Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Channel Catfish, U.S. Farmed
Ictalurus punctatus

(illustration copyright by Joseph R. Tomelleri)

Final Report
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About Seafood Watch® and the Seafood Reports

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 the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.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 Choice", "Good Alternative", 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® Fisheries 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 (831) 647-6873 or emailing seafoodwatch@mbayaq.org.

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Executive Summary

Channel catfish (*Ictalurus punctatus*) have been introduced around the world and are widely cultivated in the United States as a food fish. Native to the U.S. and other parts of North America, catfish are the largest volume and dollar aquaculture species in the U.S., and consumption has be increasing over the past 20 years. Catfish are omnivorous and can survive on very low levels of fishmeal, with inclusion rates rarely topping 4%. Aquaculture facilities are most often situated on old agricultural land in shallow ponds. Catfish are harvested by seine from these ponds. Ponds require infrequent draining, and, when draining occurs, better management practices (BMPs) are in place to control environmental impacts. Catfish production has a low risk of fish escapes or disease transfer to wild stocks because ponds are contained. Very little information exists on the population structure of the native, wild catfish stock, however, so it is difficult to quantify the effects of escaped fish on wild populations. Furthermore, native populations have been and continue to be highly disturbed by introduction and stocking programs sponsored by federal, state, and local governments, making it difficult to identify escapees from stocked fish. Management exists for catfish production, but is scattered among local, state, and federal agencies. Although local regulations are generally considered effective, there is, as several panels have echoed, an ongoing need to create a more comprehensive management regime at the national level.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	Low	Moderate	High	Critical
Use of Marine Resources	√			
Risk of Escapes to Wild Stocks		√		
Risk of Disease/Parasite Transfer to Wild Stocks	√			
Risk of Pollution and Habitat Effects	√			
Management Effectiveness	√			

About the Overall Seafood Recommendation:

- A seafood product is ranked "**Avoid**" if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.
- A seafood product is ranked "**Good Alternative**" if the five criteria "average" to yellow (Moderate Conservation Concern) OR if the "Status of Stocks" and "Management Effectiveness" criteria are both of Moderate Conservation Concern.
- A seafood product is ranked "**Best Choice**" if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.

Overall Seafood Recommendation:

Channel catfish, farmed: **Best Choice** | Good Alternative | Avoid

Introduction

Basic Biology
The channel catfish (*Ictalurus punctatus*) is indigenous to the United States Southeast, ranging form the Gulf States through the Mississippi Valley, North to Canada and South to Mexico (Tucker 2000). However, today the channel catfish can be found nationwide as it has been introduced widely as a sportfish in nonnative rivers and lakes (CA, NV, CO, etc). The channel catfish has also been introduced worldwide to 32 countries mainly for aquaculture purposes (FAO Database on Introductions of Aquatic Species, http://www.fao.org/figis/servlet/introsp), but is not known to be produced on a commercial scale in those countries (Craig Tucker, pers. comm.). There are 39 species of catfish in North America, six of which have potential for commercial production: channel (*Ictalurus punctatus*), blue (*I. furcatus*), white (*I. catus*), black bullhead (*I. melas*), brown bullhead (*I. nebulosus*), yellow bullhead (*I. natalis*), and flathead catfish (*Pylodictis olivaris*). The channel catfish, however, is the only commercially-cultivated catfish species (Wellborn 1988).

In the wild, channel catfish prefer clear water habitats with gravel, sand, or rubble bottoms in streams, lakes, and ponds, and will tolerate mud-bottomed habitats. Although they are primarily a freshwater species, they can also survive in brackish water. They feed near the bottom on plant and animal material, consuming snails, crawfish, green algae and other aquatic plants, seeds, and small fish. Catfish will also feed on terrestrial insects, and, on a rare occasion, birds. In the wild, adult catfish will get up to 75% of their food from consuming fish. They feed visually as well as by using taste buds that cover their entire body. Their maximum age in the wild is 40 years, their maximum size is 58 lbs, and they mature at 3 years old. Channel catfish reach 1 lb at 2-4 years old and most wild catfish are caught at 2-3 lbs. Farm-raised catfish are harvested at 2 years old and 1¼ lb. Spawning in the wild occurs between February and August. Adult males build nests in holes, undercut banks, hollow logs, or rocks. Spawning occurs once per year, and females each produce 3,000-4,000 eggs per pound of body weight. The eggs hatch in 5-10 days, and attached yolk sacs feed fry for 2-5 days until they are ready to eat on their own (Wellborn 1988).

Native Wild Populations
Channel catfish have been stocked, for recreational purposes, in lakes and reservoirs across the U.S., since the 1920s. This practice has resulted in the spread of the species to many areas where it was not native (Clapp 1929; Hargreaves 2002). Studies on the health of individual metapopulations of catfish have been limited. Jackson (2004) raises concerns that stocked catfish may impact wild populations through competition and loss of genetic variation. Furthermore, Cloutman et al. (1999) found that stocked fish outperform wild, native fish.

Wild Populations

Populations of wild catfish can be divided for management purposes in two ways: as a single management unit for lakes and ponds, where movement is limited by the boundaries of the water body; or as a larger, multi-state management unit for rivers (Jackson 2004), each of which must be assessed individually. Due to the number of individual management units, there is no single assessment of the total wild population. There are, however, a number of individual studies, although none of them are true stock assessments. Amongst the studies available, stock health ranged from exploitation rates well below those needed to meet F_{BMSY} (Gerhardt and Hubert 1991) to a spawning potential ratio (SPR) of only 10-20% (Spilke et al. 2002). These results indicate that there are large variations in stock health between management units.

Status of Introduced Channel Catfish

The Database on Introductions of Aquatic Species (http://www.fao.org/figis/servlet/introsp) raises concerns over the potential impact of channel catfish on native fish. One of the few documented examples is the Yaqui River catfish, whose endangered status is exacerbated by actual and possible interbreeding with channel and blue catfish, neither of which are native to the region (USFWS 1994). The ability of channel catfish to establish itself in a range of habitats (see FAO FIGIS), as well as their ability to survive well in disturbed environments (Jackson 2005) means that there is potential for channel catfish to be a successful invader.

Wild Commercial Fishery

The fishery for wild channel catfish is small compared to most marine fisheries. Carlander (1954) reports that, at one time, the fishery landed over 1400 metric tons (mt) annually, but landings dropped to just over 500 mt by the 1950s. Jackson (2004) states that "currently, there is little full time commercial fishing for catfish in these (Tyus and Saunders) and other systems in North America." Furthermore, Brown et al. (1996) states that the fishery has been reduced to an artisanal fishery. In some localities, however, the commercial fishery for catfish is the dominant fishery in that body of water. Out of 8 total studies with exploitation rates, four studies calculated commercial exploitation rates, all which showed commercial exploitation was higher than recreational exploitation (Timmons 1999). Fishermen took approximately 404.8 mt of wild catfish in 2003, valued at $471,406. The amount of wild fish taken for commercial purposes is decreasing annually, and is down from a high of nearly 1,200 mt in 1998 (NMFS commercial landings database, http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html).

