
| Total ammonia-nitrogen (mg/L) | 0.01–7.71 | 1.13 ± 1.19 |
| Nitrite-nitrogen (mg/L) | 0.001–1.37 | 0.065 ± 0.05 |
| Nitrate-nitrogen (mg/L) | 0.18–16.8 | 0.70 ± 0.80 |
| Dissolved oxygen (mg/L) | 1.9–16.8 | 8.7 ± 4.0 |
| pH (standard units) | 6.0–9.3 | 8.2 ± 0.5 |

Drainage effluent occurs much less frequently than overflow effluent; catfish ponds are drained to facilitate seining/harvest, to adjust fish inventory, or for maintenance. Catfish fingerling ponds are drained annually, broodfish ponds are drained on average every 3.9 years, while foodfish ponds are drained on average every 11.7 years (USDA NAHMS 2010a). Partial drawdown of watershed ponds occurs about every 15 years. For ponds with long intervals between draining, most of the effluent volume is from overflow events. For ponds that are drained more frequently (e.g., fry and fingerling ponds), effluent volume from draining can exceed overflow discharge.

Most commercial catfish ponds have fixed internal drains with water inlets located on the pond bottom. Upon opening the drain, sediment that has accumulated in and around the drainpipe inlet is discharged with the first flush of water, resulting in a high initial solids concentration in the effluent. After the accumulated sediment has been scoured from the area immediately surrounding the drain inlet, the quality of the water discharged is nearly identical to the bulk pond water for the remainder of pond draining (Hargreaves et al. 2005a). It is common practice for drains to discharge into vegetated ditches; although the primary function of the ditches is to carry water away from the pond, they also function as informal settling basins that can reduce nutrient loads and suspended solids in the effluent prior to entering receiving waters (Hargreaves et al. 2005b) (Hargreaves and Tucker 2003). For example, Hargreaves et al. (2005b) showed that after initial effluent plumes flowed 492 to 656 feet (150 to 200 m) through a ditch, nearly all solids, nitrogen, and phosphorus in the initial effluent were assimilated into the surrounding environment, and their concentrations were lower than in bulk pond water (Hargreaves et al. 2005b). The duration of poor water quality of initial effluent from catfish ponds with internal drains is brief (approximately 10 min), and discharged solids settle rapidly after flowing through 492 to 656 feet (150 to 200 m) of vegetated ditch extending from pond effluent outfalls (Hargreaves et al. 2005b).

In both cases of effluent—overflow and drainage—the water quality is likely to be worse than that of the receiving waterbody. However, the volume of these effluents relative to the receiving waterbody and the relative contribution of aquaculture effluents, in comparison to other factors such as agriculture, has been shown to be negligible in area-based cumulative impacts.

For drainage systems' response to potential nutrient-related contamination, Stephens and Ferris (2004) examined two commercial channel catfish farm drainage systems considered representative of a "typical farm" and the receiving streams affected in northeast Arkansas. The research used modified rapid bioassessment protocols and additional biological impairment testing to conduct an instream community assessment of the affected receiving stream. Though physicochemical analyses indicated minor differences between fish pond effluents and receiving stream water, taxa richness of benthic macroinvertebrates and fish were not significantly different between receiving systems: upstream, facility effluent, and downstream. The authors stated that "these findings suggest minimal detrimental instream effects result from the introduction of aquaculture effluents into receiving waters."

Similarly, Silapajarn et al. (2004) analyzed the effects of catfish ponds on water quality in the Big Prairie Creek Watershed, where catfish ponds (primarily watershed ponds) represented 7.5% of the watershed area and roughly half of the area devoted to catfish farming in Alabama. Their results found that, although catfish farming "has measurable impacts on stream water quality," the water quality of Big Prairie Creek Watershed was not impaired and is considered superior to the fish and wildlife propagation standard set forth by the Department of Environmental Management (Silapajarn et al. 2004). These findings of negligible impact were in accordance with a previous study by Boyd et al. (2000), which found no significant difference in water quality among stream samples upstream and downstream of catfish farms on eight streams in Alabama.

Although aquaculture growout facilities are typically believed to have the most potential for ecological impact, evidence corroborates the lack of effluent-related impact from catfish hatcheries. In the U.S., channel catfish hatcheries typically operate from late April through late June, corresponding to the natural breeding cycle of broodstock. Tucker (2005) sampled water supply and effluent from five channel catfish hatcheries in northwest Mississippi. Samples were evaluated for total suspended solids, soluble and total phosphorus, total ammonia, total nitrogen, and 5-day biochemical oxygen demand. Net pollutant loads were found to be low for all variables. The highest average effluent concentrations were lower than the corresponding concentrations in most potential effluent-receiving streams in northwestern Mississippi (Tucker 2005). The total effluent volume from channel catfish hatcheries in 2005 constituted less than 0.02% of total annual streamflow in the region (Tucker 2005). The author stated that "it is therefore unlikely that catfish hatchery effluents will have a negative effect on receiving stream water quality." Tucker (2005) also stated that the water quality of catfish hatchery effluents was better than that of receiving streams, comparing his results to values for total suspended solids, total phosphorus, and total nitrogen obtained from 24 permanent streams in northwestern Mississippi during the spring season (Tucker and Lloyd 1985). It is important to note, though, that catfish hatchery effluents are not largely representative of foodfish production effluents.

The Wolf Lake watershed encompasses 27,113 acres in Humphreys and Yazoo counties in west-central Mississippi. The lake is listed as impaired due to sediment/siltation and excess nutrients (MDEQ 2003). A study team evaluated the relationship between the sources of inputs, their loading characteristics, and the resulting conditions in the lake (MDEQ 2003). Catfish ponds covered approximately 5% (1,256 acres (508 ha)) of the watershed. It was concluded that catfish ponds contributed less total solids per acre than row crops, hardwood forest, pasture/fallow land, or residential areas (Table 2). Catfish ponds contributed 83% less phosphorus input than row crops and were similar to hardwood forests, pasture/fallow lands, and residential land uses. Catfish ponds contributed more nitrogen on a per acre basis than other land uses, resulting in 11% of the total nitrogen loading to the watershed.

**Table 2.** Percentages of watershed land use and pollutant loadings to Wolf Lake, Mississippi[1]

| | | Pollutant loadings (% of total loading) | | |
|---|---|---|---|---|
| Land use | Area (%) | Solids | Phosphorus | Nitrogen |
| Row crops | 44 | 81.8 | 79.6 | 64.1 |
| Hardwood forest | 28 | 6.1 | 7.8 | 5.9 |
| Pasture/fallow cropland | 23 | 11.6 | 10.8 | 18.8 |
| Catfish ponds | 5 | 0.4 | 1.5 | 10.8 |
| Residential | 1 | 0.2 | 0.3 | 0.4 |

[1] From MDEQ 2003.

“Aquaculture” has been historically listed as a contributor in the non-point source category in multiple TMDLs in Mississippi and Alabama in the mid-2000s, indicating that catfish ponds do contribute to cumulative impact on the natural waterbody. They often represent a small fraction of the total nutrient and sediment loads entering the waterbody; for example, the average embankment pond (10.8 acres) will discharge 21.5 kg (47 lbs) N per year in overflow effluents, whereas permitted point source and non-point source discharges in the same region total in the thousands of pounds N and P per day (Boyd et al. 2000) (USEPA 2008). In addition, these nutrient loads are regulated and managed to be reduced over time to meet the water quality standards; as of December 2016, only one creek in Alabama lists aquaculture as a major contributor to impairment—sedimentation—and has been listed as impaired since 2014 (ADEM 2016). None of the previously approved TMDLs that listed aquaculture as a contributor in Mississippi, like Wolf Lake, are on the current impaired waters list (MDEQ 2016).

Aquaculture is generally not listed as a contributor to eutrophication in degraded waterbodies, but the water quality of streams in major production areas like the Mississippi Delta is often higher than that of catfish effluents. In spite of Tucker’s conclusion (2005) that catfish hatchery effluents were of higher quality than receiving streams in northwestern Mississippi, data collected by the Mississippi Department of Environmental Quality (MDEQ) and United States

Geological Survey (USGS)[1] show recent water quality (2012 to 2016) in sampling sites throughout Leflore, Humphreys, and Sunflower counties (the most intensive production region in the U.S.) to generally be of higher quality than the overflow effluent values obtained from 2001 to 2003 (Table 1a) (Tucker and Hargreaves 2003). Of over 800 samples taken across 30 sites from 2012 to 2016, more than half were of higher quality for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) than the overflow effluent values in Tucker and Hargreaves (2003); the median values (0.95 mg/L TN, 0.33 mg/L TP, 121 mg/L TSS) were also all of higher quality than those found in Tucker and Hargreaves (2003).

Overall, the quality of catfish aquaculture discharge and overflow effluents can be worse than that of receiving waterbodies, yet their volume and frequency of discharge is low, and data show no evidence that effluent discharges cause or contribute to cumulative impacts at the waterbody/regional scale beyond those that are regulated to be ecologically safe.

**Conclusions and Final Score**

As shown, U.S. catfish pond culture appears to result in few effluent-related impacts when assessed on the basis of waste discharge. Low-exchange ponds are effective at trapping solids and sequestering phosphorus; however, the use of commercial feeds in catfish farming results in a relatively nitrogen-rich effluent. Due to the overall low volume of effluent and relatively minor contribution to cumulative impact in the receiving waterbody, catfish farming does not result in significant effluent related environmental impacts. Any contribution to cumulative impact is well regulated and managed to be reduced to an ecologically safe level. Data show no evidence that effluent discharges cause or contribute to local or regional impacts beyond those that are regulated to be ecologically safe.

The final score for Criterion 2 – Effluent is 8 out of 10.

[1] Water quality data obtained through the National Water Quality Monitoring Council's online portal: https://www.waterqualitydata.us/portal/

# 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 | | 7 |
| F3.2a Content of habitat regulations | 3 | |
| F3.2b Enforcement of habitat regulations | 5 | |
| F3.2 Regulatory or management effectiveness score | | 6 |
| **C3 Habitat Final Score (0-10)** | | **6.67** |
| Critical? | NO | **GREEN** |

**Brief Summary**

Catfish ponds are sited in moderate-value habitats that were historically altered (more than 15 years ago) by activities such as agriculture, yet they represent a small fraction of disturbance overall in the ecosystems they are sited in; catfish ponds also provide critical habitat to a variety of taxa that would otherwise be lost as cropland, which ponds have replaced. Thus, catfish ponds are said to maintain ecosystem functionality with moderate impacts. Regulations governing farm siting vary by state from absent to comprehensive, while other elements of land development and pond construction are well regulated. There are limited considerations of cumulative habitat impacts. Enforcement of these regulations is highly effective and active at the area-based scale, while the permitting, licensing, and enforcement history is transparent and accessible.

When combining the Factor 3.1 score of 7 out of 10 with the scores for Factors 3.2a (3 out of 5) and 3.2b (5 out of 5), a final score of 6.67 out of 10 is given for Criterion 3 – Habitats.

**Justification of Ranking**

**Factor 3.1. Habitat conversion and function**

Channel catfish production in the U.S. occurs in manmade, inland, freshwater ponds. The majority of U.S. channel catfish production occurs in five states in the southeast (Alabama, Arkansas, Louisiana, Mississippi, and North Carolina), as well as California and Texas. The two major producing areas are 1) a portion of the Mississippi alluvial valley that includes northwest

Mississippi and southeast Arkansas, and 2) the Blackland Prairie region of west Alabama and east Mississippi. Over 88% of the U.S. channel catfish production comes from farms in these two regions (USDA NASS 2015). In both of these regions, the habitats in which catfish farms are sited are considered to be moderate value, because they feature primarily riparian land and floodplains as well as temperate broadleaf and mixed forests (USFS 2016) (USDA NRCS 2016).

Northwest Mississippi is the most intensely developed channel catfish producing region in the U.S., with ponds occupying more than 30,000 acres (> 12,100 ha) of land (USDA NASS 2012). Despite this intensive production, ponds account for less than 1% of land use in the region. Even in sub-watersheds in the Yazoo River basin (Mississippi) with more intense development, ponds account for only 5% to 10% of the watershed by area.

The ecosystem functionality of floodplain habitats in the Mississippi alluvial valley was degraded in the early 1800s with the construction of the Mississippi River levee system (Kemp 2000). Beginning in the early 1900s, large tracts of hardwood forests in the region were cleared for agricultural use (mainly soybeans and rice) (McWilliams and Rosson Jr. 1990); today, over 90% of the Mississippi alluvial plain has been cleared and drained for agricultural use (USFS 2016). These forests "historically provided some of the essential habitat for wintering waterfowl […] in the lower Mississippi alluvial plain" (Christopher et al. 1988), and conversion for agriculture significantly damaged ecosystem functionality. As agricultural commodity prices fell in the 1980s, low-yielding fields were converted to catfish ponds (Boyd et al. 2008). Similar to the Mississippi alluvial valley, the majority of ponds in the Blackland Prairie region are located on former pasture land (Boyd et al. 2000). The rolling terrain of this area is poorly suited for producing most row crops.

