The Safina Center
at Stony Brook University

AND

Monterey Bay Aquarium
Seafood Watch®

Bowfin

Amia calva

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Louisiana
Set gillnets

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Seafood Watch Consulting Researcher

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Seafood Watch Standard used in this assessment: Standard for Fisheries vF3

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About The Safina Center

The Safina Center (formerly Blue Ocean Institute) translates scientific information into language people can understand and serves as a unique voice of hope, guidance, and encouragement. The Safina Center (TSC) works through science, art, and literature to inspire solutions and a deeper connection with nature, especially the sea. Our mission is to inspire more people to actively engage as well-informed and highly motivated constituents for conservation.

Led by conservation pioneer and MacArthur fellow, Dr. Carl Safina, we show how nature, community, the economy and prospects for peace are all intertwined. Through Safina's books, essays, public speaking, PBS television series, our Fellows program and Sustainable Seafood program, we seek to inspire people to make better choices.

The Safina Center was founded in 2003 by Dr. Carl Safina and was built on three decades of research, writing and policy work by Dr. Safina.

The Safina Center's Sustainable Seafood Program
The Center's founders created the first seafood guide in 1998. Our online seafood guide now encompasses over 160-wild-caught species. All peer-reviewed seafood reports are transparent, authoritative, easy to understand and use. Seafood ratings and full reports are available on our website under Seafood choices. tsc's sustainable seafood program helps consumers, retailers, chefs and health professionals discover the connection between human health, a healthy ocean, fishing and sustainable seafood.

- Our online guide to sustainable seafood is based on scientific ratings for more than 160 wild-caught seafood species and provides simple guidelines. Through our expanded partnership with the Monterey Bay Aquarium, our guide now includes seafood ratings from both The Safina Center and the Seafood Watch® program.
- We partner with Whole Foods Market (WFM) to help educate their seafood suppliers and staff, and provide our scientific seafood ratings for WFM stores in the US and UK.
- Through our partnership with Chefs Collaborative, we created Green Chefs/Blue Ocean, a free, interactive, online sustainable seafood course for chefs and culinary professionals.
- Our website features tutorials, videos, blogs, links and discussions of the key issues such as mercury in seafood, bycatch, overfishing, etc.

Check out our Fellows Program, learn more about our Sustainable Seafood Program and Carl Safina's current work at www.safinacenter.org .

The Safina Center is a 501 (c) (3) nonprofit organization based in the School of Marine & Atmospheric Sciences at Stony Brook University, Long Island, NY. www.safinacenter.org admin@safinacenter.org | 631.632.3763

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 Watch Assessment. Each assessment 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." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, 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 assessments 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 Watch assessments in any way they find useful.

Guiding Principles

The Safina Center and Seafood Watch define sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

Based on this principle, Seafood Watch and the Safina Center have developed four sustainability **criteria** for evaluating wild-catch fisheries for consumers and businesses. These criteria are:

- How does fishing affect the species under assessment?
- How does the fishing affect other, target and non-target species?
- How effective is the fishery's management?
- How does the fishing affect habitats and the stability of the ecosystem?

Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and **rating**

Once a rating has been assigned to each criterion, we develop an overall recommendation. Criteria ratings and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide and the Safina Center's online guide:

Best Choice/Green: Are well managed and caught in ways that cause little harm to habitats or other wildlife.

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

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

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

Summary

This report provides a recommendation for bowfin (*Amia calva*) caught in the freshwaters of Louisiana, United States. Bowfin are primarily caught with gillnets in shallow waters. There has been an increase in commercial interest for this species in recent years; currently, five states report commercial landings of bowfin, but only Louisiana is considered here.

Bowfin is a freshwater species that inhabits turbid, highly vegetated areas from southeastern Canada throughout most of the eastern United States. Bowfin often feeds at night and is an opportunistic predator with a diet consisting mainly of other fish, crayfish, and grass shrimp, but may also include small rodents, snakes, frogs, turtles, leeches, and large insects. Due to its ability to air breathe (out of water), it is commonly used in physiological studies; however, little research has focused on bowfin ecology because it was not viewed as a commercially or recreationally important species until recently. Little is known about abundance, but the species is not highly vulnerable to fishing pressure. Fishing rates are not expected to be unsustainable and measures are in place to protect immature fish and entire spawning populations.