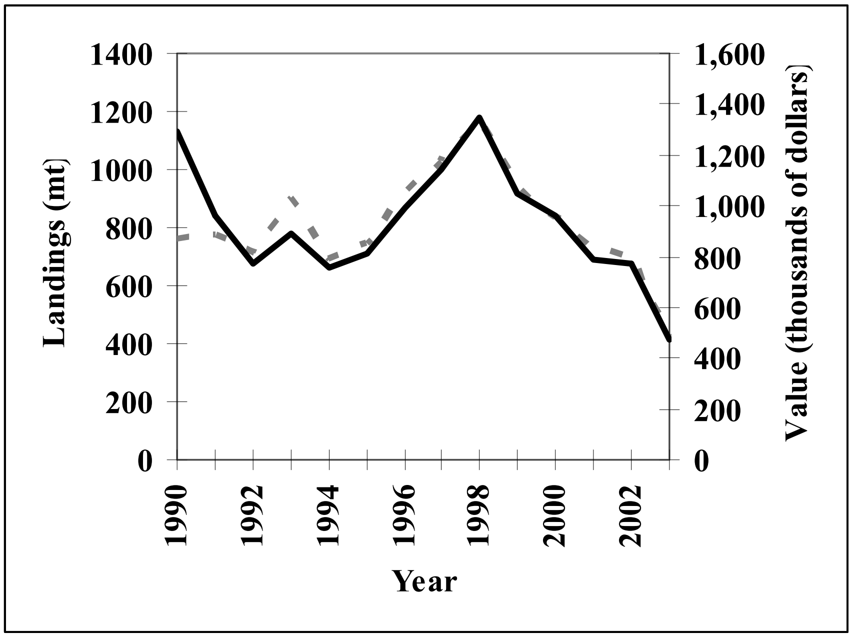

Figure 1. U.S. commercial landings of channel catfish (grey, dashed line) and value of landed fish (black solid line).

Aquaculture History

Initial attempts to widely introduce as well as propagate catfish were made by the U.S. Fish and Fisheries Commission. By the 1920s catfish were propagated in a number of state and federal hatcheries (Hargreaves 2002), and in 1929 the State of Kansas began a pond stocking program to increase recreational fishing. This introduction began the spread and culture of channel catfish throughout the United States (Clapp 1929). Commercial production emerged in Arkansas with the farmed catfish industry developing in other states somewhat independently. By the 1970s Northwest Mississippi gained the lead status in catfish production (Smitherman and Dunham 1993; Hargreaves 2002).

Current Status

Today, channel catfish are raised almost exclusively in 13 states of the U.S., with the majority of catfish raised in Mississippi, Arkansas, Alabama, and Louisiana (Table 1 Boyd et al. 2000; Jolly et al. 2001; NASS 2004). The catfish aquaculture industry is a major employer within the U.S. Southeast region. Employment estimates for Mississippi alone are 11,300 direct and indirect jobs, totaling an $845 million economic output (Jimmy Avery, pers. comm.). Most catfish farms are family farms or partnerships; approximately 88% of catfish farms are small businesses with annual sales less than $750,000 (USDA 2003). The average catfish operation has 19 ponds covering 206 acres with an average depth of 4-5 ft, with farms in Arkansas, Louisiana, and western Mississippi (25.3 ponds covering 290 acres) tending to be larger than those in Alabama and eastern Mississippi (13 ponds covering 130 acres). While ponds with a surface area greater than 20 acres represent just over 2% of all ponds, they constitute more than 50% of total pond surface area (USDA 2003).

Table 1. 2003 U.S. acres available for catfish production by area (from USDA 2003).

State	Number (Acres Intended for Utilization) During January 1 to June 30, 2003 Foodsize	Fingerlings	Broodfish	2002 Total Sales (x $1,000)	January 1, 2003, Number of Operations
Alabama*	22,900	1,500	630	76,045	231
Arkansas*	28,500	4,200	650	56,380	155
California	1,810	360	90	7,875	38
Florida	590	45	15	756	34
Georgia	700	115	60	1,411	43
Illinois	65	45	10	226	12
Kentucky	460	95	15	1,180	60
Louisiana*	8,600	1,050	170	15,812	57
Mississippi*	86,000	16,800	3,000	243,226	405
Missouri	690	590	55	1,070	31
North Carolina	1,480	140	60	3,143	46
South Carolina	70	25	20	617	13
Texas	175	105	55	2,087	30
Total (4 study States*) Percent of U.S.	146,000 (96.0%)	23,550 (93.9 %)	4,450 (92.1%)	391,463 (95.5%)	848 (73.4%)
Total U.S. (13 States)	152,040	25,070	4,830	409,828	1,155

Teichert-Coddington (1997) states that the characteristics of ideal finfish species for pond aquaculture include controlled reproduction, efficient conversion of natural foods and formulated feeds, tolerance of a broad range of water quality, low susceptibility to disease, tolerance of high density culture conditions and handling, acceptability in the market, and profitable production. Channel catfish maintain all of these attributes, making it a good option for aquaculture.

Aquaculture Systems

Facilities and culture practices vary within the southeastern United States, the leading catfish-producing region in the nation. The two major catfish producing areas are: 1) the Mississippi River Alluvial Valley, including northwest Mississippi (MS), southeast Arkansas (AR), and northeast Louisiana (LA); and 2) west-central and central Alabama (AL) (USDA 1997). Most of the production in Arkansas, Louisiana, and Mississippi are embankment ponds, also known as levee ponds, whereas the predominant pond type in Alabama is the watershed pond (Hargreaves and Tucker 2004). Overall, by operation size in acres, about 90% of commercial catfish ponds in production in the U.S. are embankment ponds, whereas the remaining 10% are watershed ponds (USDA 1997). Embankment ponds are initially filled with groundwater, while watershed ponds are first filled with storm runoff and rainfall. Both types of ponds are maintained with precipitation; however, some additional groundwater is added to embankment ponds to counter seepage and evaporation (Hargreaves and Tucker 2004).

Catfish aquaculture operations use a culture system that employs high quality feed and mechanical aeration to allow for commercial-level farming (Boyd and Queiroz 2001). Catfish production in ponds involves four phases: 1) broodfish production; 2) hatchery production; 3) fry nursery production; and 4) grow-out production. Broodfish are held in ponds and allowed to randomly mate in the spring. Spawning occurs when the water temperature rises above 70ºF. Fertilized eggs are taken to the hatchery for 5 to 15 days and raised into fry. The fry are then taken to the nursery pond where they are fed manufactured feed through the summer and fall and grow into fingerlings. Fingerlings weighing 0.7-1.4 oz are seined from nursery ponds and transferred to foodfish (grow-out) ponds in winter or spring, where they are fed manufactured feed until they reach desired size for processing, usually 1-2 lbs. In the southeastern U.S., 18-30 months is required to produce a foodsize fish. Many farmers combine all of these aspects of production whereas some farmers specialize in producing fingerlings. Catfish are typically harvested by seines from earthen ponds, although ponds that are not harvestable by seine often use cages in the ponds or harvest by hook and line. Harvests occur 15-18 months after hatching, at a size of 1.5 to 2.0 lbs (Hargreaves 2002).