There is little to no expansion of catfish pond acreage into unaltered habitat; in recent years, pond acreage being brought into production has increased (though there have been net declines in production acreage) due to higher market prices, yet these ponds are being constructed in previous catfish pond acreage or cropland taken out of production (USDA NASS 2016). Any growth in the U.S. catfish industry will most likely occur in the same locations that were previously used for production due to existing infrastructure, proximity to processing capacity, and access to physical resources. As acreage has declined, surviving operations have become more vertically integrated and will be positioned to take the greatest advantage of any increase in production.

In stark contrast to row crops, catfish ponds "represent a substantial area of permanent, artificial wetlands available to waterfowl" and are known to be a major source of habitat for a variety of birds (Feaga et al. 2015) (Christopher et al. 1988). A recent comprehensive study found that richness of winter waterbird species at aquaculture production sites was similar to that of virgin bottomland hardwood forest, and significantly higher than nearby areas under other land uses, such as agriculture (Feaga et al. 2015). Though catfish ponds are not pristine bottomland hardwood forest and are significantly less biodiverse than original habitat, they do provide considerable habitat to a wide range of taxa including reptiles, amphibians, and mammals that other land uses, like agriculture, do not (pers. comm., Dr. Brian S. Dorr, May

2017). In this respect, the development of catfish ponds in developed cropland can be considered beneficial and partially restorative toward original wetland habitat (Feaga et al. 2015). The overall loss of ecosystem functionality of floodplain habitats can be attributed to historic agricultural operations, and for the purposes of this assessment, catfish ponds are considered to maintain ecosystem functionality with moderate impacts. The final score is 7 out of 10 for Factor 3.1 – Habitat conversion and function.

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

F3.2a Content of habitat regulations

Regulation governing aquaculture in the United States is complex, with a number of various state and federal laws affecting aquaculture operations nationwide (Engle and Stone 2013). Because most catfish farming occurs on privately owned land, relevant regulations governing the expansion of the industry deal primarily with permitting, zoning, and land use; currently, no operating permits are required for the farming of channel catfish in the major production states of Mississippi or Alabama, while Arkansas requires an annual "fish farmer" permit to operate.

Catfish producers assess a site's potential by evaluating physical resources and legal and regulatory issues. The physical resource potential requires an ecological assessment of water source, soil characteristics, topography, wetlands, climate, contaminants, and predators (Avery 2010). The primary sources of information needed to conduct the site evaluation are various government agencies such as USDA Natural Resources Conservation Service, U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. National Weather Service, local water management districts, or private businesses. Catfish producers in the southern United States who develop enterprises on privately owned lands are not required to conduct environmental impact assessments (King 2006).

Regulations governing the siting of catfish farms are at the federal, state, and local level; for the most part, these regulations and permits cover "zoning, building, water use, waste discharge, [and] species certification related to wildlife management…" (NALC 2017). The content of these regulations vary widely by jurisdiction: for example, in North Carolina, state code specifies suitable watersheds for aquaculture of certain species, among other restrictions (e.g., trout farms cannot damage downstream habitat; NC General Statutes Ch. 106 Article 63); whereas, in Mississippi—the largest catfish producer in the U.S.—there appear to be no relevant state regulations governing the siting of catfish ponds, and catfish aquaculture is specifically exempted from other aquaculture provisions (Mississippi Code § 79-22-1). Indeed, regulations governing the siting of catfish ponds are absent from state codes for several other major producer states, such as Alabama[2] and Arkansas.[3] But Texas, the fourth-largest producer in 2016, has language in the Texas Agriculture Code that applies to licensing, siting, planning, and

[2] Alabama State Code: http://codes.findlaw.com/al/

[3] Arkansas State Game and Fish Commission: http://www.agfc.com/enforcement/Documents/agfc_code_of_regulations.pdf

operations; it contains basic language aimed at long-term conservation of natural resources required by aquaculture (such as water quality). This language authorizes oversight of aquaculture by state agencies and outlines punishments for violations of code. The Code also has stipulations aimed at preventing the siting of aquaculture facilities in sensitive habitat areas.

Regulations governing the construction of catfish ponds in either retired cropland, or current expansion into old pond sites, are primarily related to pond and facility construction, such as grading and clearing of land and stormwater discharge prevention. Both grading and stormwater discharge are permitted by the respective state through general permits in compliance with the NPDES program. Permits are intended to prevent the discharge of pollutants in runoff and stormwater (including sediment and chemicals) into the receiving waterbody at levels that are inconsistent with water quality standards (MDEQ 2016b). Additional permits for land clearing and development may be required at the county or municipal level. Similarly, permits to divert or withdraw water to fill catfish ponds (e.g., building a well) are required in all major producer states.

High-value wetland habitats are avoided for siting channel catfish ponds in the United States. Proposed farm site locations must be inspected by the federal U.S. Army Corps of Engineers (or state agencies) to evaluate if pond construction will impact wetland habitats, in compliance with Section 404 of the Clean Water Act (CWA Section 404). The Corps takes into account cumulative impacts to water quality and impacts to other wildlife when considering permit decisions. Siting channel catfish ponds in wetlands is avoided due to potential impacts on these sensitive ecosystems, increased economic costs of production, and long-term management problems. Farmers can get contact information for the U.S. Army Corps of Engineers through the USDA Natural Resources Conservation Service office located in each county. Developers who do disturb wetlands are required to mitigate any damage and are subject to civil penalty (USEPA 2008b) or to revocation or suspension of any permit (USEPA 2015).

Overall, the scope of regulations governing catfish pond siting is moderate; while some producer states (like Texas) have more comprehensive regulations, the major producer states (like Mississippi) do not appear to have any specific regulations governing pond siting. Other state and federal laws work to mitigate environmental impact of land development and pond construction, though they are not specific to aquaculture. There are limited considerations of cumulative habitat impacts, so Factor 3.2a is scored 3 out of 5.

<u>F3.2b. Enforcement of habitat regulations</u>

It has been estimated that more than 1,300 laws apply to U.S. aquaculture, and even though the majority have been issued by individual states, the cumulative regulatory burden has increased over time (Engle and Stone 2013). A major regulatory category is environmental management, which includes farm siting. The U.S. Army Corps of Engineers handles permit requests for construction of ponds in wetlands (CWA Section 404). The Corps has mapped catfish ponds in flood plains, which cover most of the Mississippi Delta region.

The enforcement of the above regulations is carried out by federal and state agencies. The U.S. Army Corps of Engineers, which handles permit requests for construction of ponds in wetlands (CWA Section 404), is easily contactable via phone, email, or in person at one of many district offices. In the major catfish producing states, the NPDES program (associated with stormwater discharge prevention) is carried out and enforced by state departments of agriculture, game and fish, or natural resources agencies. These departments have location information along with GIS mapping that shows adjacent habitat and have local offices, so identifying and contacting appropriate authorities is not an obstacle. Counties and municipalities that may issue additional permits, such as for land clearing, are easily reached.

The regulatory process is transparent: the public can acquire siting requests from local and federal governments, and the USDA National Agriculture Statistics Service reports catfish acreage and number of operations by state (USDA NASS 2015). Many states also report acreage by county. Evidence of compliance can be obtained through federal, state, and local records.

The enforcement of habitat regulations governing the U.S. catfish industry is highly effective, because organizations are identifiable and reachable with resources appropriate to the scale of the industry; enforcement is active at the area-based scale; and permitting, licensing, and enforcement history is transparent and accessible. Factor 3.2b is scored 5 out of 5.

**Conclusions and Final Score**

Catfish ponds are sited in moderate-value habitats that were historically altered (more than 15 years ago) by activities such as agriculture, yet represent a small fraction of disturbance overall in the ecosystems they are sited in; catfish ponds also provide critical habitat for a variety of taxa that would otherwise be lost as cropland, which ponds have replaced. Thus, catfish ponds are said to maintain ecosystem functionality with moderate impacts. Regulations governing farm siting vary by state from absent to comprehensive, while other elements of land development and pond construction are well regulated. There are limited considerations of cumulative habitat impacts. Enforcement of these regulations is highly effective and active at the area-based scale, and permitting, licensing, and enforcement history is transparent and accessible.

When combining the Factor 3.1 score of 7 out of 10 with the scores for Factors 3.2a (3 out of 5) and 3.2b (5 out of 5), a final score of 6.67 out of 10 is given for Criterion 3 – Habitats.

# Criterion 4: Evidence or Risk of Chemical Use

***Impact, unit of sustainability and principle***

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments*
- *Principle: 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 (0-10) | **9** | |
| Critical? | NO | **GREEN** |

**Brief Summary**

Overall, chemical use in U.S. catfish aquaculture results in minimal environmental impacts. This finding is based on the use and limits approved by the EPA, the infrequent use due to few disease outbreaks and a high economic cost of chemical treatment, and the long residence time and microbial activity that provide both time and opportunity for dissipation of the chemical before discharge (Boyd and Hargreaves 2004). Chemical use is highly restricted and strongly regulated in U.S. aquaculture. Regulation is based on thorough risk analysis, including data on residues, fate, and toxicity to target and non-target species. Survey data indicate that high-risk chemicals (i.e., antibiotics) are used infrequently across the industry, particularly in foodfish ponds, which account for the majority of the production cycle and industry acreage. In addition, it appears that chemical usage is declining, based on a lower percentage of total operations using chemicals and an overall reduction in number of farms, but robust data to verify this are lacking. The impact of chemical treatments during a production cycle is mediated by high water volumes and low discharge rates (i.e., the production system does not intentionally discharge water over multiple production cycles). But, as stated, fully up-to-date and detailed data on the volume of chemicals used are not available. Catfish production ponds typically discharge water once every 6 to 10 years, and medicated feeds are not normally applied during winter months when overflow effluents are most likely to occur, thereby minimizing the risk of discharging active chemicals and/or their by-products. Thus, the environmental impacts of chemical use in channel catfish aquaculture are minimal. The final numerical score for Criterion 4 – Chemical Use is 9 out of 10.

**Justification of Ranking**

Federal drug and pesticide approval programs in the U.S. are intended to protect public health and the environment. The effectiveness of these programs in catfish farming is dependent on enforcement by regulatory agencies and adherence to label requirements by catfish producers. Pesticide product labels provide critical information about how to safely handle and use pesticide products. Drug labels provide specific information on which species can be treated, which diseases are controlled, dosage rates, and withdrawal times.

Drugs

In the U.S., the Food and Drug Administration (FDA) regulates the drug approval process as authorized in the Federal Food, Drug, and Cosmetic Act (FFDCA; 21 USC §301-397) and various regulatory documents that can be accessed from the FDA website (USFDA 2016). The FDA Center for Veterinary Medicine is responsible for ensuring that drugs and medicated feeds used in channel catfish production are safe and effective and that food from harvested fish is safe for human consumption. The drug approval process in the U.S. is rigorous and must demonstrate drug effectiveness, target-animal safety, adequate methods to detect drug residues, drug metabolism and depletion, and mandatory drug withdrawal times if potential drug residues pose a human health hazard (LaPatra and MacMillan 2008). These data include environmental safety data that are used in an environmental risk assessment for the drug. Approved drugs have already been screened by the FDA to ensure that they do not cause significant adverse public health or environmental impacts when used in accordance with label instructions. But it is important to note that these environmental assessments do not include the effects of antimicrobial resistance, a major environmental concern that is reflected in the Seafood Watch Aquaculture Standard.

There are three FDA approved antimicrobials for use in channel catfish. These are Terramycin® 200 for Fish (oxytetracycline dihydrate), Romet-30® (sulfonamide/ormetoprim), and Aquaflor® (florfenicol). These antimicrobials can only be administered through feed. Beginning on January 1, 2017, all medicated feeds are regulated under a Veterinary Feed Directive (VFD), which requires veterinary prescription and oversight to use medicated feeds (VFD 2015). Prior to use, the farmer is first required to submit a fish sample for diagnostic evaluation. If the catfish have been found to be positive for a disease, the veterinarian may issue a prescription to be used by the feed mill for an exact number of pounds of the appropriate medicated feed (VFD 2015). Because channel catfish farmers do not manufacture their own feed, medicated feed is distributed by feed manufacturers. Specific volumes of antibiotics used are proprietary information, so they are not available to the public. Data regarding antibiotic usage by catfish farmers in the U.S. have been documented in two large-scale producer surveys conducted by the United States Department of Agriculture, National Animal Health Monitoring System (USDA NAHMS 2010b/c).

Terramycin 200 for Fish is used to control bacterial hemorrhagic septicemia caused by *Aeromonas liquefaciens* and pseudomonas disease in channel catfish. Oxytetracycline is listed by the World Health Organization (WHO) as a “highly important” antimicrobial for human medicine. According to the aforementioned surveys, Terramycin 200 for Fish is the least-used antibiotic in channel catfish production (only 2% of foodfish operations used this antibiotic in 2009) (USDA NAHMS 2010a).