The Louisiana Department of Wildlife and Fisheries (LDWF) is the managing entity of the bowfin fishery in Louisiana. Bycatch is largely unknown, but most species are likely retained. Blue catfish and buffalofish commonly account for >5% of landings with bowfin; these species are rated as "Least Concern" by the International Union for Conservation of Nature (IUCN). There are size requirements, gillnet mesh restrictions, seasonal closures, and locational closures in place in the bowfin fishery. LDWF conducts sampling surveys and monitors the fishery through a trip ticket program. Management is considered "moderately effective" overall.

Ecosystem-based fisheries management is considered to be of "moderate" concern because of uncertainty about their roles in the ecosystem and how their removal may be impacting the food web.

Overall, bowfin caught by gillnets in Louisiana are rated yellow or "Good Alternative."

Final Seafood Recommendations

SPECIES/FISHERY	CRITERION 1: IMPACTS ON THE SPECIES	CRITERION 2: IMPACTS ON OTHER SPECIES	CRITERION 3: MANAGEMENT EFFECTIVENESS	CRITERION 4: HABITAT AND ECOSYSTEM	OVERALL RECOMMENDATION
Bowfin Louisiana, Set gillnets	Yellow (2.644)	Yellow (2.644)	Yellow (3.000)	Green (3.240)	**Good Alternative (2.871)**

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

- **Best Choice/Green** = Final Score >3.2, and either Criterion 1 or Criterion 3 (or both) is Green, and no Red Criteria, and no Critical scores
- **Good Alternative/Yellow** = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern2, and no more than one Red Criterion, and no Critical scores
- **Avoid/Red** = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

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[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

__Introduction__

__Scope of the analysis and ensuing recommendation__

This report provides recommendations for bowfin (*Amia calva*) caught in the freshwaters of Louisiana. Bowfin in the US are typically caught using gillnets and are primarily targeted for the roe which is often marketed as "cajun caviar."

__Species Overview__

Bowfin (*Amia calva*) is a freshwater species that inhabits turbid, highly vegetated areas from southeastern Canada throughout most of the eastern United States (Davidson et al. 1991) (Davis 2006) (Midwood et al. 2017). It is the last extant species of its order (Amiiformes) and family (Amiidae) (Koch et al. 2009). The bowfin often feeds at night and is an opportunistic predator with a diet consisting mainly of other fish, crayfish, and grass shrimp, but may also include small rodents, snakes, frogs, turtles, leeches, and large insects (Becker 1983) (Davis 2006). Due to its ability to air breathe (out of water), it is commonly used in physiological studies; however, little research has focused on bowfin ecology because it was not viewed as a commercially or recreationally important species until recently (Midwood et al. 2017). Most state fish and wildlife agencies haven't introduced harvest regulations, and as of 2013, Louisiana was the only state with minimum commercial and recreational size limits (Porter et al. 2014).

Figure 1 Bowfin distribution (shaded area) in North America. Figure from Davis 2006.

In Louisiana, bowfin live up to 10 years with most individuals reaching sexual maturity at 2 years of age (Davis 2006). Females may produce anywhere from 1,900 eggs to 75,000 eggs (Davis 2006). Fecundity is positively related to the female's size and age, with a mean of 15 eggs produced per gram of body weight (Davis 2006). Females spawn in the late winter and early spring when water temperatures exceed 14°C (57.2°F); however, it is unclear whether or not spawning occurs every year (Davis 2006). Females deposit eggs in a nest (one or more females may deposit in the same nest) made by a male bowfin who protects the eggs and subsequent young until they reach approximately 102 mm (4 inches) in length, about 2 to 2.5 months after the males begin building their nests (Becker 1983).

Bowfin are sexually dimorphic with females growing larger and living longer than males and displaying different external physical characteristics (Davis 2006). Although both males and females have an olive-colored body with a possible darker, net-like mottling, male bowfin have a distinguishing dark tail spot surrounded by an orange halo and green coloration on the pelvic, pectoral, and anal fins, which intensifies during the spawning season (Becker 1983) (Davis 2006). Immature females may display a faint tail spot without the orange halo, but mature females have no tail spot and fins have either a red to orange hue or are absence of color altogether (Davis 2006).

The Inland Fisheries Section of the Louisiana Department of Wildlife and Fisheries (LDWF) manages freshwater fisheries in Louisiana through licensing, gear restrictions, a trip ticket program, and spatial and seasonal closures. LDWF hasn't conducted stock assessments or established reference points for bowfin.