Scope of the analysis and the ensuing recommendation:
This analysis encompasses farmed catfish from the U.S. that is available in the market to U.S. consumers. Basa catfish is not considered in this report. The importance of imported Basa catfish (*Pangasius hypopthalmus and P. barcourti*) in the U.S. market has grown in recent years. Basa was previously allowed to be sold as catfish, and was often marketed under names like "Cajun Boy Catfish." In order to avoid confusion for consumers, this practice was stopped, and only U.S. catfish can be sold as "catfish."

Availability of Science

Literature on catfish farming in the U.S. is replete in both peer-reviewed and grey literature. Primary literature focuses on feeding strategies and basic nutrition, pond water quality management and resulting discharge, genetic strain evaluation, and disease management (e.g., Dunham et al. 1986, Robinson and Li 1999, Boyd et al. 2000). The Southern Regional Aquaculture Center, established by Congress under the U.S. Department of Agriculture (USDA) and based at Mississippi State University, funds extensive studies and surveys regarding current trends and advances in the catfish industry. The USDA (2003) has released a report compiling statistics on many facets of catfish production from the four leading states (MS, AR, AL, LA), and the National Agricultural Statistics Survey (NASS). There are extensive grey literature resources available to catfish farmers and the public on recommendations for feeding strategies, disease recognition and control, and best management practices. Data on the health of native wild populations are scarce, although more work has been done on interactions between native and stocked wild catfish and overall population size for wild (combined native and stocked) catfish. Additionally, data on stocking practices, feeding, age and length data, and the recreational and commercial catfish fishery are available. Still, studies of the relationship between aquaculture and wild catfish populations are lacking.

Market Availability

Common and market names:
Scientific name: *Ictalurus punctatus*
Common name: Channel catfish
Market name: Farmed catfish, U.S. farmed catfish

Seasonal availability:
Farmed catfish is available year-round.

Product forms:
U.S. channel catfish are available in a variety of forms, from whole to dressed as steaks, fillets, nuggets, strips or fingers, both fresh and frozen (The Catfish Institute, www.catfishinstitute.com).

Import and export sources and statistics:
There is substantial competition in the catfish market from Vietnamese producers selling other fish marketed as catfish, such as Basa (Jolly et al. 2001). Despite this competition, consumption of channel catfish increased by 9% in the 1990s (Jolly et al. 2001). Recent trade restrictions have stopped the use of the name catfish for species other than U.S. farm-raised catfish and imposed duties on imported fish, which has eased competition (http://www.eurofish.dk). Total catfish processed continued to increase in 2003 to over 660 million pounds (NASS 2004). Despite increases in fish processed, water acres for production and price producers received per pound declined (NASS 2004).

Catfish is nearly exclusively raised in the U.S., and most catfish product is consumed in the U.S. Primary importers of U.S. farmed catfish are Canada and the United Kingdom. Imports of catfish to the U.S. in 2004, none of which were reported as channel catfish, came exclusively from China, and totaled only 123,000 lbs (NASS 2004).

Analysis of Seafood Watch® Sustainability Criteria for Farm-raised Species

Criterion 1: Use of Marine Resources

Farmed Catfish Feed Use
Channel catfish are generally omnivores in the wild, feeding near the bottom on plant and animal material, consuming snails, crawfish, seeds, small fish, and, to a lesser extent, green algae and other aquatic plants. In aquaculture, catfish are fed a pelleted floating feed containing mainly vegetarian feed with minor amounts of fishmeal and fish oil. Most farms use a 32% or 28% protein feed (USDA 2003). The vegetarian feed is composed of soybean meal, corn, cottonseed meal, wheat, rice, and bran (Cho and Lovell 2002). Catfish feeds can be made wholly vegetarian with lysine added; however, this is not yet economically feasible (Craig Tucker, pers. comm.). Due to dietary and protein needs for different life stages, the amount of fishmeal and fish oil incorporated into catfish feed is different for different stages of catfish production. Catfish fry feed contains 60% fishmeal, fingerling feed contains 12% fishmeal, and grow-out feed contains

4% fishmeal (Robinson and Brunson 2002). Because the majority of production time is spent at grow-out, this report considers only the 4% "inclusion rate" for grow-out feed. The issue of using reduction fisheries for farmed fish feed is presently in the spotlight due to the state of many of the wild populations of the small fish harvested, as well as concern over long-term sustainability given projected growth in aquaculture, generally. The fish used for fishmeal in catfish feed comes primarily from Atlantic menhaden (*Brevoortia tyrannus*), and, to a lesser extent, Atlantic herring *(Clupea harengus)* and whitefish (Robinson et al. 2001).

Feed conversion ratio (FCR)
The general definition for FCR is the amount of dry feed required to produce one unit of wet fish (Weber 2003), and estimates of FCR vary with the aquaculture operation. Catfish have a relatively high food conversion ratio, ranging from 1.6 to 2 (Boyd et al. 2000); this report uses the mode value of 1.8. Lower feed ratios can be achieved (1.3-1.5 range) in research ponds under conditions where fish are less crowded, waste less food, and live in water with better aeration than is commonly found on most commercial farms (Boyd and Tucker 1995). The feed conversion ratio is a tool used by operators to measure the efficiency of the feed system. If stocking rates are too low, efficient feeding is more difficult (because of low fish density) and increasing stocking rates generally improves the FCR, assuming there is no natural food available to fish. Available natural foods decrease FCR, and fish are best able to utilize this resource at low densities (Craig Tucker, pers. comm.). If stocking rates are too high, to the point where water quality is negatively impacted and fish are stressed, then the FCR increases (poorer efficiency).

Inclusion rates
Inclusion rates vary according to the age of the fish being raised and the feed manufacturer. Catfish fry feed contains 60% fishmeal, fingerling feed contains 12% fishmeal, and grow-out feed contains 4% fishmeal (Robinson and Brunson 2002). Fish oil is restricted to no more than 1% of feed (Robinson et al. 2000); however, some percentage of oil comes from "recycled" catfish oils (Craig Tucker, pers. comm.).

Transfer efficiency
Tyedmers (2000) estimated the transfer efficiency of wild fish to fish meal and fish oil from four different sources: South American fish meal; British Columbia herring meal; Gulf of Mexico menhaden oil; and British Columbia mixed fish oil. Conversion from whole fish to oil or meal, called reduction, depends on five characteristics: the species being reduced; the season and hence the condition of the fish at the time of capture; whether round fish or fish wastes are being reduced; the freshness of the fish upon processing; and the efficiency of the reduction plant. Conversion rates range from 16-22% for fish meal and 2-12% for fish oil. This report uses the mean for calculating the amount of wild fish per unit of fishmeal or fish oil at 19% and 7%, respectively.