Romet-30 is used to treat enteric septicemia of catfish (ESC) and is only available from FDA-licensed feed mills; the active ingredient sulfadimethoxine/ormetoprim (a potentiated sulfonamide) is listed by the WHO as a "highly important" antimicrobial for human medicine. Many farmers prefer to control light ESC outbreaks in fingerlings by restricting feeding over treatment with Romet-30. Its use is not considered common or widespread anymore; however, it was the most widely used antibiotic in foodsize fish operations in 2009 (USDA NAHMS 2010c).

Aquaflor is used to control ESC or to treat columnaris disease; the active ingredient, florfenicol, is listed by the WHO as a "highly important" antimicrobial for human medicine.

The percentage of U.S. channel catfish operations that used chemicals in 2002 and 2009 is presented in Table 3. For fingerling operations in 2009, 29% of operations fed medicated feed. In terms of overall number of operations, 4% of operations fed Terramycin 200 for Fish while 8% used Romet-30 and 17% used Aquaflor. For foodfish operations in 2009, only 8.2% of operations fed medicated feed. In terms of total foodfish operations, 2% fed Terramycin, 4% fed Romet, and 3% fed Aquaflor (USDA NAHMS 2010a). Table 3 shows that there was an overall decline in the use of chemicals in U.S. catfish farming in 2009 relative to 2002, though no information is available for years in between or since; it is believed that antibiotic use has declined further by an estimated 50% since 2009 (pers. comm., Carole Engle, December 2016).

Additional chemicals approved by the FDA for use as drugs for channel catfish include formalin, hydrogen peroxide, and tricaine methanesulfonate (MS-222) (USFDA 2011). Formalin is approved to control external parasites of channel catfish and their eggs. Hydrogen peroxide is approved for bacterial and fungal infestations on catfish eggs. Tricaine methanesulfonate use is limited to anesthetizing broodstock prior to stripping of eggs. Only those chemicals manufactured by specific companies with specific drug approvals can be used (USFDA 2011).

The FDA has developed a list of Low Regulatory Priority Compounds (non-drugs) that can be used under certain circumstances (USFDA 2011). The compounds that can be used on channel catfish include calcium chloride to increase calcium concentrations in hatcheries and ponds, fuller's earth and papain to dissolve egg matrix in hatcheries, ice to reduce metabolic rate during transport, povidone iodine as an egg disinfectant, and sodium chloride as an osmoregulatory aid.

Pesticides

The U.S. Environmental Protection Agency (EPA) regulates pesticides under authority of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA; 7 USC §136-136y) and the Federal Food, Drug, and Cosmetic Act. The EPA also evaluates whether a pesticide may cause adverse effects on humans, wildlife, fish, and plants, including endangered species and non-target organisms. Before a pesticide can be registered for use, the EPA is required to determine if the pesticide poses a "reasonable certainty of no harm." Registration is required for all pesticides sold or distributed in the U.S. With respect to channel catfish culture, EPA has jurisdiction over disinfectants, sanitizers, and aquatic treatments used solely for the control of algae, bacterial slime, or pest control (aquatic weeds). State departments of agriculture have primary authority for compliance monitoring and enforcing against use of pesticides in violation of the labeling requirement.

**Table 3.** Percentage of U.S. channel catfish operations that used chemical treatments in 2002 and 2009 (USDA NAHMS 2010c).

| Production Phase | Treatment | Chemical | % of Total Operations | |
|---|---|---|---|---|
| | | | 2002 | 2009 |
| Hatcheries | Treat egg masses | Iodine | 48% | 39% |
| | Adjust alkalinity | Calcium | 38% | 35% |
| | Treat fungal infections[a] | Iodine | 32% | 12% |
| | | Copper sulfate | 26% | 18% |
| | | Formalin | 17% | 18% |
| | | Potassium permanganate | 7% | - |
| | | Hydrogen peroxide | - | 4% |
| | | Salt | 11% | 14% |
| | Treat bacterial infections[b] | Iodine | 16% | 12% |
| | | Copper sulfate | 12% | 18% |
| | | Formalin | 13% | 18% |
| | | Potassium permanganate | 4% | - |
| | | Hydrogen peroxide | - | 4% |
| | | Salt | 7% | 12% |
| | Vaccinate fry against ESC | Vaccines | 11% | 4% |
| Fingerling ponds | Fertilize fry/fingerling ponds | Fertilizers | 58% | 46% |
| | Prevent nitrite toxicity | Salt | 46% | 31% |
| | Control rams horn snail | Copper sulfate | 15% | 12% |
| | | Hydrated lime | 9% | 8% |
| | Medicated feed[c] | Terramycin® for Fish | 22% | 4% |
| | | Romet-30® | 11% | 8% |
| | | Aquaflor® | NA | 17% |
| Foodfish ponds | Prevent nitrite toxicity | Salt | 54% | 50% |
| | Adjust alkalinity | Calcium | 14% | 10% |
| | Control algae[d] | Copper sulfate | 58% | 54% |
| | | Diuron | 52% | 52% |
| | Control rams horn snail | Copper sulfate | 13% | 9% |
| | | Hydrated lime | 11% | 4% |
| | Medicated feed[e] | Terramycin® for Fish | 7% | 2% |
| | | Romet-30® | 5% | 4% |
| | | Aquaflor® | NA | 3% |

[a] Based on 76% (2002) and 61% (2009) of respondents who indicated they treated for fungus in the hatchery.
[b] Based on 57% (2002) and 61% (2009) of respondents who indicated they treated for bacteria in the hatchery.
[c] Based on 27% (2002) and 29% (2009) of respondents who indicated they fed medicated feed to fry/fingerlings.
[d] Based on 72% (2002) and 66% (2009) of respondents who indicated they practiced algae management.
[e] Based on 11% (2002) and 8% (2009) of respondents who indicated they fed medicated feed to foodfish.

In 2009, 66% of channel catfish farmers prevented algae growth with a prophylactic control program. In terms of overall number of operations, 54% used copper sulfate, 51% used diuron, and 16% used native species of fish as biological control (e.g., threadfin or gizzard shad) (USDA NAHMS 2010a). Copper, from copper sulfate applied to ponds to prevent algae growth, precipitates rapidly in ponds and does not contaminate effluent (McNevin and Boyd 2004).

Aquatic vegetation control is necessary to maintain pond culture conditions and the structural integrity of the ponds themselves. Herbicides are part of an integrated management approach that includes physical removal, biological control, and stimulating aquatic blooms to shade pond bottoms. Long periods of time between draining and the shading created by dense phytoplankton blooms prevent aquatic vegetation growth in foodfish ponds.

Vaccines

The USDA Animal and Plant Health Inspection Service (APHIS) regulates veterinary biologics. These duties are performed by the APHIS Center for Veterinary Biologics. Although veterinary biologics refers to a wide range of products, those used in channel catfish are classified as vaccines. Vaccines contain live organisms and are used to increase the natural ability of channel catfish to resist the disease caused by the organism from which the vaccine is derived. Two immersion vaccines, AQUAVAC- COL and AQUAVAC-ESC, are approved for use in channel catfish (Bowker et al. 2012). These have not been widely adopted by industry due to "lack of recognized efficacy and nominal economic returns" (Wise et al. 2015); in 2009, 3.9% of channel catfish fingerlings operations vaccinated fry against ESC (USDA NAHMS 2010a). A potential reason for the lack of efficacy of approved vaccines may be that catfish fry have underdeveloped immune systems at the age of immersion, which may limit vaccine efficacy; new vaccines that are delivered orally and administered at the fingerling stage, when immune systems are better developed, are being developed and evaluated (Wise et al. 2015).

Factors Limiting Drug Use

The following practical considerations play a role in limiting indiscriminate use of drugs and chemicals by the U.S. channel catfish industry:

- Federal and state regulations limit or specify the diseases that can be treated, the fish on which the agent can be used, the type of culture system in which the agent can be used, treatment rates, treatment duration, and withdrawal periods.
- U.S. channel catfish processors require a certificate of compliance from the producer that the producer is not using an unapproved drug or an approved drug in a manner that will cause hazards.
- Beginning on January 1, 2017, all medicated feeds are regulated under a veterinary feed directive (VFD), which requires veterinary prescription and oversight to use medicated feeds (VFD 2015). Though not a legislated limit, this regulation is intended to limit the prophylactic and excessive use of medicated feeds.
- Drugs used in channel catfish production are not approved for use as growth promoters. Research has shown that fish fed medicated feeds tend to grow more slowly than fish fed non-medicated diets (Rawles et al. 1997).

Impact of Chemical Use

The genesis and spread of antibiotic-resistant microorganisms in the environment is recognized as an important environmental and human health issue and a potential impact of chemical use in aquaculture. Recent literature has demonstrated the transfer of antimicrobial resistance factors (resistomes) from pathogens in the aquatic environment to the terrestrial environment, including human pathogens (Cabello et al. 2016) (Cabello et al. 2013) (Laxminarayan et al.

2013). Risk of transfer is in part mediated by the openness of the system, or how frequently the system is discharging water into the receiving environment. In U.S. channel catfish ponds, water exchange is nearly static, with intentional partial or full drainage usually occurring once every 6 to 10 years (USDA NAHMS 2010a). Overflow from excess rainfall is seasonal and may not occur some years, but can represent up to 20% of pond volume annually; however, because diseases generally occur during the summer months and catfish producers slow feeding in the winter due to low growth rates, medicated feeds are often not used in the winter (Tucker and Hargreaves 2003) (Boyd et al. 2000). Thus, it is unlikely that overflow effluents represent a significant chemical and/or antibiotic resistance discharge risk.

**Conclusions and Final Score**

Overall, chemical use in U.S. catfish aquaculture results in minimal environmental impacts. This finding is based on use and limits approved by the EPA, the infrequent use due to few disease outbreaks and a high economic cost of chemical treatment, and the long residence time and microbial activity that provide both time and opportunity for dissipation of the chemical before discharge (Boyd and Hargreaves 2004).

Chemical use is highly restricted and strongly regulated in U.S aquaculture. Regulation is based on thorough risk analysis, including data on residues, fate, and toxicity to target and non-target species. Survey data indicate that high-risk chemicals (i.e., antibiotics) are used infrequently across the industry, particularly in foodfish ponds, which account for the majority of the production cycle and industry acreage. In addition, it appears that chemical usage is declining, based on a lower percentage of total operations using chemicals (Table 3) (pers. comm., Carole Engle, December 2016) and an overall reduction in number of farms, but robust data to verify this are lacking. The ecological impact of chemical treatments during a production cycle is mediated by high water volumes and low discharge rates (i.e., the production system does not intentionally discharge water over multiple production cycles), but as stated, fully up-to-date and detailed data on the volume of chemicals used are not available. Catfish production ponds typically discharge water once every 6 to 10 years, and medicated feeds are not normally applied during winter months when overflow effluents are most likely to occur, thereby minimizing the risk of discharging active chemicals and/or their by-products. Thus, the final numerical score for Criterion 4 – Chemical Use is 9 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) | 0.40 | 9.01 |
| F5.1b Source fishery sustainability score | -5.00 | |
| F5.1: Wild fish use score | | 8.61 |
| F5.2a Protein IN (kg/100kg fish harvested) | 60.09 | |
| F5.2b Protein OUT (kg/100kg fish harvested) | 25.71 | |
| F5.2: Net Protein Gain or Loss (%) | –57.22 | 4 |
| F5.3: Feed Footprint (hectares) | 2.04 | 9 |
| **C5 Feed Final Score (0-10)** | | **7.56** |
| Critical? | NO | **GREEN** |

**Brief Summary**

As a result of the fishmeal and fish oil inclusion rates, the eFCR, and the by-product use, the FFER value for U.S. channel catfish production is calculated to be 0.40 (based on the fish oil inclusion). This means that 0.40 tons of wild fish would need to be caught to produce 1 ton of farmed channel catfish. This equates to a score of 9.01 out of 10 for Factor 5.1a. The sustainability of both domestic and imported source fisheries for catfish feed ingredients was assessed, and resulted in a score of –5 out of –10 for Factor 5.1b due to concerns over fish stock management, and combines to score 8.61 for Factor 5.1. The overall protein lost by feeding channel catfish is estimated at 57.22%, considering edible protein inputs, feed conversion ratio, and usable protein outputs, and is scored 4 out of 10 for Factor 5.2. The total feed footprint is 2.04 ha per ton of harvested channel catfish, calculated by estimating primary productivity and acreage required to produce the marine, crop, and land-animal ingredients in channel catfish feed; this results in a final score of 9 out of 10 for Factor 5.3. Combined, the final score for Criterion 5 – Feed is 7.56 out of 10.

**Justification of Ranking**

Channel catfish must be fed a nutritionally complete diet because contributions from primary productivity in the pond are small compared to total nutrient requirements. The scientific information on catfish feeds is more abundant than for any other assessed criterion and feeds and feed manufacturing are tightly regulated.

**Factor 5.1. Wild Fish Use**

5.1a Feed Fish Efficiency Ratio (FFER)

The feed fish efficiency ratio (FFER) ratio 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 byproducts or whole fish targeted by wild capture (i.e., reduction) 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).