Figure 2 Sexually dimorphic characteristics of male (top) and female (bottom) bowfin collected from the Upper Barataria estuary [Louisiana, United States] in December 2005 (top) and January 2006 (bottom). Figure from Davis 2006.

Production Statistics

Commercial interest in bowfin has increased significantly since the early 1990s when sturgeon and paddlefish populations, primary sources of caviar, began to decline (Davis 2006). The highest commercial landings in Louisiana since 1958 occurred in 2014 at 563,239 lb (NOAA 2018). The commercial landings for 2015 and 2016 were 370,539 lb and 287,464 lb, respectively (NOAA 2018).
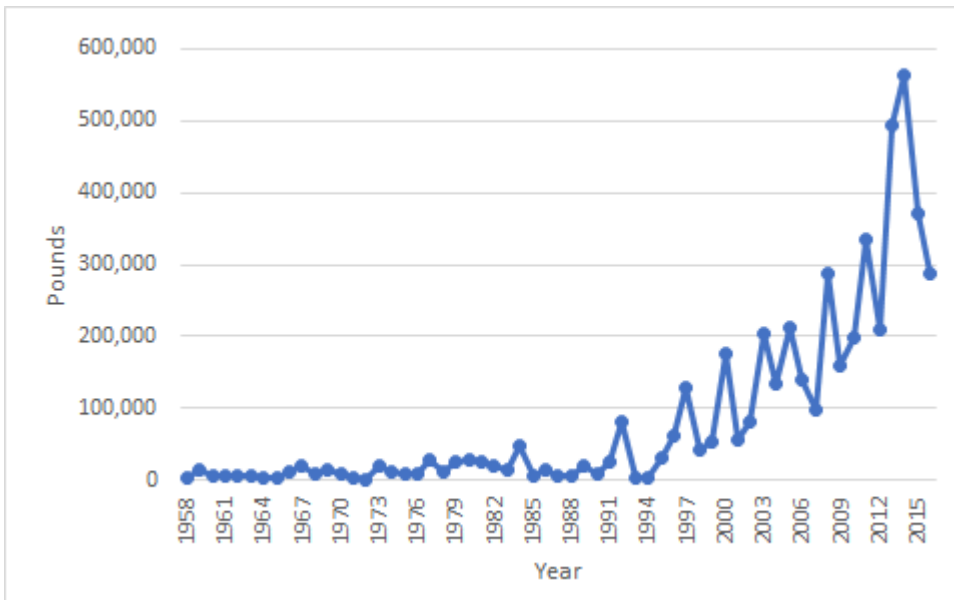
Figure 3 Louisiana commercial bowfin landings in pounds 1958-2016. Data source: NOAA 2018.

Importance to the US/North American market.

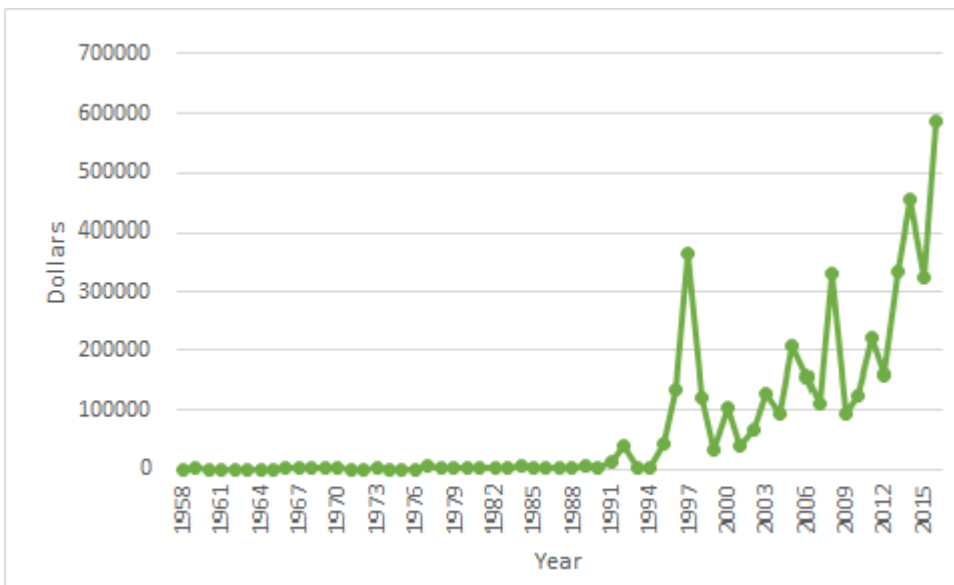In 2016, 287,464 lb of Louisiana bowfin brought in $586,897, the highest amount since 1958 (NOAA 2018).