Multiplying the transfer efficiency by the inclusion rate and FCR, we can calculate the amount of wild fish needed to produce one pound of farmed fish (Equation 1).

$$\left[\frac{1}{c_m}(i_m)+\frac{1}{c_o}(i_o)\right](FCR)=input:output \tag{1}$$

In Equation 1, above, c_m is the conversion from whole fish to fish meal, c_o is the conversion from whole fish to fish oil, i_m is the inclusion rate of fish meal, and i_o is the inclusion rate of fish oil. Using the inclusion rates of 4% and 1% for fish meal and fish oil, respectively, and an FCR of 1.8, the estimate of the ratio of wild fish used to produce farmed-raised catfish is approximately 0.636:1.

$$[5.263(.04)+14.2857(0.01)](1.8)=0.636 \tag{2}$$

	Conversion Efficiency
Whole fish to fish meal	19%
Whole fish to fish oil	7%
Inclusion of fish meal	4%
Inclusion of fish oil	1%
Feed Conversion Ratio	1.8

Stock Status of the Reduction Fishery

Atlantic menhaden

Atlantic menhaden is a euryhaline species that inhabits nearshore and inland tidal waters from Florida to Nova Scotia, Canada (Ahrenholz 1991). The Atlantic menhaden resource is believed to consist of a single stock or population, based on tagging studies (Nicholson 1978). This stock is fished as a reduction fishery and also as a bait fishery. The stock is managed by seasonal limits, area closures, and changes in license fees. In some states, the use of purse seines in commercial menhaden fishing operations has been prohibited. Atlantic menhaden have supported one of the United State's largest fisheries since colonial times. Menhaden have repeatedly been listed as one of the nation's most important commercial fisheries species in terms of quantity. Total menhaden landings (Gulf of Mexico and Atlantic) in 2001 were 1.7 billion lbs (816,467 mt), valued at $102.7 million (NMFS 2002). Atlantic menhaden landings for reduction in 2002 totaled 384 million lbs (174,068 mt). The Virginia Institute of Marine Science studied levels of finfish bycatch in the Atlantic menhaden fishery. Results from that study indicated that bycatch in the 1992 Atlantic menhaden reduction fishery was minimal, comprising about 0.04% by number (Austin et al. 1994).

Atlantic menhaden are not managed by a federal fishery management plan (FMP). They are instead managed by the Atlantic States Marine Fisheries Commission's (ASMFC's) Interstate Fisheries Management Plan for Atlantic Menhaden (Council 2003). The Atlantic Menhaden Technical Committee is recommending changing from a spawning stock biomass (SSB)-based target and threshold to a fecundity-based target and threshold. The Technical Committee is also recommending that the fishing mortality target and threshold be modified. Based on an overall examination of stock and fishery information, the Technical Committee has concluded that on a coast-wide basis, Atlantic menhaden are not overfished and overfishing is not occurring (NMFS 2003).

Atlantic herring

Atlantic herring in the Gulf of Maine-Georges Bank region serve as a key forage species for predatory fishes, marine mammals, and seabirds (Overholtz et al. 1991). The U.S. Atlantic herring coastal stock complex includes two distinct spawning stocks that occupy discrete areas in the Gulf of Maine and on Georges Bank/Nantucket Shoals in the summer and fall. Currently, the stock complex biomass is stable and increasing over time. It may increase in size even further in the near future under current exploitation and recruitment patterns. The preliminary catch data reports 100,676 metric tons (mt) of Atlantic herring caught during the 2003 fishing year. This amount is about 8,082 mt greater than the previous year (Gamble et al. 2004).

The predominant gear types in the Atlantic herring fishery are purse seines and mid-water trawls (mobile gear) and, to a much lesser extent, stop seines and weirs (fixed gear). The management scheme relies on an overall total allowable catch (TAC) with effort control measures (landing restrictions, Internal Water Processing quotas) to avoid overfishing the resource. The TACs were developed for specific management areas to reflect the current state of knowledge concerning migratory behavior and mixing rates of Atlantic herring. The Law Enforcement Committee noted general concern for adequate monitoring of bycatch mortality in the herring fisheries. The law enforcement report highlighted concern for the mortality of groundfish, dogfish, and marine mammals caught as bycatch in the herring fishery in the state of Maine.

The Atlantic herring fishery is jointly managed by the New England Fishery Management Council (NEFMC), the Atlantic States Marine Fisheries Commission (ASMFC), and the National Marine Fisheries Service (NMFS) (NEMFC 2001). While it was determined that the Atlantic herring stock complex is not overfished and overfishing is not occurring, the Transboundary Resource Assessment Committee (TRAC) could not reach consensus on the most appropriate model (a virtual populations analysis or a forward projection model) to assess this transboundary resource (Gamble et al. 2004).

Source of seed stock

During the early stages of industry growth in the 1970s, original farmed catfish broodstock was taken from wild catfish populations (Smitherman and Dunham 1993). However, due to the extent and ease of catfish production today, broodstock is readily available from hatchery or aquaculture facilities (Boyd et al. 2000; USDA 2003) and wild stock is not used. Many operations produce fry or fingerlings to sell to grow-out facilities (Table 2), while larger farms tend to produce their own fry (USDA 2003).

Table 2. Percentage of foodsize fish operations that stocked any fish into foodsize fish ponds, by source and size of operation (from UDSA 2003b).

	Percent Operations									
	Size of Operation (Foodsize Surface Acres)									
	1-19		20-49		50-149		150 or More		All Operations	
Source	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error
Purchased as fry from another source	5.5	(1.2)	7.8	(1.1)	17.6	(1.2)	28.3	(1.8)	17.5	(0.8)
Purchased as fingerlings from another operation	66.7	(2.1)	84.7	(1.6)	75.5	(1.4)	54.7	(2.0)	69.4	(0.9)
Produced by this operation	34.3	(2.1)	11.0	(1.5)	11.0	(1.1)	27.9	(1.8)	19.6	(0.8)

Synthesis
Use of marine resources in farming channel catfish is generally low. Husbandry methods are well established, and nearly all fry used in the aquaculture operations are produced on farms. Catfish survive well on a low fishmeal diet, and the inclusion rate of fishmeal for the grow-out stage of production is typically around 4%, resulting in substantially less than one pound of wild fish needed to produce one pound of farmed fish.

Use of Marine Resources Rank: **Low** Moderate High

Criterion 2: Risk of Escaped Fish to Wild Stocks

Frequency and Impact of Escapes
Hargreaves (2002) calls concerns of introductions of exotics from catfish productions "unwarranted" due to the fact that the largest concentration of catfish production occurs within the species' native range. Such a statement neglects, however, the impact that domesticated escapees may have on wild populations. Thus far there has been little to no analysis on the impact of escaped catfish on native, wild populations; however, due to infrequent draining and low flow-through of catfish ponds, there is no reason to believe that escapes occur with any frequency.

Most strains of farmed catfish can be traced back to the source of the original broodstock. The broodstock is well mixed from throughout the species range; however, most of the production in the four main catfish-producing states trace their strains to the Red River, Lake Texoma, Oklahoma (Smitherman and Dunham 1993). Breeding programs have resulted in domesticated catfish that grow 250% faster than wild catfish, with growth increasing by 2-6% per generation, although survival for farmed catfish remains the same as that for wild catfish (Smitherman and Dunham 1993). Domesticated catfish show some variation amongst farms as a result of interbreeding and maintenance of diversity from the original seed stock (Mickett et al. 2003). Furthermore, Broussard and Stickney (1981) found that there were differences in the timing of spawning between individual wild strains and between wild and domestic strains, although egg and larval quality was found to be the same. If escaped domesticated strains spawn before native, wild strains, it is likely that the domesticated strains would out-compete the native, wild strains. With the selection of domestic strains for increased growth and fecundity (Bondari 1984), escaped domesticated fish could produce far more offspring if survival is not compromised. Due to the widespread stocking and introduction of channel catfish throughout the U.S., it is unclear how much localized genetic diversity remains among the wild catfish population, thus escapes of genetically distinct strains from farms may not adversely impact wild populations.