U.S. channel catfish operations report that their average feed conversion ratio is 2.2 (i.e., 2.2:1) (USDA NAHMS 2010c) (Boyd and Polioudakis 2006). In controlled experiments, the true biological efficiency of channel catfish to convert feed has been reported to be as low as 1.5 to 1.8. The economic feed conversion ratio (eFCR) required for calculations used in this report is assumed to be the farmer-reported 2.2, because over 98% of foodsize catfish production in the United States was sent to processors, live haulers and brokers, and retail outlets (the remaining 1.5% was destined for recreational stocking and “other” outlets) (USDA NASS 2017).

Historically, fishmeal has been used at various levels in catfish feeds, with fry and fingerlings receiving higher levels than foodfish. Currently, because of its high cost, little if any fishmeal is used in commercial catfish feeds except for fry starter feeds (Li and Robinson 2013) (Robinson and Li 2012). Fry starter feeds are only used in hatcheries and are estimated to account for less than 0.1% of annual feed fed (pers. comm., Menghe Li, Mississippi State University 2017). To account for the small amount used in fry starter feeds and some experimental diets, a fishmeal inclusion rate of 1% was used in these calculations as a precautionary approach to maximum usage estimation.

Catfish offal oil, menhaden fish oil, poultry fat, or a mixture of these oils is sprayed on channel catfish feed to improve the integrity of the pellets; this generally represents 2% of a diet formulation (Li and Robinson 2013) (Robinson and Li 2012). Catfish offal oil is a processing by-product of the rendering of catfish offal into meal. Menhaden fish oil is not derived from processing fish by-products. Plant oils can be used but are generally too expensive. When wild marine fish oils are included, they are limited to 1% inclusion levels (pers. comm., Menghe Li, Mississippi State University 2017).

The use of by-products in channel catfish feeds is difficult to estimate because availability is highly variable and data collection is poor. According to the International Fishmeal and Fish Oil Organization (IFFO), 25% of fishmeal and fish oil currently produced in the U.S. comes from trimmings and by-products (Jackson and Shepherd 2012) (Chamberlain 2011). It is not possible to determine the precise inclusions of domestic fishmeals and fish oils used in domestic channel catfish feeds, because most feed producers formulate feeds based on market prices and availability. A review of data regarding domestically produced and imported fishmeals and fish oils indicates that approximately 25% of fishmeal and 10% of the fish oil in the U.S. are from byproducts, and these numbers are used as proxies for inclusions in U.S. channel catfish feeds (Jackson and Shepherd 2012) (Chamberlain 2011).

**Table 4.** The parameters used and their calculated values to determine the use of wild fish in feeding farmed U.S. catfish.

| Parameter | Data |
|---|---|
| Fishmeal inclusion level | 1% |
| Percentage of fishmeal from byproducts | 25% |
| Fishmeal yield (from wild fish) | 22.5%[4] |
| Fish oil inclusion level | 1% |
| Percentage of fish oil from byproducts | 10% |
| Fish oil yield | 5.0%[5] |
| Economic feed conversion ratio (eFCR) | 2.2 |
| **Calculated Values** | |
| Feed fish efficiency ratio (FFER) (fishmeal) | 0.07 |
| Feed fish efficiency ratio (FFER) (fish oil) | 0.40 |
| **Seafood Watch FFER Score (0-10)** | **9.01** |

The combination of low fishmeal/fish oil inclusions and an eFCR of 2.2 results in an initial FFER score (Factor 5.1a) of 9.01 out of 10. This score is adjusted based on the sustainability of the wild source fisheries from which fishmeal and fish oil is derived.

5.1b. Sustainability of Wild Fish Source

The specific source of fishmeal and fish oil used in fish feeds is variable and subject to change, depending on market price and availability. Globally, the majority of fishmeal and fish oil comes from small wild pelagic fish, including herring, menhaden, and anchoveta (Pauly and Watson 2009). In the U.S., fishmeal and fish oil are primarily produced from Gulf and Atlantic menhaden, with contributions from Atlantic and Pacific herring, as well as California sardine (Peron et al. 2010). As mentioned previously, roughly 25% of fishmeal and fish oil produced in the U.S. are sourced from fishery by-products (e.g., offal, processing trimmings) (Jackson and Shepherd 2012) (Chamberlain 2011). Additional supplies of fishmeal and fish oil, primarily

[4] 22.5% is a fixed value from the Seafood Watch Aquaculture Standard based on global values of the yield of fishmeal from typical forage fisheries. Yield estimated by Tacon and Metian (2008).
[5] 5% is a fixed value from the Seafood Watch Aquaculture Standard based on global values of the yield of fish oil from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

sourced from anchoveta and Chilean jack mackerel, are imported from countries such as Peru and Chile, with significant contributions from Mexico, Canada, Norway, and Iceland (Table 5a).

**Table 5a.** Summary of imported fishmeal and related source fisheries (data from Peron et al. 2010 and National Marine Fisheries Service 2015). All volumes are in metric tons.

| | | | | FishSource Scores | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Management Quality | | | Stock | | | | |
| | **Species** | **Landings (Peron et al. 2015)** | **% of landings** | **Precautionary?** | **Scientific?** | **Comply?** | **Healthy?** | **Future?** | **US Fishmeal Imports (2015)** | **% of imports** | **By-product** |
| **Chile** | Peruvian anchovy | 1,268,000 | 40% | >6 | >6 | >6 | 6.1 | 3.2 | 29,403 | 64.2% | 14% |
| | Chilean jack mackerel | 1,475,000 | 47% | >6 | 10 | 9.1 | 5.3 | 8.6 | | | |
| | Chub mackerel | 418,000 | 13% | <6 | n/a | n/a | n/a | n/a | | | |
| **Mexico** | California sardine | 471,000 | 95% | >6 | >6 | >6 | >6 | >6 | 7,409 | 16.2% | 50% |
| | Chub mackerel | 24,000 | 5% | n/a | n/a | n/a | n/a | n/a | | | |
| **Canada** | Atlantic herring | 187,000 | 78% | >6 | >6 | 6.8 | >6 | >6 | 2,493 | 5.4% | 100% |
| | Pacific herring | 24,000 | 10% | n/a | n/a | n/a | n/a | n/a | | | |
| | Capelin | 28,000 | 12% | n/a | n/a | n/a | n/a | n/a | | | |

**Table 5b.** Summary of imported fish oil and related source fisheries (data from Peron et al. 2010 and National Marine Fisheries Service 2015). All volumes are in metric tons.

| | | | | FishSource Scores | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Management Quality | | | Stock | | | | |
| | **Species** | **Landings (Peron et al. 2015)** | **% of landings** | **Precautionary?** | **Scientific?** | **Comply?** | **Healthy?** | **Future?** | **US Fishmeal Imports (2015)** | **% of imports** | **By-product** |
| **Peru** | Peruvian anchovy | 7,200,000 | 95% | >6 | 9.7 | >6 | >6 | >6 | 9,818 | 58.7% | 2% |
| | Chilean jack mackerel | 274,000 | 4% | >6 | 10 | 9.1 | 5.3 | 8.6 | | | |
| | Chub mackerel | 87,000 | 1% | <6 | n/a | n/a | n/a | n/a | | | |
| **Norway** | Blue whiting | 720,000 | 76% | <6 | <6 | 10 | 9.8 | 6.3 | 1,812 | 10.8% | 22% |
| | Capelin | 229,000 | 24% | >6 | 10 | 10 | >6 | >6 | | | |
| **Chile** | Peruvian anchovy | 1,268,000 | 40% | >6 | >6 | >6 | 6.1 | 3.2 | 1,646 | 9.8% | 14% |
| | Chilean jack mackerel | 1,475,000 | 47% | >6 | 10 | 9.1 | 5.3 | 8.6 | | | |
| | Chub mackerel | 418,000 | 13% | <6 | n/a | n/a | n/a | n/a | | | |
| **Iceland** | Capelin | 665,000 | 53% | >6 | 10 | 10 | >6 | >6 | 1,446 | 8.6% | 32% |
| | Blue whiting | 359,000 | 28% | <6 | <6 | 10 | 9.8 | 6.3 | | | |
| | Atlantic herring | 238,000 | 19% | >8 | 10 | 9.2 | 10 | 8 | | | |

**Table 5c.** Summary of domestic fishmeal and fish oil production and related source fisheries (data from Peron et al. 2010 and National Marine Fisheries Service 2015). All volumes are in metric tons.

| | | | FishSource Scores | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Management Quality | | | Stock | | | | |
| **Species** | **Landings (Peron et al. 2010)** | **% of landings** | **Precautionary?** | **Scientific?** | **Comply?** | **Healthy?** | **Future?** | **Retained Fishmeal (2015)** | **Retained Fish Oil (2015)** | **By-product** |
| Gulf menhaden | 479,000 | 53% | >6 | >8 | >6 | 8.8 | 10 | 81,500 | 36,000 | 25% |
| Atlantic menhaden | 212,000 | 23% | >6 | >6 | 10 | 7.6 | 10 | | | |
| Atlantic herring | 96,000 | 11% | >8 | 10 | 9.7 | 7.1 | 9.9 | | | |
| 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 | | | |

In 2015, these imports totaled approximately 49,500 MT and 17,000 MT for fishmeal and fish oil, respectively (NMFS 2015). When compared with the estimated total retained domestic production (produced minus exported) of fishmeal and fish oil of 81,500 MT and 36,000 MT, respectively (FAO 2016b) (NMFS 2015), it is clear that domestic fishmeal and fish oil products are much more significant than imports in the U.S. However, for the purposes of this assessment, the sustainability of both domestic and imported source fisheries for catfish feed ingredients was assessed.

To aid in the assessment of sustainability of wild fish sources, the FishSource[6] database was used. According to FishSource, the U.S. Gulf menhaden fishery scores >6 in all management categories, with current stock health and future stock health scoring 8.8 and 10, respectively (Table 5c). Recent reports claim that the U.S. Atlantic menhaden fishery is not considered overfished, and the fishery is of an acceptable size (SEDAR 2015). The U.S. Atlantic menhaden fishery currently scores > 6 in all management categories, with current stock health and future stock health scoring 7.6 and 10, respectively (Table 5c).

Imported fishmeals are primarily from Chile, Mexico, and Canada, with multiple species sourced. Each fishery from Chile has one FishSource score that is < 6, and the remainder of source fisheries all score > 6 (Table 5a). Imported fish oils are primarily from Peru, Chile, Iceland, and Norway; two fisheries from Peru have one FishSource score that is < 6, while fisheries from Norway and Iceland—representing more than 10% of fish oil imports—have two scores < 6 (Table 5b).

Together, source fisheries of domestic and imported fishmeals and fish oil result in a score of –5 for Factor 5.1.b – Source Fishery Sustainability.

When Factor 5.1a and Factor 5.1b are combined, the final score for Factor 5.1 – Wild Fish Use is 8.61 out of 10.

**Factor 5.2. Net Protein Gain or Loss**

The protein content of commercial catfish feeds ranges from 26% to 35%. The protein content of foodfish feed is either 28% or 32%. In a national survey conducted in 2009, 57.3% of foodfish operations reported that they primarily used 28% protein feed (USDA NAHMS 2010c). Because 96% of catfish feed delivered in 2009 was fed to foodsize catfish (USDA NASS 2010), a 30% protein content of catfish feed was used to determine protein inputs.

Channel catfish diets are based primarily on plant proteins. The more expensive animal protein feedstuffs, such as fishmeal, have been mostly replaced with poultry by-product meal or porcine meal (Li and Robinson 2013). Expensive soybean meal is being replaced by less expensive feedstuffs such as cottonseed meal, corn gluten feed, or distillers' dried grains with solubles. Cottonseed meal, wheat middlings, and distillers' dried grains are by-products of cotton, wheat milling, and ethanol production, respectively. Additionally, the amount of corn grain used has also been reduced considerably. Nearly 9% of feed protein comes from sources that are considered nonedible by humans, such as porcine meat and bone meal (Li and

[6] www.fishsource.org

Robinson 2013). Although the actual diet formulations are proprietary, a typical 28% to 30% protein diet is described in Table 6.

**Table 6.** Typical 28% to 30% protein diet formulations used for channel catfish foodfish in 2013.[1]

| Ingredient | Food Fish Feed Composition | | |
|---|---|---|---|
| | **32% protein** | **30% protein (estimated)** | **28% protein** |
| Soybean meal (48%[2]) | 44.10 | 38.50 | 32.90 |
| Cottonseed meal (41%[2]) | 10.00 | 10.00 | 10.00 |
| Porcine meat & bone meal (52%[2]) | 5.00 | 5.00 | 5.00 |
| Corn grain | 20.00 | 22.50 | 25.00 |
| Wheat middlings | 18.20 | 21.26 | 24.32 |
| Oil (Animal or Plant)[3] | 2.00 | 2.00 | 2.00 |
| Lysine HCl | 0.00 | 0.04 | 0.08 |
| Dicalcium phosphate | 0.50 | 0.50 | 0.50 |
| Catfish vitamin premix | included | included | included |
| Catfish mineral premix | included | included | included |

[1] From Li and Robinson 2013.
[2] Values represent % protein.
[3] Sprayed on top of feed.