Figure 4 Louisiana commercial bowfin landings in dollars 1958-2016. Data source: NOAA 2018.

Common and market names.

Common names include bowfin, marshfish, mudfish, western mudfish, choupique, choupiquel, freshwater dogfish, beaverfish, grinnel, grindle, cypress trout, cottonfish, lawyer, speckled cat, scaled ling, and poisson-castor.

Primary product forms

Bowfin roe is the primary commercial product.

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the Species Under Assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2=Red or High Concern*

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical

Criterion 1 Summary

BOWFIN			
**Region	Method**	**Abundance**	**Fishing Mortality**	**Score**
Louisiana	Set gillnets	2.33: Moderate Concern	3.00: Moderate Concern	Yellow (2.644)

Criterion 1 Assessment

SCORING GUIDELINES

Factor 1.1 - Abundance

Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly vulnerable.*
- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*
- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality

Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*

- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

BOWFIN

Factor 1.1 - Abundance

LOUISIANA, SET GILLNETS

Moderate Concern

In 2011, the International Union for the Conservation of Nature (IUCN) assessed bowfin (*Amia calva*), as a species of "Least Concern" (NatureServe 2013). Because of a dated IUCN assessment and increase in commercial interest for bowfin, a Productivity and Susceptibility Analysis (PSA) was performed (see below); bowfin is not highly vulnerable to fishing pressure. Due to the PSA results and IUCN ranking, abundance is assessed as "moderate" concern.

Justification:

Productivity Attributes	Value	Score (1 = low risk; 2 = medium risk; 5 = high risk)	Reference
Average age at maturity (years)	2.5	1	(Koch et al. 2009)
Average maximum age (years)	13	2	(Koch et al. 2009)
Fecundity (eggs/yr)	44,000	1	(Davidson et al. 1991)
Average maximum size (cm) (not to be used when scoring invertebrate species)	53.4	1	(Froese and Pauly 2018)
Average size at maturity (cm) (not to be used when scoring invertebrate species)	45	2	(Davidson et al. 1991)
Reproductive strategy	Demersal egg layer or brooder	2	(Becker 1983)
Trophic level	3.8	3	(Froese and Pauly 2018)
Density dependence (invertebrates only)	NA		
Quality of Habitat	Moderately altered	2	(Kesel 1989) (Davis 2006)(Kearney et al. 2011)
Productivity Subscore		1.75	

Susceptibility Attribute	Information	Score (1 = low risk; 2 = medium risk; 5 = high risk)	Reference
Areal overlap	Bowfin are fished commercially in Louisiana, Michigan, Virginia, and North Carolina*	3	(NOAA 2018)
Vertical overlap	Bowfin prefer shallow, vegetated, nearshore areas	3 (default score for target species)	(Midwood et al. 2017)
Selectivity of fishery	Bowfin is targeted, or is incidentally encountered, and is unlikely to escape the gear	2	(LDWF 2018)
Post-capture mortality	Default score for retained species	3	
Susceptibility Subscore		2.33	

Productivity-Susceptibility Score	**2.91**
Vulnerability Rating (high, medium, or low)	**Medium**

* Bowfin is only commercially harvested in five states, though its range extends into 32 states and two Canadian provinces. There is no evidence to suggest that most of the species concentration is unfished by any fishery (i.e., commercial, recreational, and tribal fisheries). Therefore, a default score of 3 for areal overlap is awarded. Although a score of 2 for areal overlap would change the overall vulnerability rating, the score for abundance would not change because the PSA demonstrates that the species is not highly vulnerable to fishing.

Factor 1.2 - Fishing Mortality

LOUISIANA, SET GILLNETS

Moderate Concern

Reference points have not been identified for bowfin in Louisiana. Landings for bowfin have been recorded by the National Marine Fishery Service (NMFS) since 1958. The species' roe became popular in the early 1990s (Davis 2006). Commercial landings have increased since that time with the highest commercial landings recorded in 2014 at 563,239 lb (NOAA 2018). It is unknown whether fishing mortality is at a sustainable level, which results in a "moderate" concern score.