Comparisons of the genetics of wild catfish stocks to farmed strains show that levels of heterozygosity in both farmed and wild stocks are high and generally similar in magnitude (Waldbieser and Bosworth 1997). While this bodes well for the overall genetic diversity of the catfish population, these similarities do not translate to ecological similarity or to a benign impact of escaped fish. Studies of escaped Atlantic farmed salmon and wild Atlantic salmon show levels of heterozygosity similar to those of channel catfish, as well as similar numbers of alleles at given loci (Crozier 2000; Skaala et al. 2004), yet a number of studies exist documenting the interactions between wild and escaped aquaculture fish (e.g., Crozier 2000, Youngson et al. 2001, and Metcalfe et al. 2003). Furthermore, Borrell (2004) found that high levels of heterozygosity and similar levels of heterozygosity do not necessarily correlate with phenotypic expression of traits. This being said, it may be more appropriate to compare phenotypic behaviors or traits between wild and farmed populations than genetic differences when considering the impact of escaped individuals.

Channel catfish have been subject to a number of genetic studies. These studies have been instrumental in advancing husbandry to improve the broodstock for farming. Selection, crossbreeding (Dunham et al. 1986), and, to a much lesser extent, genetic engineering (Dunham et al. 1983; Dunham and Smitherman 1987), are currently programs emphasized in catfish production research, but these practices are restricted to research farms (Hugh Warren, Executive Vice President, Catfish Farmers of America, pers. comm.). A selected line developed for commercial aquaculture, NWAC103, accounts for 5.9% of fish stocked (USDA 2003). The most researched interspecific hybrid and the hybrid with the most potential for implementation is the channel X blue (Jolly et al. 2001). Channel X blue hybrids grow faster in higher density ponds and are more resistant to low oxygen concentrations than other lines (Dunham et al. 1983). In high density ponds, hybrid catfish grow 3.4 times as fast as channel catfish. This faster growth rate in certain strains has been attributed to increased feed conversion efficiency and increased food consumption. Currently, this hybrid accounts for less than 2% of fish used in aquaculture (USDA 2003), and estimates put use at less than 0.2% (Jimmy Avery, pers. comm.). Because of the discrepancy in growth rate between domesticated hybrid catfish or strains of domesticated channel catfish and wild catfish, there may be cause for concern regarding domestic escapees out-competing wild fish. However, hybrids are functionally sterile, so interbreeding is not a concern (Jimmy Avery, pers. comm.).

Synthesis

The risk of escaped fish to wild stocks criterion must consider the frequency and magnitude of escapes as well as the impacts that escaped fish could have on native, wild fish. Channel catfish aquaculture presents a special case because intentional introductions and stocking of a few strains of fish are widespread within and beyond their native range and aquaculture facilities are primarily based within the native range. Frequency and magnitude of escapes from facilities is low due to the use of closed system pond culture; however, wild populations were, at one time, genetically distinct by region, so escapes, should they occur, could be a conservation concern. Wide, intentional introduction of a few strains throughout the native range may have resulted in the loss of this genetic diversity, but there have been no comprehensive studies on individual metapopulations. The risk of domesticated fish interbreeding with wild fish would have been a high concern, had stocking programs and intentional introductions not been occurring. To fully understand the impacts of escaped fish on wild populations, more research on localized genetics of wild populations needs to be done. In the context of sustainability, the burden of proof should rest on the aquaculture industry to demonstrate on impact, rather than on assuming the safety of the system. Despite the very low frequency of escapes, lack of information regarding how escaped fish would perform in the wild and lack of information on remaining populations of wild, native catfish result in some concern regarding the impact that escaped farmed fish may have on the ecosystem. The uncertainty surrounding the impacts of escapes and status of native, wild populations, therefore, results in a moderate conservation concern of the risk of escaped fish on wild stocks.

Risk of Escaped Fish to Wild Stocks Rank: Low **Moderate** High

Criterion 3: Risk of Disease and Parasite Transfer to Wild Stocks

Another risk associated with escaped farmed fish is the amplification, retransmission, or introduction of disease or parasites to wild fish stocks. This is generally more of a concern in open net pens than in closed-pond systems like those used to raise catfish. To date there is no evidence that channel catfish have introduced or translocated novel diseases or parasites to wild populations. Although disease poses the greatest risk of failed stocks for all catfish producers, as 50% of all farmed catfish mortalities are from disease (Jolly et al. 2001), the risk of these diseases and parasites being introduced or translocated to wild stocks is very low due to the nature of the closed-pond system used for all commercial production of catfish.

High fish densities, fertilization, and stressful environmental conditions due to low dissolved oxygen levels can lead to the outbreak and rapid spread of infectious diseases in channel catfish ponds. The three most prevalent disease outbreaks in foodsize fish operations in 2002 were: Enteric septicemia of catfish (ESC), which affected 60.6 percent of operations; Columnaris (*Flexibacter columnaris, Cytophaga columnaris, Bacillus columnaris*), which affected 50.4% of operations; and "winter-kill syndrome", which affected 32.9% of operations (USDA 2003). ESC is the leading bacterial disease in commercial catfish production. This disease costs the industry millions of dollars annually in fish mortalities and expenses for preventive measures and treatments. Both ESC and Columnaris are bacterial diseases that result from stressful conditions and can be controlled by preventing poor water quality conditions that can lead to outbreaks. Stocking healthy fish into ponds with carriers or stocking infected fish into ponds with healthy fish can spread ESC. Fish that survive an ESC outbreak may carry bacteria for up to 200 days. Transmission of ESC from fish to fish is likely to occur via water contamination, with bacteria shed in feces, or by cannibalism of dead or infected fish (Hawke et al. 1998). Due to the closed-system ponds used in catfish production, these types of direct interactions are unlikely to occur with wild populations and no empirical evidence of such interactions has been found. Only two FDA-approved drugs, oxytetracycline (Terramycin) and sulfadimethoxine-ormetroprim (Romet), are effective against ESC, although usage of these drugs is low. In 2002, an average of 10.65% of operations vaccinated against ESC. Of these operations, 18% of all fry were vaccinated in 2002 (USDA 2003). "Winter-kill" is a disease associated with external fungal conditions and the causes for this disease are not well understood. There are no cost-effective treatments available for fungal infections in large commercial ponds (Whitman et al. 2002).

Synthesis
There is very little risk of either the amplification or retransmission of disease or parasites from farmed catfish to wild stocks. There is no evidence of species introductions or translocations of diseases or parasites to wild stocks. This is due to the land-based, closed-systems generally used to raise catfish. Closed systems have controls on effluent release, thereby reducing any likelihood of contaminating the surrounding environment. The risk of disease transfer to wild stocks therefore rates as a low conservation concern.