The protein content of whole catfish is 14.9% (Boyd 2007), with edible yield (fillet + nugget, 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). It is estimated that 90% of harvesting by-products (e.g., head, rack, viscera) are further used (pers. comm., Carole Engle, December 2016).

**Table 7:** Net protein transformation calculations.

| Parameter | Data |
|---|---|
| Protein content of feed | 30% |
| Percentage of total protein from nonedible sources (i.e., by-products) | 8.95% |
| Percentage of protein from edible sources (i.e., edible marine and crop) | 91.05% |
| Economic feed conversion ratio | 2.2 |
| Protein INPUT per 100 kg of farmed catfish | 60.09 kg |
| Protein content of whole harvested catfish | 14.9% |
| Edible yield of harvested catfish | 45% |
| Percentage of farmed catfish by-products used | 90% |
| Used protein OUTPUT per ton of farmed catfish | 25.71 kg |
| **Net protein gain** | –57.22% |
| **Seafood Watch Score (0–10)** | **4** |

Calculations in Table 7 show that channel catfish farming results in a net protein loss of 57.22% and the final score for Factor 5.2 – Net Protein Gain or Loss is 4 out of 10.

**Factor 5.3. Feed Footprint**

The feed footprint considers how much physical ocean and land area is required to produce the ingredients for enough feed to grow 1 ton of fish. Using the feed formulation described above (2% marine-derived ingredients), it is estimated that a typical U.S. channel catfish feed contains approximately 2%, 92.5%, and 5% marine, crop, and land-animal products, respectively. Based on the average primary productivity of ocean and land ecosystems, this feed requires 1.36 ha of ocean area and 1.06 ha of land area per ton of catfish produced.

**Table 8:** Ocean area of primary productivity and land area appropriated by feed ingredients.

| Parameter | Data |
|---|---|
| Marine ingredients inclusion | 2.0% |
| Crop ingredients inclusion | 92.5% |
| Land animal ingredients inclusion | 5.0% |
| Ocean area (hectares) used per ton of farmed catfish | 1.14 |
| Land area (hectares) used per ton of farmed catfish | 0.89 |
| Total area (hectares) | 2.04 |
| **Seafood Watch Score (0–10)** | **9** |

The total feed footprint is 2.04 ha per ton of U.S. channel catfish production, and results in a final score of 9 out of 10 for Factor 5.3 – Feed Footprint.

**Conclusions and Final Score**

Feed for channel catfish in the U.S. uses less fish in the feed than are produced (FFER value of 0.40 and score of 9.01 for Factor 5.1a). These fish are mostly from relatively well-managed fisheries that have healthy stocks, although some management concerns exist (score of –5 for Factor 5.1b and 8.61 out of 10 for Factor 5.1). The overall protein lost by feeding channel catfish is estimated at 57.22% (score of 4 out of 10 for Factor 5.2), and the area required to support the primary productivity that produces channel catfish feed is 2.04 ha per ton of harvested catfish (score of 9 out of 10 for Factor 5.3). Together, these contribute to a final score of 7.56 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 System escape risk | 8 | |
| F6.1 Recapture adjustment | 0 | |
| F6.1 Final escape risk score | | 8 |
| F6.2 Competitive and genetic interactions | | 8 |
| **C6 Escape Final Score (0-10)** | | **8** |
| Critical? | NO | **GREEN** |

**Brief Summary**

Channel catfish is farmed in closed pond systems that either drain at harvest (nursery ponds) or do not exchange any water, even at harvest, for over 10 years on average (growout ponds). These facilities are outfitted with multiple fail-safe escape prevention devices, and the likelihood of a farmed channel catfish entering the receiving waterbody is low. This low risk of escape in conjunction with a low risk of additional competition and genetic introgression (as demonstrated by genetic studies and the nature of receiving waterbodies that were intentionally stocked with millions of domestic catfish) results in a final score of 8 out of 10 for Criterion 6 – Escapes.

**Justification of Ranking**

**Factor 6.1a. Escape risk**

Escapes can be defined as the unintentional release of cultured animals to the environment. The primary mechanisms by which channel catfish can escape include a breach in the drainage structure, topping of levees due to flooding events, and loss during fish transfer. As is the case for all aquaculture production, escapes represent a loss of potential revenue, so there is a strong economic incentive to construct and manage production units to minimize losses from escapes.

Commercial catfish ponds have fixed internal drains with screened water outlets located on the pond bottom. These screens are permanently attached to the drainage structure and sized to retain the smallest size fish in the culture unit. Because pondwater is typically discharged only during draining, the potential for escape via the drainage structure occurs only during draining of the pond. This possibility is minimized due to the long interval between draining of foodfish ponds (11.7 years) and broodfish ponds (3.9 years) (USDA NAHMS 2010a). Although fingerling ponds are drained more frequently (often between crops), the ponds are seined multiple times to ensure that the biomass of fish left in the pond is as low as possible before draining. The remaining fish are larger than the screen size on the drain, so a small number of fish remain in the pond after draining and are eliminated with fish toxicants. Thus, it is unlikely for a catfish to escape during drainage.

Almost all channel catfish ponds are located above the 100-year flood elevation as determined by the U.S. Army Corps of Engineers. Most channel catfish ponds in the U.S. are not subject to flash floods, but they may be subject to back-water flooding created by rising water of major rivers being pushed up their tributaries. The Mississippi River Flood of 2011 set new record stages at Vicksburg, Mississippi, located at the southern end of the Mississippi alluvial plain. The peak streamflow at Vicksburg exceeded the estimated peak streamflow of both the Great Mississippi Flood of 1927 and the measured peak streamflow of the 1937 flood. Despite the devastating nature of this 500-year, record-high flood, only one catfish operation was inundated (McCall 2011). Given the slow nature of back-water flooding and the ability to accurately estimate crest stages, the farmer was able to sell market-ready fish and move the remaining fish to ponds built on higher ground, thereby reducing the potential for escapes.

Overflow effluent represents another avenue by which catfish could escape from ponds. Although it is unlikely due to the generally benthic nature of channel catfish and the relatively small amount of overflow effluent annually (<20% pond volume; see Criterion 2 – Effluent), it is possible for catfish to escape from the pond during an overflow event. It is important to note that ponds are located a significant distance away from rivers, and ponds drain into drainage ditches on site (Hargreaves et al. 2005b) (Simmons et al. 2006); it is therefore unlikely for any fish that do escape to reach a receiving waterbody alive.

Production of channel catfish is accomplished in phases, necessitating the movement of fish between culture units (Tucker et al. 2004). Channel catfish fry are stocked into nursery ponds from a hatchery and then harvested and stocked into foodfish production ponds. At harvest, foodfish are graded, loaded into transport trucks, and hauled to a processing plant (Tucker et al. 2004). Escape of fish from harvesting seines or loading baskets only results in accidental transfer to an adjoining pond on the facility. Hauling units do not require water exchanges during transport due to the short travel time to their final destination (either another pond or the processing facility), so there is no possibility of fish being released into other waterbodies.

Although overall escape volume is estimated to be low for all phases, the transition between the hatchery and nursery phase, as well as the nursery to growout phases, likely accounts for the highest number of escapes. Fry can be washed down the drains of hatching/rearing troughs as they are drained to move fry within the hatchery or out to nursery ponds (Tucker et al. 2004). Similarly, nursery ponds are drained between each crop, and represent an escape risk during harvest for transport to growout ponds. However, the survival rate of fry (in transfer from hatchery to nursery) is expected to be low due to the resulting physical damage in the drain system, inherent fragility at this life stage, lack of parental care, and predation. The recorded survival rates of outplanted fry (67%) in nursery ponds indicate that, even under controlled conditions free from predation, mortality of fry is significant (USDA NAHMS 2010b). Nursery/fingerling ponds represented roughly 15% of total catfish production acreage in 2017 and, as mentioned before, it is unlikely for any fish that do escape to reach a receiving waterbody alive due to the use of drainage ditches—further mitigating the escape risk.

There are no regulations requiring the data collection and reporting of escaped catfish in the four major producer states (Mississippi, Alabama, Arkansas, and Texas). As a result, there are no data regarding the number of escapes in catfish aquaculture in the United States, and no reasonable estimate can be made regarding that number.

The majority of catfish ponds are static with no water discharge (including at harvest) over multiple production cycles; nursery ponds that do drain externally at harvest are a small portion of the industry, and the majority of both growout and nursery ponds discharge into drainage ditches, further mitigating the risk of escape. Therefore, the overall escape risk for channel catfish ponds is low, and results in a final score for Factor 6.1 – Escape Risk is 8 out of 10.

**Factor 6.2 Competitive and Genetic Interactions**

The channel catfish is a native North American freshwater fish whose original range extended from northern Mexico and the states bordering the Gulf of Mexico, up the Mississippi River and its tributaries, and west to the Rocky Mountains. This original distribution represents 20 states, including those currently used for catfish farming, and about half of the total land area in the continental U.S. (Hubert 1999). Channel catfish have since been widely introduced intentionally throughout most of the rest of the United States to enhance recreational sport fisheries. Therefore, channel catfish is considered “native” for the purposes of this assessment.

The major aquaculture areas of Alabama, Arkansas, Mississippi, and Texas are in the center of the native range for the fish. Fish strains now used in farming are derived from native fish caught in local waters, though all fish used in commercial production are several generations domesticated; these breeding programs have been used to improve stock. The primary traits that are selected/hybridized for are growth rate/feed conversion, disease resistance, seinability, edible yield, stress tolerance, and reproduction (Liu 2008). Studies have shown selection and hybridization to have improved feed conversion as much as 50%, as well as caused a marked improvement in the other traits (Liu 2008). These improved traits represent a competitive risk to native channel catfish and other wild fauna populations, if a wild fish were to escape.

Commercial catfish producers are supplied by private hatcheries exclusively operating for the aquaculture industry, but public and private hatcheries[7] that stock for recreation also seek

[7] Private hatcheries, such as Henneke Hatchery in Texas, advertise aggressive feeding, fast growing catfish for sale.

similar improved traits for the catfish they produce (Jackson 2004). From 2014 to 2016, over 17 million channel catfish were intentionally released for recreational stocking via private and public stocking programs, likely dwarfing the number of potential escapees (USDA NASS 2017).

The primary concern over the genetic interaction between escapees and wild fish is related to a potential reduction in fitness from the transfer of genes from cultured stocks into wild populations. Researchers have examined the genetic differences between farmed fish and wild fish to identify any differences, as well as how much introgression has or has not occurred.

Waldbeiser et al. (1997) examined the allelic differences between wild channel catfish and two commercial strains. Though the number of alleles varied within each population, the wild channel catfish population from the Mississippi River had more alleles than either of the two commercial strains. A commercial strain of interest (USDA 103s) had a subset of alleles at each locus, suggesting that the commercial strain was simply a "subset" of the wild fish population. Further, Padhi (2013) used phylogenetic analyses to reveal the existence of six distinct matrilineal genetic lineages of channel catfish in the United States. Channel catfish from the Mississippi River and its tributaries, southwest Gulf Coast drainages, and a small percentage of individuals sampled from the Pearl River (Mississippi) and Alabama River (Alabama) all share the same lineage.

But considering the significant genetic improvement (for production) of farmed channel catfish lines, the risk of genetic introgression is high even though they may share the same lineage as wild catfish. Simmons et al. (2006) evaluated the potential impact of domesticated channel catfish on the genetic make-up of wild channel catfish populations. Domesticated catfish were collected from 17 farms and fingerling suppliers while individuals from 14 wild populations from different watersheds were collected both upstream and downstream from domestic catfish farms. The study found that wild channel catfish populations harbored a greater level of genetic variation than their domesticated counterparts, but there was no evidence of apparent impact of domesticated channel catfish on wild populations. It was hypothesized that if large numbers of domestic catfish had been released or escaped, wild populations of catfish closer to catfish farms (proximal) would have a significantly more similar genotype to the domestic populations than would wild populations farther from the farm (distal). The results indicated that there was no significant difference in genetic distance between the proximal and distal wild populations, yet both wild populations were significantly different from the domestic populations (Simmons et al. 2006). Thus, it appears that there has been no genetic impact from farmed channel catfish on wild, native populations.

Considering the low potential escape numbers of farmed channel catfish in conjunction with the large volume of intentional stocking of channel catfish for recreation, as well as the demonstrated lack of genetic introgression in wild populations despite generations of selective breeding, escaped channel catfish pose a low risk of competition, predation, disturbance, or other impacts to wild species.

Therefore, the score for Factor 6.2 – Competitive and Genetic Interactions is 8 out of 10.