Justification:

In a study evaluating the effect of minimum conservation sizes on overfishing, researchers found that a 500-mm minimum length limit likely results in growth overfishing, while limits of 500 mm, 559 mm, and 584 mm can lead to recruitment overfishing; only a 635-mm minimum prevented recruitment overfishing in the study population (Koch et al. 2009). Louisiana currently has a 22-in (559-mm) minimum size limit (LDWF 2018).

However, it should be noted that the study is from the upper Mississippi River, where growth rates may differ (Koch et al. 2009). Further, most bowfin taken during sampling in the 1990s from 6-in stretched gillnets were above 610 mm (mean size of 705 mm), indicating the current minimum mesh size allows for full recruitment into the fishery (Davidson et al. 1991).

Bowfin may be more resistant to overfishing than similar species that are harvested for their roe (e.g., paddlefish and sturgeon) because bowfin mature early, are not as long-lived, spawn annually, and exhibit sexual dimorphism (fishers can distinguish males from females and avoid harvesting males) (Koch et al. 2009). Further, because of faster growth and earlier maturity, bowfin populations in southern latitudes are likely to respond differently to fishing mortality (e.g., for eggs) than their northern counterparts (Porter et al. 2014).

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤=3.2=Yellow or Moderate Concern*
- *Score ≤=2.2=Red or High Concern*

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding Principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Only the lowest scoring main species is/are listed in the table and text in this Criterion 2 section; a full list and assessment of the main species can be found in Appendix A.

BOWFIN - LOUISIANA - SET GILLNETS					
Subscore:	**2.644**	**Discard Rate:**	**1.00**	**C2 Rate:**	**2.644**
Species		**Abundance**	**Fishing Mortality**		**Subscore**
Buffalofish (unspecified)		2.33:Moderate Concern	3.00:Moderate Concern		Yellow (2.644)
Blue catfish		2.33:Moderate Concern	5.00:Low Concern		Green (3.413)

Bycatch in freshwater fisheries is understudied, especially in comparison to marine fisheries (Raby et al. 2011). The bowfin fishery in Louisiana is no exception. Bowfin accounts for around 30% of winter freshwater gillnet landings in Louisiana, but it is difficult to determine what species might be incidentally caught (bycatch) or co-targeted as part of a multispecies fishery (D. Morris, personal communication 2018). A total of 17 species are reported to LDWF during peak bowfin harvests, but those species may or may not be caught in the same sets as bowfin, since fishers target different species with gillnets in the same areas where bowfin are caught (D. Morris, personal communication 2018). Catch data is confidential in cases when there are fewer than three harvesters or dealers. However, LDWF reviewed this data and found that only blue catfish and buffalo fish exceed 5% of gillnet landings that contained bowfin during the primary fishing months: December to February (H. Blanchet, personal communication 2019). Most species caught with bowfin have markets and are therefore retained (H. Blanchet, personal communication 2019). Because most fish that are caught with bowfin are landed, and blue catfish and buffalo account for >5% of landings, the bowfin fishery is considered to have two other main species.

Spotted gar (*Lepisosteus oculatus*) and gizzard shad (*Dorosoma cepedianum*) were caught in similar numbers to bowfin in a study in the Upper Barataria estuary in Louisiana (Davis 2006), but mesh size in this study varied and we are not able to extrapolate this to determine if this result is representative of the commercial fishery targeting bowfin.

LDWF has conducted long-term gillnet surveys using multiple mesh sizes (H. Blanchet, personal communication 2019). Although this monitoring cannot completely describe potential bycatch in the bowfin fishery, it does provide insight to species that *may* be encountered in the fishery. Blue sucker (*Cycleptus meridionalis*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) have been captured in surveys within the Lower Atchafalaya Floodway, an area of bowfin harvest (LDWF 2019) (H. Blanchet, personal communication 2019). Both species are species of concern in Louisiana, but there has been just one shovelnose sturgeon caught in 10 years of surveys and blue sucker are too small to be captured in the gillnets used for bowfin (H. Blanchet, personal communication 2019). Therefore, shovelnose sturgeon and blue sucker are not included as main species. LDWF suggests that only the oldest and largest gizzard shad may be caught by gillnets targeting bowfin, while most forage fish are not susceptible to the mesh size used in this fishery (H. Blanchet, personal communication 2019).