Risk of Disease Transfer to Wild Stocks Rank: **Low** Moderate High

Criterion 4: Risk of Pollution and Habitat Effects

Habitat and Water Use
Catfish farms in the U.S. are usually sited on former crop or pasture land. When farms are sited on cropland, they typically replace lower-value rice or soybean farms, rather than higher quality cotton farm land. Water usage for farms ranges from 13-99 inches/year, with the high end of use constrained to the Central Valley of California. Water use in catfish farms often exceeds water use on the crops they replaced (Boyd and Tucker 1995). Ponds are managed to capture and store excess rain water and minimize need for pumped ground or surface water. Maintenance of pond depths 6-12 inches below the height of overflow structure creates 160,000-325,000 gallons of storage capacity/surface acre of pond that is available to capture rain water. This leads to reduction in the amount of overflow and amount of potential pollutants released to the environment. Capturing of rainfall and reducing overflow lowers the need for pumping additional water to compensate for evaporation and infiltration (Tucker et al. 2002).

Production, Stocking Density, and Feeding Rates
Catfish are intensively raised (Boyd and Tucker 1995). At harvest, average yield is approximately 3,570-4,460 lbs/acre (Boyd et al. 2000). The average stocking rate for fingerlings is about 6000 fingerlings per acre, with a range between 3,000 and 10,000 fingerlings per acre. Larger operations stock at higher densities (USDA 2003). During grow-out, ponds may contain an excess of 10,120 adult catfish/acre (Boyd et al. 2000).

Water quality is dependent on the ability of a pond to assimilate wastes and on the ability of the catfish to incorporate feed; thus it is directly related to stocking densities and feeding rates (Tucker et al. 2002). The amount of feed required to support high density stocking levels adds many excess organic nutrients to catfish ponds. Water quality is dependent on feeding intensity. Highest feeding rates occur in summer months, corresponding with higher growth (USDA 2003). Feeding rates often exceed 100 lbs/acre per day in the summer, with aeration (Hargreaves 2002), and decline dramatically in the winter (Tucker et al. 2002). Rates above 89-107 lbs/acre per day can cause hypereutrophic conditions with low concentrations of dissolved oxygen. Thus, controlling feeding rates can help maintain water quality (Boyd and Tucker 1995).

Lower feeding in the winter corresponds with the period of the largest runoff; therefore the majority of effluent discharge occurs in winter. With less metabolic wastes and excess food, which contribute greatly to degraded water quality, effluent discharge in the winter has minimal impact on the environment (Boyd et al. 2000). Furthermore, reduced metabolic wastes combined with reduced light leads to lower phytoplankton growth in pond water. Phytoplankton growth typically contributes more organic matter and solids than feed and metabolic wastes (Tucker et al. 2002).

Pond Water Quality

Concentrations of total phosphorus and total suspended solids are most problematic in terms of water pollution potential in catfish ponds (Schwartz and Boyd 1994). Most of the pollution is assimilated into pond sediment and remains in the sediment unless resuspension occurs. When ponds are drained, the re-suspended pollutants can be released into the environment. However, there are many management strategies in practice to minimize harmful effluent discharge. Sediment resuspension can be avoided if drains are closed after about 75-80% of pond water has been released (Boyd and Queiroz 2001).

Copper sulfate and diuron are also often added to reduce the occurrence of “off-flavoring” by blue-green algae. However, studies suggest that copper sulfate treatment will not contaminate effluent from catfish ponds because of the short time that applied copper remains in the water column; it is quickly assimilated into bottom sediment and remains there until resuspension occurs (McNevin and Boyd 2004). Furthermore, the most frequent applications of copper sulfate occur in late summer months when rainfall is minimal and pond overflow is rare (McNevin and Boyd 2004).

Catfish need dissolved oxygen levels of 15 milligrams (mg)/gallon or more to survive. Paddlewheel aerators are commonly used to generate increased dissolved oxygen and allow for intensive culture of catfish (Hargreaves 2002). These mechanical aeration systems are required to maintain adequate water quality in ponds and improve water quality by mixing water layers, thus preventing thermal stratification. By increasing oxygen concentrations, the capacity of ponds to assimilate organic nutrients through aerobic processes also increases (Boyd and Queiroz 2001).

Management Practices to Reduce Effluent Discharge

Discharge from farms comes primarily from three sources: overflow when rainfall exceeds pond storage capacity; overflow or discharge when water is pumped into catfish ponds for flushing; and discharge when ponds are drained. The first source of discharge occurs with some frequency if no measures are taken into account for rainfall. The second source of discharge occurs infrequently due to high expense, and regular flushing achieves very little improvement in pond water quality. The final source of discharge occurs infrequently for grow-out ponds, as ponds are drained decadally (Tucker et al. 2002).

Because effluent discharge is released directly into adjacent ecosystems, the environmental risk from these pollutants is dependent on the frequency and volume of discharge. Pond drainage results in the largest volumes of effluent entering the ecosystem at any one time. On average, ponds are drained every 9 years and undergo complete renovation every 11 years. Larger ponds are drained and renovated less frequently (Table 3, USDA 2003).

Table 3. Average number of years between draining or complete renovation of ponds, by size of operation (from USDA 2003).

	Operation Average Number Years									
	Size of Operation (Foodsize Surface Acres)									
	1-19		20-49		50-149		150 or More		All Operations	
Pond Management	Avg.	Std. Error	Avg.	Std. Error	Avg.	Std. Error	Avg.	Std. Error	Avg.	Std. Error
Drain	6.1	(0.3)	8.2	(0.4)	8.7	(0.2)	10.7	(0.2)	9.1	(0.1)
Complete renovation	8.7	(0.4)	10.8	(0.3)	10.3	(0.2)	12.0	(0.2)	11.0	(0.1)

The volume of effluent discharged depends on the type of pond, extent of rainfall, and management practices. Watershed ponds have more overflow than embankment ponds because they collect not only the rainwater falling directly on the pond, but also the runoff from the surrounding watershed (Tucker et al. 2002). This is especially common during seasons of high rainfall (late fall to mid spring), where the excess water is discharged to the surrounding watershed and overflow is more difficult to control. Watershed ponds have discharge equal to the volume of runoff entering the ponds from watersheds, which can vary with the ratio of watershed area to pond storage volume (Boyd et al. 2000). Additionally, because the runoff from both types of ponds is overflow, runoff water is of the same quality as surface pond water (Schwartz and Boyd 1994), indicating that it is suitable for fish habitat.

Tucker (1996) showed that the reuse of water reduces overall effluent volume. This study modeled the effect of water reuse and effluent discharge on nutrients and organic matter for ponds at 3 time intervals (1, 3, and 5 years). Results showed that harvesting fish without draining ponds between crops reduced the volume discharged each year. Reduction was greatest when ponds were managed to maintain storage potential. For ponds not managed to maintain storage potential, the models showed that using ponds for 5 years, without draining, reduced annual average waste discharge by 45% over those ponds that are drained annually. When ponds were managed for excess water storage, ponds drained every 5 years reduced annual average waste discharge by 60% over ponds drained annually.