**Conclusions and Final Score**

Channel catfish is farmed in closed pond systems that either drain at harvest (nursery ponds) or do not exchange any water, even at harvest, for over 10 years on average (growout ponds). These facilities are outfitted with multiple fail-safe escape prevention devices, and the likelihood of a farmed channel catfish entering the receiving waterbody is low. This low risk of escape in conjunction with a low risk of additional competition and genetic introgression (as demonstrated by genetic studies and the nature of receiving waterbodies that were intentionally stocked with millions of domestic catfish) results in a final score of 8 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**

Disease Evidence-Based Assessment

| Pathogen and parasite parameters | Score | |
|---|---|---|
| C7 Disease Score (0-10) | 8 | |
| Critical? | NO | GREEN |

**Brief Summary**

A variety of pathogens and parasites are known to occur in catfish farming in the United States, but management practices have resulted in moderately successful mitigation of disease occurrence and losses in the industry. The ponds used to produce channel catfish are static and do not intentionally discharge water over multiple production cycles, reducing the risk of transfer of disease to wild populations. Though it is necessary to consider the potential discharge of overflow effluents (at times up to 20% of pond volume per year), such overflow generally occurs in the winter months when disease outbreaks are less common. Data from the U.S. Fish & Wildlife Service National Wild Fish Health Survey Database suggest that on-farm pathogens and/or parasites that may be transmitted to receiving waters do not amplify those found at natural or background levels. Criterion 7 – Disease scores 8 out of 10.

**Justification of Ranking**

It can be difficult to assess the risk of disease transfer from cultured fish to wild populations. The relationship among pathogens, fish, and the environment is complex and the mere presence of a pathogen does not necessarily induce clinical disease. The major bacterial diseases, fungal diseases, and parasites associated with channel catfish production are either well established in the environment or specific to the culture environment. Natural outbreaks of Enteric septicemia of catfish (ESC), columnaris, winter kill, trematodes, proliferative gill disease (PGD), gill parasites, and ich in wild populations are documented in the scientific literature. Other diseases like visceral toxicosis of catfish (VTC), channel catfish virus (CCV), and anemia are confined to catfish culture ponds. There is no historical record of disease transfer from cultured U.S. channel catfish to wild fish populations. Data from the U.S. Fish & Wildlife Service National Wild Fish Health Survey Database suggest that on-farm pathogens and/or parasites that may be transmitted to receiving waters are not amplified beyond those found at natural or background levels. Thus, the data score is 7.5 and the evidence-based assessment is used.

Report of Losses on Catfish Operations

The USDA Animal and Plant Health Inspection Service National Animal Health Monitoring System (USDA NAHMS) surveyed catfish producers in 1996, 2002, and 2009 concerning catfish health and production practices (USDA NAHMS 1997a) (USDA NAHMS 1997b) (USDA NAHMS 2003a) (USDA NAHMS 2003b) (USDA NAHMS 2010a) (USDA NAHMS 2010b) (USDA NAHMS 2010c). One of the objectives was to identify the percentage of operations that lost fish to disease. In 1996, surveyors did not separate the percentage of operations that lost fish to diseases by whether they occurred on foodfish or fingerling operations, so these responses were combined. Because most bacterial diseases were mixed infections of ESC and columnaris, surveyors also combined these two diseases as one category. Beginning with the 2002 survey, foodfish and fingerlings operations were separated, as well as losses due to ESC and columnaris. The USDA NAHMS report (2010c) compared channel catfish operators' 2002 and 2009 responses to questions concerning production and fish health practices. The results of these surveys are presented in Table 9.

**Table 9.** Percentage of U.S. catfish operations that reported lost foodfish or fry/fingerlings due to disease (- indicates no response).

| | **All Operations**[a] | **Foodfish Operations**[b] | | **Fingerling Operations**[b] | |
|---|---|---|---|---|---|
| **Disease** | **1996** (%) | **2002** (%) | **2009** (%) | **2002**[d] (%) | **2009**[e] (%) |
| ESC | 78.1[c] | 60.6 | 36.6 | 52.9 | 19.3 |
| Columnaris | -[c] | 50.4 | 39.0 | 45.2 | 17.4 |
| PGD | 19.8 | 12.7 | 13.6 | 8.9 | 0 |
| Ich | 5.2 | 4.1 | 4.9 | 5.1 | 3.8 |
| Trematodes | - | 4.3 | 4.2 | 1.9 | 1.9 |
| Winter kill | 35.8 | 32.9 | 20.6 | - | - |
| Anemia | 8.4 | 14.4 | 7.9 | - | - |
| CCV | 4.6 | - | - | 6.9 | 0 |
| Gill parasites | - | - | - | 4.0 | 1.9 |
| VTC | - | 9.7 | 5.2 | - | - |

[a] USDA NAHMS 1997a
[b] USDA NAHMS 2010c
[c] ESC/Columnaris cases combined
[d] For 2002, the question asked about fry stocked during the last 2 years that did not survive until harvest as fingerlings.
[e] For 2009, the question asked about fry stocked in 2009 that did not survive until harvest as fingerlings.

Of the eight causes of foodfish loss common to 2002 and 2009, operations reporting losses decreased for all disease causes except for a slight increase for ich (0.8% increase) and proliferative gill disease (0.9% increase). The data for fingerling losses is not as clear-cut, given the survey protocol. NAHMS surveyors in 2002 asked about fry stocked during the last 2 years that did not survive until harvest as fingerlings (equivalent to 2 years of loss). In 2009, surveyors asked about fry stocked in 2009 that did not survive until harvest as fingerlings (1 year of losses). If an assumption is made that producers lost the same amount of fish in 2001 and 2002, operations reporting losses decreased for ESC (26.5% vs. 19.3% in 2009), columnaris (22.6% vs. 17.4% in 2009), PGD (4.5% vs. 0% in 2009), and CCV (3.5% vs. 0% in 2009). There was a slight increase for ich and trematodes, similar to foodfish operations for the same periods. There were no responses by fingerling operations regarding winter kill, anemia, and VTC because these diseases occur mostly in foodfish.

This survey suggests that there has been a reduction in disease losses in channel catfish production, though the data are incomplete. There is a lack of detailed data regarding disease loss numbers, and the next USDA NAHMS survey will take place in 2019[8]. The decrease in losses from ESC may be due to the availability of Aquaflor® (as a treatment) in the 2009 survey period but not the 2002 survey. The poor economy, increased production costs, and increased competition that has led to a major reduction in acreage has also caused many producers to attempt to improve fish health management. The use of hybrid catfish may also have led to deceased disease rates because hybrids are demonstrably more disease resistant than channel catfish (Dunham et al. 2008).

**Diseases, Pathogens, and Parasites Affecting Catfish Operations**

Bacterial Diseases

Enteric septicemia of catfish (ESC) is an important infectious bacterial disease of farm-raised channel catfish. Natural fish kills in wild populations of catfish due to ESC are rare, with only two cases reported in the past 15 years (Hawke and Khoo 2004). The causative agent of ESC is a gram-negative bacterial species, *Edwardsiella ictaluri* (Hawke et al. 1981). Although channel catfish is the most susceptible to infection, blue catfish *(Ictalurus furcatus)*, white catfish *(Ictalurus catus)*, brown bullhead *(Ameiurus nebulosus)*, and walking catfish *(Clarias batrachus)* are also susceptible (Hawke et al. 1998). *E. ictaluri* has also been isolated from diseased ornamental fish such as the danio *(Danio devario)* (Waltman et al. 1985), green knife fish *(Eigemannia virescens)* (Kent and Lyons 1982), and rosy barb *(Puntius conchonius)* (Humphrey et al. 1986).

ESC was first recognized in pond-raised channel catfish in 1976 (Hawke 1979). Treatments include early intervention with approved antibiotics (Wise et al. 2004), restricting feed (Wise and Johnson 1998), and vaccination (Shoemaker et al. 1999). Though it is unclear whether these treatments are directly responsible, catfish operations have reported decreased losses of foodfish and fry/fingerlings due to ESC in recent years (USDA APHIS 2011).

Columnaris disease is one of the most common diseases of warmwater fish and infects at least 36 species of cultured and wild fish (Plumb 1999). The causative bacterium has been renamed and reclassified many times, but the current name is *Flavobacterium columnare* (Bernardet et al. 1996). This disease is either the first- or second-most reported cause of fish loss on catfish

[8] https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/nahms/nahms_aquaculture_studies

operations in the U.S., depending on year and operation type (i.e., foodfish or fingerling production) (Table 9). Although columnaris disease is often considered a secondary infection following periods of stress or infection by other parasitic or microbial agents, it can also occur as the sole causative agent (Soto et al. 2008). Treatment of columnaris typically depends on whether the infection is external or internal. Low regulatory-priority agents such as potassium permanganate, formalin, and copper sulfate have been used in attempts to control external infections. However, antibiotic therapy using medicated feed is generally recommended for all columnaris outbreaks (Wise et al. 2004).

Motile aeromonad septicemia is a disease complex caused by members of the genus *Aeromonas.* These bacteria are widespread in the aquatic environment and cause disease in wild populations as well as fish grown in ponds and recirculating systems (Thune et al. 1993). They are capable of producing disease as the sole causative agent in immunosuppressed populations or as secondary invaders (Camus et al. 1998). The disease syndrome in channel catfish is also referred to as hemorrhagic septicemia. Secondary *Aeromonas* infections have typically been a minor cause of losses in catfish operations (Table 9). However, in 2009, a virulent strain of *Aeromonas hydrophila* caused severe losses—over 3 million lbs (1,339 MT) across 48 farms—in western Alabama catfish ponds (Pridgeon and Klesius 2011). There is no information regarding whether the disease emerged across the farms or if it was transmitted from farm to farm; however, three different strains were isolated and revealed to be closely related (97% to 99% nucleotide sequence similarities) (Pridgeon and Klesius 2011). Terramycin® is labeled for use in channel catfish to treat motile aeromonad septicemias.

<u>Fungal Diseases</u>

Fungal infections caused by water molds can lead to mortalities in wild fish populations and cultured species. Most fungal pathogens cause disease when there is preexisting illness, mechanical injury, or environmental stress (Durborow et al. 2003). The most common fungal disease of cultured channel catfish is referred to as “winter kill” or “winter mortality syndrome” (Francis-Floyd 1993). The term “winter kill” should not be confused with fish losses resulting from anoxic conditions that develop in ice-covered ponds in colder northern climates. Sudden decreases in temperature combined with the presence of a significant number of pathogenic zoospores has been identified as the primary risk factor for this disease (Bly et al. 1992). Chemical treatment of saprolegniasis is ineffective once an infection is established and the efficacy and economic feasibility of preventative measures are questionable (Wise et al. 2004). Control of winter kill currently focuses on production strategies that minimize inventories of large catfish held during winter months.

<u>Parasites</u>

Proliferative gill disease (PGD) causes losses in channel catfish ponds (Gravois 1992) and has been found in wild channel catfish from the Tennessee-Tombigbee Waterway in Mississippi (Thiyagarajah 1993). Organisms resembling the PGD parasite were also found in the gills of largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis macrochirus)* in the same study. The causative agent of PGD is the myxozoan parasite *Henneguya ictaluri* (Pote et al. 2000). The organism develops in an oligochaete worm *(Dero digitata)* that releases infective actinospores that are capable of infecting the gills of channel catfish (Mitchell et al. 1998). The high mortality rate and the lack of mature spores in the host tissue indicate that catfish may be an unnatural host.

There are currently no chemotherapeutic or biological control measures for PGD; however, researchers have developed diagnostic techniques that can determine the amount of actinospores in commercial catfish ponds (Griffin et al. 2009). These assays provide an additional resource to be used in conjunction with current diagnostic and management protocols to maximize information provided to catfish producers.

Ich is a common name for the disease caused by the parasite *Ichthyophithirius multifilis*. It is also referred to as “white spot” disease because fish infected with ich may have white, raised bumps on their skin. Ich has an indirect life cycle consisting of three stages (Hines and Spira 1973). The parasite can be transmitted by a carrier fish, water source, and other animals. All freshwater fish species are susceptible to the ich parasite (Durborow et al. 1998). Catfish producers have reported losses of both foodfish and fingerlings due to ich (Table 9). Multiple treatments of formalin, copper sulfate, or potassium permanganate may be required to break the life cycle of this parasite.

Digenetic trematodes have a complex life cycle that involves multiple hosts (Hawke and Khoo 2004). A digenetic trematode identified as *Bolbophorus damnificus* has caused mortality and decreased production in channel catfish since its emergence in 1997 (Hawke and Camus 1998) (Terhune et al. 2003). Reported losses due to this trematode have remained constant from 2002 to 2009, with losses to foodfish operations being higher than fingerling losses (Table 9). But even light and moderate infections—which may go unnoticed by producers—can seriously impact farm production (Wise et al. 2008).

The final host for this trematode is the American white pelican *(Pelicanus erythorhynchos)*, while the ram’s horn snail *(Heliosoma trivolvis)* and catfish are intermediate hosts. Fish-to-fish transmission is not possible, so infected fish cannot spread the parasite to wild populations (USDA APHIS 2003). The only mechanism for the infestation to spread is through movements of the final host. There is no FDA-approved treatment for fish infested with trematodes. Prevention of trematode infestation requires reducing snail populations through a combination of chemical treatments, biological control species, and aquatic weed control (Terhune et al. 2003).