Environmental Study
Boyd et al. (2000) conducted an environmental assessment of catfish farming in Alabama by comparing the water quality of stream water above and below commercial catfish ponds. This study concluded that catfish farm effluents do not have any adverse effects on stream water quality. However, the study did find that some local impact on the biodiversity of stream benthos may occur in areas of effluent outfall due to erosion and sedimentation.

Common Practices to Control Effluent Quality
Some ponds require partial drainage to capture fish that reside in deeper waters (Tucker et al. 2002). When water is used for several years between draining events, the volume of effluent discharge is greatly reduced (Tucker et al. 1996). In addition to biological processes of ponds that help to reduce levels of organic material and buildup of nitrogen and phosphorus, catfish farmers implement several best management practices (BMPs) to help improve water quality. Practices that lower effluent volume include lowering the water level below the level of the drain and not draining water between subsequent crops, thereby reducing the volume of water discharge (Boyd and Tucker 1995).

Synthesis
Effluent drainage from catfish farms produces a potential risk of environmental degradation of adjacent habitats. However, infrequent draining, low input of excess nutrients (excess feed), and antibiotics combined with pond management strategies effectively reduces the load of harmful effluent discharge to the surrounding environment. Due to siting of farms primarily on old agricultural land, the low frequency of drainage, and effluent consisting primarily of overflow, the conservation concern for the risk of pollution and habitat effects is low.

Risk of Pollution and Habitat Effects Rank: **Low** Moderate High

<u>Criterion 5: Effectiveness of the Management Regime</u>

Effluent Management
Standards for required permits for controlling the effluent load from some aquaculture facilities are determined federally by the Environmental Protection Agency (EPA). These effluents are subject to control by the National Pollution Discharge Elimination System (NPDES) of the Clean Water Act. Only concentrated aquatic-animal production (CAAP) facilities fall under NPDES. Most catfish farms do not fall under the designation of a CAAP. CAAP facilities are divided into cold and warm water categories, defined by the following:

> The cold water species category includes facilities where animals are produced in ponds, raceways, or other similar structures that discharge at least 30 days per year but does not include facilities that produce less than approximately 20,000 pounds per year or facilities that feed less than approximately 5,000 pounds during the calendar month of maximum feeding. The warm water species category includes facilities where animals are produced in ponds, raceways, or other similar structures that discharge at least 30 days per year, but does not include closed ponds that discharge only during periods of excess runoff or facilities that produce less than approximately 100,000 pounds per year.
> (EPA 2004)

Under these current guidelines, catfish aquaculture is exempt from federal NPDES permitting because production facilities primarily discharge only during periods of excess runoff. This means that warm water aquaculture operations with 25 acres or less of ponds do not require a permit for discharge, and by timing periods of discharge with periods of high rain, the larger facilities also do not require permits. State-specific regulations are in place in some states by their respective agencies. In most catfish-production states, there is no permitting for effluent discharge; however, permits are required when building ponds in watersheds and at processing facilities.

***State-specific regulations*:**

Mississippi: State guidelines are no more restrictive than federal guidelines, and no permitting is required for effluent discharge (MS Dept. agric. and commerce, Guidelines for Aquaculture Activities in Mississippi). Catfish are explicitly excluded from the Mississippi Aquaculture Act (1998).

Arkansas: State guidelines are no more restrictive than federal guidelines and no permitting is required for effluent discharge. The Arkansas Game and Fish Commission requires annual permits to culture aquaculture species for a cost of $15 (Arkansas Game and Fish Commission Code 42.01).

Alabama: State guidelines are no more restrictive than federal regulations and no permitting is required for effluent discharge. No fish farming permits are required. Under Alabama Department of Environmental Management (ADEM), permits are required to construct ponds located in wetlands (http://www.aces.edu/pubs/docs/A/ANR-0195/anr195fifteen.html, Alabama cooperative extension services, 2004). Processing facilities must be certified and inspected by the Alabama Department of Public Health.

Louisiana: State guidelines are no more restrictive than federal regulations and no permitting is required for effluent discharge.

Better Management Practices (BMPs)

Unlike other Concentrated Animal Feeding Operations (CAFOs), retention ponds are not feasible BMPs for controlling runoff due to the volume of water they must process (Tucker et al. 2002). There are, however, a number of other options that are suitable for aquaculture facilities, some of which are widely used:

1) **Infrequent draining of production ponds:** Water quality in ponds does not decline over time. Since the most detrimental effluents occur when re-suspended sediments are discharged, minimizing draining can provide a large reduction in the amount of contaminants entering the environment (Tucker et al. 2002).

2) **Maintenance of ponds below water capacity for rainfall collection:** Lowering water levels to accommodate for rainfall can prevent overflow and reduce the need for pumping groundwater to maintain water levels. This BMP is most effective in levee (embankment) ponds (Tucker et al. 2002).

3) **Settlement of solids before final discharge:** By holding the last 15-20% of water in ponds after draining, water quality improves drastically due to reduced settleable solids, nitrogen, phosphorus, and biochemical oxygen demand (BOD) (Tucker et al. 2002). Then the settled water is released slowly to prevent resuspension.

4) **Effective feed management:** Excess feed and metabolic wastes lead to increased nutrients and solids. The amount of feed needed to commercially produce catfish must be used in conjunction with aeration to maintain water quality (Tucker et al. 2002).

These are just a few of the many BMPs that are easily implemented. Other BMPs that have been suggested, but deemed impracticable, include wetland filtration, where the minimum wetland area would have to be 0.7 times the pond area in order to be effective during pond draining (Schwartz and Boyd 1995), and settlement ponds, which would have to be large enough to hold all pond overflow as well as most of the water in a pond during draining (Tucker et al. 2002).

Disease Treatment and Outbreaks
Terramycin and Romet-30 (medicated feeds) are used by 12.6% of farms with acreage greater than 150 acres. The overall average usage of Terramycin and Romet-30 for farms of all sizes is 7.8 and 5.3, respectively (USDA 2003). Antibiotics are also used in fry production (Hugh Warren, Executive Vice President, Catfish Farmers of America, pers. comm.). The Food and Drug Administration (FDA) regulates dosage, and requires withdrawal of catfish products from production during treatment (Table 4, www.fda.gov)

Table 4. Drugs approved for use in aquaculture and used in catfish production. (From www.fda.gov/cvm/index/aquaculture/appendixa6.htm)

Drug	**Species**	**Indication**	**Dosage regimen**	**Limitations/Comments**
Oxytetracycline monoalkyl trimethyl ammonium (Terramycin® by Pfizer, Inc.)	Catfish	Control bacterial hemorrhagic septicemia and pseudomonas disease (*A. liquefaciens*, *Pseudomonas*)	2.5 to 3.75 g/100 lb/day for 10 days	• In mixed ration • Water temperature not below 62° F • 21 day withdrawal time
Sulfadimethoxine, ormetoprim (Romet-30® by Alpharma, Inc.)	Catfish	Control enteric septicemia (*Edwardsiella ictaluri*)	50 mg/kg/day for 5 days	• In feed • 3 day withdrawal time

Formalin (Parasite-S® by Western Chemical) Formalin (Formalin-F® by Natchez Animal Supply Co. & Paracide-F® by Argent Laboratories)	All finfish	Control protozoa (*Chilodonella, Costia, Epistylis, Ichthyophthirius, Scyphidia, Trichodina* spp.) and monogenetic trematodes (*Cleidodiscus, Dactylogyrus, Gyrodactylus* spp.)	Earthen ponds: 15 to 25 µl/L, indefinitely	• Drug must not be subjected to temperature below 40° F • Do not apply to ponds when water is warmer than 80° F, when there is a heavy phytoplankton bloom, or when dissolved oxygen is less than 5 mg/L • Ponds may be retreated in 5 to 10 days if needed • Use is very rare

Depredation
Permitting for depredation is granted by the U.S. Fish and Wildlife Service and USDA Animal Damage Control (Coon et al. 1996). Predators cost catfish producers approximately 12 million dollars in 1996, with nearly 70% of farms reporting problems with wildlife predation. The three most frequently cited predators for losses at catfish farms are the Double-crested Cormorant *(Phalacrocorax auritus),* herons (*Ardea* spp.), and the Great Egret (*Egretta alba*) (Wywialowski 1999). Cormorants are controlled by shooting, disturbing night time roosts, and scaring (Dorr et al. 2004); shooting is the most common control method for all types of predators, although scaring and vehicle patrol are used nearly as often (Wywialowski 1999). Because of the rapid increase in the cormorant population, the Fish and Wildlife Service (order #63 FR 10550) in 1999 allowed aquaculture producers in 13 states (including Mississippi and Alabama) to shoot, without a federal permit, Double-crested Cormorants that threaten fish in aquaculture facilities (Wywialowski 1999; Dorr et al. 2004). Nets are not practical as a method for controlling predators due to the size of the individual ponds.

Synthesis
The U.S. currently lacks a national oversight agency for aquaculture. There are stringent federal laws governing effluent discharge, but most catfish farms have infrequent, non-overflow discharge that is not subject to NPDES permitting. Permitting for farms varies state by state, with most attention focused on processing. Regulations for predator controls, therapeutant use, and disease management are extensive. The most common means of bird depredation is through lethal means (i.e., shooting). While the high mortality of bird depredation is a conservation concern, the expansion of the Double-crested Cormorant population makes this concern less immediate. The population should, however, continue to be monitored. Furthermore, legislation is in the works for general management of aquaculture systems, especially related to permitting.

Due to the effectiveness of BMPs and the existence of relatively strong regulations, catfish management is considered highly effective, despite high bird mortalities from depredation.

Effectiveness of Management Rank:

Highly Effective | Moderately Effective | Ineffective

Overall Evaluation and Seafood Recommendation

The use of marine resources in channel catfish aquaculture production ranks as a low conservation concern because the ratio of wild fish input (in the form of fishmeal and fish oil) is substantially less than the amount of farmed fish that is produced. Additionally, because channel catfish are predominantly raised in land-based, closed systems, there is a relatively low (but unknown) risk of farmed fish escaping to potentially compete with wild stocks of channel catfish. More effort, however, needs to be put into researching the status of wild, native channel catfish to better understand any risk of escaped fish. Closed systems also reduce the risk of parasites and disease being transferred to wild stocks. Due to infrequent draining and numerous siting regulations, the risk of pollution or habitat degradation from catfish farms is also low. Basic regulation of inputs and land use are strong and effective and regulations that do exist are enforced. Management regulations that allow shooting of birds is an ongoing conservation concern that needs to be monitored closely. Overall, management is deemed highly effective. U.S farm-raised channel catfish continue to provide a low-input, relatively "clean" source of sustainable seafood and thus receive an overall seafood recommendation of "Best Choice".

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	Low	Moderate	High	Critical
Use of Marine Resources	√			
Risk of Escapes to Wild Stocks		√		
Risk of Disease/Parasite Transfer to Wild Stocks	√			
Risk of Pollution and Habitat Effects	√			
Management Effectiveness	√			

Overall Seafood Recommendation:

Channel catfish, farmed: **Best Choice** | Good Alternative | Avoid

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Scientific review does not constitute an endorsement of Seafood Watch on the part of the reviewing scientists; Seafood Watch is solely responsible for the conclusions reached in this report.

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Appendix 1: Rankings of Individual Criteria

Factor	Ranking
Estimated wild fish used to produce farmed fish (ton/ton) Green: Low use (WI:FO=0-1.1), Yellow: Moderate use (WI:FO=1.1-2), Red: Extensive use (WI:FO>2)	Green
Stock status of the reduction fishery used for feed for the farmed species Green: Underexploited, Yellow: Close to B_{MSY}, Red: Substantially below B_{MSY}	Yellow
Source of stock for the farmed species Green: Hatchery or no impact from wild collection, Yellow: Potential impact from wild collection, Red: Wild collection results in depletion	Green
Conservation Concern: Use of Marine Resources	Green

Factor	Ranking
Evidence that farmed fish regularly escape to the surrounding environment Green: Evidence of rare escapes or no evidence of escapes, Yellow: Infrequent or unknown escapes, Red: Regular and frequent escapes	Green
Status of farmed fish escaping to the surrounding environment Green: Native and genetically and ecologically similar, Yellow: Non-native but widely established or unknown, Red: Non-native and not established or native and genetically and ecologically distinct from wild stocks	Yellow
Where escaping fish is non-native: Evidence of the establishment of self-sustaining feral stocks	NA
Where escaping fish is native: Evidence of genetic introgression through successful crossbreeding Green: No evidence of introgression, Yellow: Introgressions likely or unknown, Red: Empirical evidence of introgression	Yellow
Evidence of spawning disruption of wild fish	Yellow
Evidence of competition with wild fish for limited resources or habitats	Yellow
Stock status of affected wild fish	Yellow
Conservation Concern: Risk of Escaped Fish to Wild Stocks	Yellow

Factor	Ranking
Risk of amplification and retransmission of disease or parasites to wild stocks	Green
Risk of species introductions or translocations of novel disease/parasites to wild stocks	Green
Bio-safety risks inherent in operations	Green
Stock status of potentially affected wild fish	Yellow
Conservation Concern: Risk of Disease Transfer to Wild Stocks	Green

Factor	Ranking
Effluent water treatment	Yellow
Evidence of substantial local effluent effects	Green
Evidence of regional effluent effects	Green
Extent of local or regional effluent effects	Green

Potential to impact habitats: Location	🟩
Potential to impact habitats: Extent of operations	🟩
Conservation Concern: Risk of Pollution and Habitat Effects	🟩

Factor	**Ranking**
Demonstrated application of existing federal, state, and local laws to current aquaculture operations	🟩
Use of licensing to control the location (siting), number, size, and stocking density of farms	🟨
Existence and effectiveness of "better management practices" for aquaculture operations, especially to reduce the number of fish escapes	🟩
Existence and effectiveness of measures to prevent disease and treat those outbreaks that do occur	🟩
Existence of regulations for therapeutants, such as antibiotics, biocides, and herbicides, including their release into the environment	🟩
Use and effect of predator controls in farming operations	🟥
Existence and effectiveness of policies and incentives utilizing a precautionary approach against irreversible risks to guide expansion of the aquaculture industry	🟨
Conservation Concern: Effectiveness of the Management Regime	🟩