There are many protozoan parasites that infest the gill and skin surfaces of fish. The primary species that impact channel catfish production include *Trichodina, Trichophrya, Ambiphrya, Icthyobodo, Chilodonella*, and *Epistylis* and constitute the “Gill Parasites” category in Table 9. Gill parasite infestations are typically caused by high stocking rates and resulting poor water-quality conditions. These species can cause mortality by 1) blocking the flow of oxygen across gill epithelia, 2) causing gill swelling, and 3) creating ulcers that make fish more vulnerable to bacterial infections (Durborow 2003). Treatments include the use of formalin, copper sulfate, and potassium permanganate.

Viral Diseases

Channel catfish virus disease (CCVD) affects fingerlings and fry shortly after transfer from the hatchery to nursery ponds. CCVD is host-specific for channel catfish (Boon et al. 1988) and broodstock are thought to be the major source of infection to young fish (Wise et al. 1988) (Boyle and Blackwell 1991). The causal agent is a herpes virus and is present in all catfish growing regions. CCVD accounted for 1.8% to 5.8% of cases submitted to the Aquatic Diagnostic Laboratory at the Thad Cochran National Warmwater Aquaculture Center in Stoneville, Mississippi, from 1997 to 2002 (Camus 2004). Fingerling operations reported no losses to CCVD in 2009, down from 6.9% in 2002 (Table 9). Although there are no effective treatments, the severity of the disease can be minimized by limiting environmental stressors when possible.

Other Diseases

Channel catfish anemia (CCA) was originally reported in 1983 (Lovell 1983). Affected individuals are characterized by lethargy, anorexia, extreme pallor, and packed cell volumes often below 5% (Camus et al. 2014). Diagnostic records from the Aquatic Diagnostic Laboratory at the Thad Cochran National Warmwater Aquaculture Center in Stoneville, Mississippi reveal that, on average, CCA accounted for 4.7% of case submissions from 1994 to 2012 (Camus et al. 2014). USDA NAHMS survey respondents reported losses due to CCA occurred on 14.4% of foodfish operations in 2002 and 7.9% in 2009 (Table 9).

A definitive cause for CCA has not been determined. Known infectious agents, parasites, water quality, feed contaminants, or feed condition have been largely excluded (Camus et al. 2014). Investigation of iron levels in CCA-affected fish revealed values consistent with iron deficiency anemia. Experiments that administered low levels of iron either through injection or orally through feed returned iron levels to within ranges of normal controls (Camus et al. 2014).

Visceral toxicosis of catfish (VTC) is characterized by the sudden death of otherwise healthy market-sized fish and broodfish in the spring and fall. Clinical signs include several neurological conditions including erratic swimming, progressive muscular weakness, and lethargy—suggesting ingestion of a toxin. The toxin responsible for VTC has been determined to be botulinum type E, which is thought to be formed in decomposing fish in contact with *Clostridium botulinum* spores on pond sediments (Gaunt et al. 2007). Mortality events due to botulinum toxins have also been reported in several cases involving farmed salmonids (Cann and Taylor 1982) (Eklund et al. 1982) (Eklund et al. 1984) (Huss and Eskildsen 1974).

Ultimately, although the diseases affecting catfish farms and their production are well understood, there appears to be a lack of available detailed data for on-farm pathogen load or wide-scope research on transmission dynamics, particularly between farms and the environment.

There is no historical record of disease transfer from cultured U.S. channel catfish to wild fish populations. Untreated effluent during disease outbreaks can contain amplified levels of shed viruses or bacteria, and are vectors by which diseases may be transmitted from catfish ponds into the receiving waterbody; however, there have been no documented cases of pathogen transmission from freshwater catfish ponds to wild fish resulting in disease outbreaks in the United States or Europe (Kurath and Winton 2011). Aquaculture's contribution to wild disease outbreaks is difficult to ascertain due to uncertainties in biological, pathogenic, geographic, and anthropogenic factors (Kurath and Winton 2011).

In addition to the lack of evidence of impact in the literature, a review of nearly 5,000 samples and pathogen tests conducted by the U.S. Fish & Wildlife Service National Wild Fish Health Survey (NWFHS) over a 20-year period in the major producer states (Mississippi, Alabama, Arkansas, and Texas) suggests that pathogens and/or parasites that may be transmitted from catfish farms to receiving waters do not amplify those found at natural or background levels (USFWS, 2017). None of the samples tested positive for any of the above diseases affecting the catfish aquaculture industry. This may be attributed to the fact that catfish ponds rarely discharge water, as well as to the industry's effective disease management procedures.

**Disease Risk Management and Mitigation**

Catfish farmers implement measures to prevent disease occurrence and to mitigate the impacts when diseases do occur. Stringent biosecurity measures are put in place to prevent disease spread from pond to pond or from farm to farm and include disinfection of equipment, clothing, and gear, as well as the prevention of human traffic between diseased and healthy ponds (Sadler and Goodwin 2007). Ponds can be sanitized by draining, drying, and treating with lime to kill parasites, though this is rarely employed (Sadler and Goodwin 2007).

Because most diseases are endemic and present in the environment, farm management practices to mitigate disease impacts and losses are also implemented. General concepts include minimizing stress by avoiding overstocking, overfeeding, and over-handling while maximizing oxygen levels (Wise et al. 2004). In case disease does occur, free water quality testing and fish disease diagnostic services are available in the major channel catfish producing states of Mississippi, Alabama, Arkansas, and Louisiana. Producers can get tentative diagnoses and consultations on fish health management options instantaneously, and final results usually within 24 to 48 hours. The extension service provides training on fish health management issues to producers. Various publications related to diseases and water quality treatments are available to producers online through university websites or the USDA NIFA Southern Regional Aquaculture Center. Treatments can include taking fish off feed, providing medicated feeds (see Criterion 4 – Chemicals), or letting the disease run its course (Wise et al. 2004). Overall, management practices have resulted in a relatively low and decreasing number of operations reporting losses due to disease (See Table 9).

**Conclusions and Final Score**

A variety of pathogens and parasites are known to occur in catfish farming in the United States, but management practices have resulted in moderately successful mitigation of disease occurrence and losses in the industry. The ponds used to produce channel catfish are static and do not intentionally discharge water over multiple production cycles, reducing the risk of transfer of disease to wild populations. Though it is necessary to consider the potential discharge of overflow effluents (at times up to 20% of pond volume per year), such overflow generally occurs in the winter months when disease outbreaks are less common. Data from the U.S. Fish & Wildlife Service National Wild Fish Health Survey Database suggest that on-farm pathogens and/or parasites that may be transmitted to receiving waters do not amplify those found at natural or background levels. Therefore, the score for Criterion 7 – Disease is 8 of 10.

## Criterion 8X. Source of Stock – independence from wild fisheries

***Impact, unit of sustainability and principle***

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

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

**Brief Summary**

100% of broodstock and juveniles in U.S. channel catfish aquaculture are produced in hatcheries. Therefore, there is no dependence on wild stocks and the score for Criterion 8X – Source of Stock is 0 out of –10.

**Justification of Ranking**

Commercial breeding operations maintain large populations of domesticated broodstock. In 2009, breeding operations reported that 83% of their broodfish came from fish originating from foodfish production ponds (USDA NAHMS 2010b). The remaining broodfish were blue catfish (3.6%) purchased from blue catfish breeders or as existing broodfish stocks (13.4%) purchased from other farms. Because commercial producers do not add outside lines in their selective breeding program, the only use of wild channel catfish broodstocks is limited to research laboratories for supplementing the genetic variation in improved lines.

Research related to the production of hybrid catfish has been ongoing since the late 1960s. The primary constraint to commercial production of the hybrid has been the lack of reliable, cost-effective methods for producing sufficient quantities of fry. However, refinements of hatchery techniques and general superiority of hybrids relative to purebred channel catfish have spurred renewed interest in the use of hybrids. The hybrid generally performs better than either parent species for several important production traits including survival, growth, disease resistance, and harvestable (i.e., edible) yield. The most commonly produced hybrid is produced by crossing a female channel catfish and a male blue catfish. The percentage of catfish farms that stocked channel x blue hybrid catfish increased from 2% in 2002 to 21% in 2009 (USDA NAHMS 2010c).

Because 100% of juveniles originate from hatcheries and no wild collection occurs, the final score for Criterion 8X – Source of Stock is –0 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" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

**Criterion 9X Summary**

| Wildlife and predator mortality parameters | Score | |
|---|---|---|
| C9X Wildlife and predator mortality Final Score (0-10) | -2 | |
| Critical? | NO | GREEN |

**Brief Summary**
Although non-lethal predator deterrents are used extensively, lethal control is known to occur. The principal predator species on U.S. channel catfish farms is the double-crested cormorant. Several government studies have shown that mortalities resulting from catfish producers are not having a population-level effect on cormorants, and the explosive population growth of double-crested cormorants can partly be attributed to the existence of catfish ponds. The federal Aquaculture Depredation Order that authorized the take of cormorants without permits was vacated in 2016, and is likely to result in significantly reduced lethal take of cormorants. In addition, catfish ponds are not pristine bottomland hardwood forest and are significantly less biodiverse than original habitat, but they do provide considerable habitat to a wide range of taxa including reptiles, amphibians, and mammals that would otherwise not exist under previous agriculture land. The impact of catfish aquaculture on wildlife can be considered low, so the score for Factor 9X – Wildlife and Predator Mortalities is –2 out of –10.

**Justification of Ranking**
The concentration of potential prey items in channel catfish ponds provides foraging opportunities for a variety of mammalian and avian predators. Excluding these predators with techniques widely employed in other pond-farming industries, such as nets, barriers, or enclosures, is impractical and prohibitively expensive given the typical size of catfish farms (e.g., in 2010, the average was 116 acres (47 ha)). Instead, partial exclusionary devices (like wires and streamers strung over ponds) and deterrents (like noise cannons or harassment patrols) are widely used (Tucker et al. 2008).

Birds are the most significant predators in channel catfish culture, although their impact varies by species. In 2009, catfish farmers reported that 54% of foodfish loss and 48% of fingerling loss was due to predation, almost entirely attributed to birds (USDA NAHMS 2010a). Wading birds, such as the great egret *(Ardea alba)*, most often prey on dead or weakened catfish around pond margins, so their economic impact appears to be minimal. Great blue heron *(Ardea herodius)* can consume significant numbers of healthy catfish fingerlings when the fish are feeding near the surface.

The double-crested cormorant *(Phalacrocorax auritas)* (DCCO) is the primary avian predator preying on channel catfish stocks (Reinhold and Sloan 1999) (Wywialowski 1999). In the early years of the catfish industry (1960s through 1980s), DCCO populations were low. However, the expansion of the channel catfish industry resulted in significant growth of the DCCO populations and an alteration of the wintering habits of the birds to exploit this new food source (Glahn et al. 1999). Once the industry became established and DCCO populations were expanding rapidly, it was too late and too expensive to consider alternative pond locations. Annual losses due to anti-predation costs and the value of fish lost have been estimated at $6 million to $12 million (Dorr et al. 2012).

From 1975 to 2002, the breeding DCCO population was increasing at a statistically significant rate of approximately 7.5% per year (Sauer et al. 2003). In northwest Mississippi, wintering DCCO increased by nearly 225% from 1989 to 2002 (USFWS 2003). In 2009, the U.S Fish and Wildlife Service (USFWS) estimated that the continental population of DCCO was approximately 2 million birds (USFWS 2009). About 70% of the continental population impacts channel catfish farming in the southeast United States. Glahn et al. (1999) found that DCCO predation of channel catfish farms has likely increased winter survival and contributed to their population growth.

The USFWS has the primary statutory authority to manage bird populations in the United States. As DCCO populations expanded during the 1970s to 1990s, fish and wildlife managers (and members of the public) began to associate these birds with a variety of resource conflicts, including adverse effects on other bird species through habitat destruction and nest competition, declines in fish populations associated with DCCO predation, destruction of vegetation where DCCOs nest, predation on federal-listed fish species, and economic losses to aquaculture producers, commercial fisheries, and fishing-related businesses (USFWS 2003).

USDA Animal and Plant Health Inspection Service—Wildlife Services (APHIS WS) personnel evaluate requests for anti-predation assistance from catfish farmers and typically recommend an integrated management approach, which could include providing a recommendation to the USFWS for a depredation permit. Channel catfish producers use a combination of lethal and non-lethal techniques to reduce predation by DCCO. When large numbers of birds are involved, lethal methods are not effective or cost-efficient because the birds that leave a site are replaced by others. Non-lethal harassment techniques become ineffective if not reinforced by lethal take. Although APHIS WS provides recommendations for the number of birds to take, the responsibility of issuing the permit and the number of birds to take rests solely with USFWS.

The USFWS began issuing depredation permits to take DCCO beginning in 1986. Applicants have to file an application that contains information on 1) where the depredation will be occurring, 2) the crops being injured, 3) the extent of injury, and 4) the species of migratory birds causing the injury. In 1998, the USFWS issued an aquaculture depredation order authorizing freshwater aquaculture producers in 13 states to take DCCO without a federal depredation permit when the birds were committing predation to aquaculture stocks.

Reporting is a requirement of depredation permits and the aquaculture depredation order. Individuals and agencies are required to report annually the number of DCCO taken to the USFWS for review. For 2004 to 2007, the annual number of DCCO taken under the aquaculture depredation order and depredation permits in 24 states was only 1.3% of the estimated continental population of DCCO; this equates to roughly 27,000 birds.

The USFWS concluded in 2003 (USFWS 2003) that:

> *"Current management practices (shooting, egg oiling, and harassment) had no significant impact on regional or continental DCCO populations."*

This was reaffirmed in 2009 (USFWS 2009) when the USFWS stated that:

> *"Given the limits on control, frequent population monitoring, and our review of annual reports and proposed control activities, we are confident that continued operations under the depredation orders will not threaten the long-term conservation of DCCO populations."*

The federal Aquaculture Depredation Order was vacated in May 2016, so producers are currently required to obtain a depredation permit before utilizing lethal means to dispatch cormorants (USFWS 2017). According to Dr. Brian Dorr of the USDA, this is likely to significantly reduce the lethal take of cormorants (pers. comm., May 2017). The USFWS does not intend to reinstate the order (USFWS 2017).

In addition, catfish ponds are not pristine bottomland hardwood forest and are significantly less biodiverse than original habitat, but they do provide considerable habitat to a wide range of taxa including reptiles, amphibians, and mammals that would otherwise not exist under previous agriculture land. In general, this wildlife is not considered a problem (pers. comm., Dr. Brian Dorr, May 2017). In rare cases, digging by muskrats may result in structural damage to pond levees, and farmers will turn to potentially lethal trapping and removal (pers. comm., Dr. Brian Dorr, May 2017).

**Conclusions and Final Score**

Although some animals are killed in predation-prevention efforts, federal and state regulations are based on risk assessment, and legal take has no overall impact on predatory populations. Effective management and prevention measures limit mortalities to those necessary to reinforce nonlethal methods, though data indicate that mortalities have historically occurred beyond "exceptional cases." When considering the demonstrated lack of population level impacts to cormorants in conjunction with the vacated federal depredation order, as well as the habitat benefits provided to a wide variety of wildlife, the impact of catfish aquaculture on wildlife is mitigated and can be considered low. The final score for Criterion 9X – Wildlife and Predator Mortalities is –2 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 secondary species parameters | | Score | |
|---|---|---|---|
| F10Xa International or trans-waterbody live animal shipments (%) | | 9 | |
| F10Xb Biosecurity of source/destination | | 7 | |
| **C10X Escape of secondary species Final Score** | | **-0.30** | **GREEN** |

**Brief Summary**
The primary catfish hatcheries are located in Mississippi and Arkansas, and they supply fingerlings to the major producer states of Mississippi, Alabama, and Arkansas. The majority of fingerlings are not shipped to different waterbodies, though some (< 10%) trans-waterbody shipments do occur. The biosecurity of both fingerling production facilities and recipient growout catfish ponds is relatively high, consisting of static ponds with screened drains and no intentional water discharge, though ponds may overflow and are also susceptible to unintentional escape/transfer of organisms by vectors such as birds. The final score for Criterion 10X – Escape of Unintentionally Introduced Species is –0.30 out of –10.

**Justification of Ranking**
Factor 10Xa International or trans-waterbody live animal shipments
Because all channel catfish farmed in the U.S. are sourced from U.S. hatcheries, the U.S. channel catfish industry is not reliant on international shipments. Communication with industry experts indicate that less than 10% of the industry is reliant on trans-waterbody live animal shipments of fingerlings (juveniles) (pers. comm., Carole Engle, December 2016). The majority of production occurs in Mississippi, Alabama, and Arkansas; accordingly, several large-scale hatcheries in Mississippi and Arkansas supply fingerlings to nearly all producers in those three states; a small percentage (< 10%) of these fingerlings are shipped to farms in a different watershed as their origin, such as Texas (4.8% of foodsize catfish sales in 2016), where the majority of fingerlings are sourced from out of state (Treece 2017). This results in a score of 9 out of 10 for Factor 10Xa.

Factor 10Xb Biosecurity of source/destination
Both the source and destination of fingerling catfish are static ponds with screened drains and no intentional water discharge over multiple production cycles. However, seasonal rainfall can result in potentially significant overflow discharge, allowing organisms to exit the ponds. Additionally, open-air ponds, particularly without robust wildlife exclusion, allow for the

possibility that such organisms may be transferred from pond to pond, or from on-farm to off-farm through phenomena such as bird predation and subsequent defecation. Therefore, the score for Factor 10Xb for both source and destination of live shipments is 7 out of 10.

**Conclusions and Final Score**

Less than 10% of catfish are shipped between watersheds in the U.S. Although ponds may overflow and are also susceptible to unintentional escape/transfer of organisms by vectors such as birds, pond water is typically not discharged outside farm boundaries for multiple production cycles or several calendar years. These two factors result in the final deductive score of –0.3 out of –10 for C10X – Escape of Unintentionally Introduced Species.

# Overall Recommendation

The overall recommendation is as follows: GREEN

The overall final score is the average of the individual criterion scores (after the three 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**

*Channel catfish (Ictalurus punctatus) and channel catfish x blue catfish hybrids (Ictalurus punctatus X Ictalurus furcatus)*

**United States (US)**

Ponds

| Criterion | Score | Rank | Critical? |
|---|---|---|---|
| C1 Data | 8.41 | GREEN | |
| C2 Effluent | 8.00 | GREEN | NO |
| C3 Habitat | 6.67 | GREEN | NO |
| C4 Chemicals | 9.00 | GREEN | NO |
| C5 Feed | 7.56 | GREEN | NO |
| C6 Escapes | 8.00 | GREEN | NO |
| C7 Disease | 8.00 | GREEN | NO |
| | | | |
| C8X Source | 0.00 | GREEN | NO |
| C9X Wildlife mortalities | –2.00 | GREEN | NO |
| C10X Secondary species escape | –0.30 | GREEN | |
| **Total** | **53.33** | | |
| **Final score (0-10)** | **7.62** | | |

OVERALL RANKING

| | |
|---|---|
| Final Score | 7.62 |
| Initial rank | GREEN |
| Red criteria | 0 |
| Interim rank | GREEN |
| Critical Criteria? | NO |

| FINAL RANK |
|---|
| **GREEN** |

## Acknowledgements

*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.*

*A quick review of the References section will reveal four names that have made significant contributions to the scientific knowledge base related to the environmental sustainability of U.S. channel catfish culture. These scientists are Dr. Claude Boyd, Dr. Craig Tucker, Dr. John Hargreaves, and Dr. Carole Engle. Much of their work was initiated prior to the interest of governmental agencies or the environmental community in this subject. Their published works and the work of their graduate students are the basis for a large component of this report and Seafood Watch would like to thank them for graciously reviewing this report for scientific accuracy.*

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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[9] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

Seafood Watch will:

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

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

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

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

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

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

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

# Appendix 1 - Data points and all scoring calculations

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

## Criterion 1: Data quality and availability

| Data Category | Data Quality (0-10) |
|---|---|
| Industry or production statistics | 10 |
| Management | 10 |
| Effluent | 10 |
| Habitats | 7.5 |
| Chemical use | 7.5 |
| Feed | 7.5 |
| Escapes | 5 |
| Disease | 7.5 |
| Source of stock | 10 |
| Predators and wildlife | 7.5 |
| Secondary species | 10 |
| Other – (e.g. GHG emissions) | n/a |
| **Total** | **90** |

| | | |
|---|---|---|
| **C1 Data Final Score (0-10)** | **8.409090909** | **GREEN** |

## Criterion 2: Effluents

Effluent Evidence-Based Assessment

| | | |
|---|---|---|
| **C2 Effluent Final Score (0-10)** | **8** | **GREEN** |
| Critical? | NO | |

## Criterion 3: Habitat

**Factor 3.1. Habitat conversion and function**

| | |
|---|---|
| F3.1 Score (0-10) | 7 |

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

| | |
|---|---|
| 3.2a Content of habitat management measure | 3 |
| 3.2b Enforcement of habitat management measures | 5 |

| | | |
|---|---|---|
| **3.2 Habitat management effectiveness** | **6** | |

| | | |
|---|---|---|
| **C3 Habitat Final Score (0-10)** | **7** | **GREEN** |
| Critical? | NO | |

# Criterion 4: Evidence or Risk of Chemical Use

| Chemical Use parameters | Score | |
|---|---|---|
| C4 Chemical Use Score (0-10) | **9** | |
| **C4 Chemical Use Final Score (0-10)** | **9** | **GREEN** |
| Critical? | NO | |

# Criterion 5: Feed

### 5.1. Wild Fish Use

| Feed parameters | Score |
|---|---|
| **5.1a Fish In : Fish Out (FIFO)** | |
| Fishmeal inclusion level (%) | 1 |
| Fishmeal from by-products (%) | 25 |
| % FM | 0.75 |
| Fish oil inclusion level (%) | 1 |
| Fish oil from by-products (%) | 10 |
| % FO | 0.9 |
| Fishmeal yield (%) | 22.5 |
| Fish oil yield (%) | 5 |
| eFCR | 2.2 |
| FIFO fishmeal | 0.07 |
| FIFO fish oil | 0.40 |
| **FIFO Score (0-10)** | **9.01** |
| Critical? | NO |
| **5.1b Susutainability of Source fisheries** | |
| Sustainability score | -5 |
| Calculated sustainability ajustment | -0.40 |
| Critical? | NO |
| **F5.1 Wild Fish Use Score (0-10)** | **8.61** |
| Critical? | NO |

### 5.2 Net protein Gain or Loss

| | |
|---|---|
| **Protein INPUTS** | |
| Protein content of feed (%) | 30 |
| eFCR | 2.2 |
| Feed protein from fishmeal (%) | |
| Feed protein from EDIBLE sources (%) | 91.05 |
| Feed protein from NON-EDIBLE sources (%) | 8.95 |
| **Protein OUTPUTS** | |
| Protein content of whole harvested fish (%) | 14.9 |
| Edible yield of harvested fish (%) | 45 |
| Use of non-edible by-products from harvested fish (%) | 90 |
| Total protein input kg/100kg fish | 66 |
| Edible protein IN kg/100kg fish | 60.09 |
| Utilized protein OUT kg/100kg fish | 25,71 |
| **Net protein gain or loss (%)** | -57.22 |
| Critical? | NO |
| **F5.2 Net protein Score (0-10)** | **4** |

### 5.3. Feed Footprint

| | |
|---|---|
| **5.3a Ocean Area appropriated per ton of seafood** | |
| Inclusion level of aquatic feed ingredients (%) | 2 |
| eFCR | 2.2 |
| Carbon required for aquatic feed ingredients (ton C/ton fish) | *69.7* |
| Ocean productivity ( C) for continental shelf areas (ton C/ha) | *2.68* |
| **Ocean area appropriated (ha/ton fish)** | 1.14 |
| **5.3b Land area appropriated per ton of seafood** | |
| Inclusion level of crop feed ingredients (%) | 92.5 |
| Inclusion level of land animal products (%) | 5 |
| Conversion ratio of crop ingedients to land animal products | *2.88* |
| eFCR | 2.2 |
| Average yield of major feed ingredient crops (t/ha) | *2.64* |
| **Land area appropriated (ha per ton of fish)** | 0.89 |
| **Total area (Ocean + Land Area) (ha)** | 2.04 |
| **F5.3 Feed Footprint Score (0-10)** | 9 |

### Feed Final Score

| | | |
|---|---|---|
| **C5 Feed Final Score (0-10)** | **7.56** | **GREEN** |
| Critical? | **NO** | |

## Criterion 6: Escapes

| | | |
|---|---|---|
| 6.1a System escape Risk (0-10) | 8 | |
| 6.1a Adjustment for recaptures (0-10) | 0 | |
| **6.1a Escape Risk Score (0-10)** | **8** | |
| **6.2. Competitive and genetic interactions score (0-10)** | **8** | |
| **C6 Escapes Final Score (0-10)** | **8** | **GREEN** |
| Critical? | **NO** | |

## Criterion 7: Diseases

| | | |
|---|---|---|
| Disease Evidence-based assessment (0-10) | 8 | |
| Disease Risk-based assessment (0-10) | | |
| C7 Disease Final Score (0-10) | **8** | **GREEN** |
| Critical? | NO | |

## Criterion 8: Source of Stock

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

## Criterion 9X: Wildlife and predator mortalities

| | | |
|---|---|---|
| C9X Wildlife and Predator Score (0-10) | **-2** | |
| **C9X Wildlife and Predator Final Score (0-10)** | **-2** | **GREEN** |
| Critical? | NO | |

## Criterion 10X: Escape of unintentionally introduced species

| | | |
|---|---|---|
| F10Xa live animal shipments score (0-10) | 9.00 | |
| F10Xb Biosecurity of source/destination score (0-10) | 7.00 | |
| **C10X Escape of secondary species Final Score (0-10)** | **-0.30** | **GREEN** |
| Critical? | n/a | |