Buffalo limit the score for C2 because the health of the stock and the sustainability of fishing rates are unknown.

Criterion 2 Assessment

SCORING GUIDELINES

Factor 2.1 - Abundance
(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality
(same as Factor 1.2 above)

BUFFALOFISH (UNSPECIFIED)

Factor 2.1 - Abundance

LOUISIANA, SET GILLNETS

Moderate Concern

Three species of buffalo fish are captured and retained in the bowfin fishery; smallmouth buffalo (*Ictiobus bubalus*) likely account for the majority of buffalo landings with bowfin, but landings of buffalo are not reported to the species level (H. Blanchet, personal communication 2019). Bigmouth buffalo (*I. cyprinellus*) and black buffalo (*I. niger*) are also caught. There are no stock assessments for any of three buffalo species in Louisiana. Each species is assessed by the International Union for the Conservation of Nature (IUCN) as species of "Least Concern" and populations appear stable (NatureServe 2013c) (NatureServe 2013d) (NatureServe 2013e).

There is limited information on the health of buffalo populations in Louisiana. Based on the IUCN status of all three species, a score of "moderate" concern is awarded.

Factor 2.2 - Fishing Mortality

LOUISIANA, SET GILLNETS

Moderate Concern

Buffalofish are retained in the bowfin gillnet fishery and targeted in commercial fisheries with multiple gears (H. Blanchet, personal communication 2019). Over the last 10 years, commercial fishers have landed an average of 1,361 MT per year of all three species combined; set gillnets are responsible for approximately 38% landings, on average (NOAA 2018). Annually, an average of 160 MT of buffalo are landed in winter gillnet fisheries (the primary bowfin season) (D. Morris, personal communication 2018). Commercial landings of buffalo have remained relatively stable (Figure 5), but there are no reference points for buffalo, so the sustainability of fishing levels is unknown. Therefore, a score of "moderate" concern is awarded.
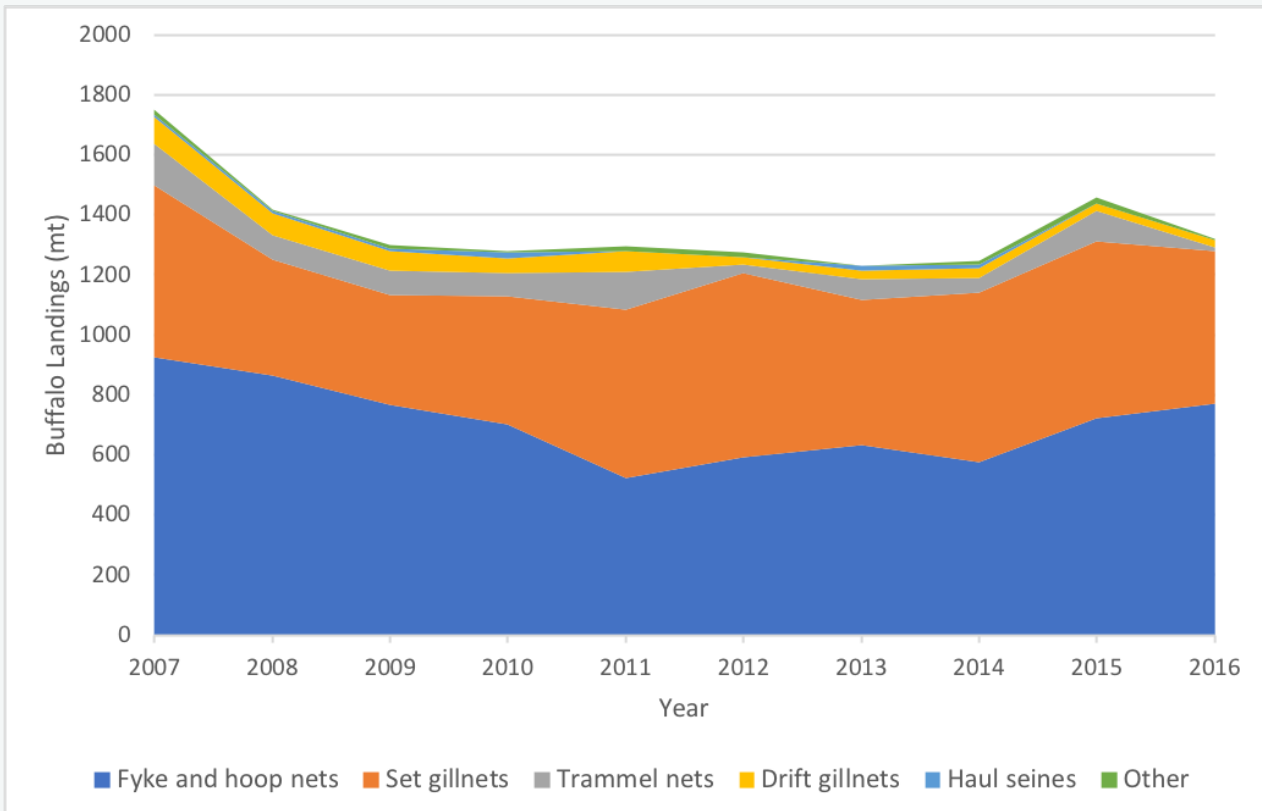
Justification:

Figure 5 Commercial landings (mt) of buffalo (bigmouth, smallmouth, and black buffalo combined) in Louisiana by gear from 2007-2016. Data source: NOAA 2018.

Factor 2.3 - Modifying Factor: Discards and Bait Use

Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

RATIO OF BAIT + DISCARDS/LANDINGS	FACTOR 2.3 SCORE
<100%	1
>=100	0.75

LOUISIANA, SET GILLNETS

< 100%

There is no information on discards for the bowfin gillnet fishery in Louisiana. Studies from other fisheries indicate average discard rates between 3 to 31% for bottom gillnets (Kelleher 2005). The amount of discards is unlikely to exceed total landings and we use a modifying factor of "1" for Factor 2.3.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2 = Red or High Concern*

Rating is Critical if Management Strategy and Implementation is Critical.

GUIDING PRINCIPLE

- The fishery is managed to sustain the long-term productivity of all impacted species.

Criterion 3 Summary

Fishery	Management Strategy	Bycatch Strategy	Research and Monitoring	Enforcement	Stakeholder Inclusion	Score
Fishery 1: Louisiana | Set gillnets	Moderately Effective	Moderately Effective	Moderately Effective	Highly Effective	Highly Effective	Yellow (3.000)

Criterion 3 Assessment

Factor 3.1 - Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

LOUISIANA, SET GILLNETS

Moderately Effective

Louisiana Department of Wildlife and Fisheries (LDWF) is the managing body over fisheries in Louisiana

waters. A fishing license is required for all commercial fishermen and a freshwater gillnet license is required for use of that gear (LDWF 2018). The legal length of bowfin is 22 inches total length (TL), with an allowable 5% of the catch below this limit; however, undersized fish may not be bought, sold, bartered, traded, or exchanged (LDWF 2018). Bowfin eggs must be attached to the fish until the fisher lands the catch (i.e., fishermen cannot remove eggs until the trip is completed) (Davis 2006). Bowfin season is closed December through February except in several parishes and rivers (see Justification section below). Legal length limits for blue catfish and buffalo are 12 inches TL and 16 inches TL respectively and a trip ticket program is used to monitor the fishery (see details below) (LDFW 2018).

There are no stock assessments for bowfin, buffalofish, or catfish, no reference points have been identified, and the fishery is managed by fishery-dependent (trip tickets) and fishery-independent (LDWF gillnet surveys) data (H. Blanchet, personal communication 2019) (LDWF 2018) (LDWF 2018a). Main, retained species are not of conservation concern (NatureServe 2013) (NatureServe 2013b) (NatureServe 2013c) (NatureServe 2013d) (NatureServe 2013e). Although there are measures in place that are expected to be effective (e.g., spatial management, seasonal closures, gear restrictions, and minimum size limits), actual effectiveness is unknown. Therefore, management strategy is assessed as "moderately effective."

Justification:

Gillnet specifications
The gillnet may not exceed 1,200 ft in length, with mesh at least 3 inches square or 6 inches stretched after treating with tar or copper, and waterproof tags. The fisher's name and license number must be attached to the cork line at the end of each net, no more than 3 ft from the webbing edge (LDWF 2018).

Trip ticket program
A trip ticket program is in place for commercial wholesale, retail and bait dealers, and commercial fishers, which requires any dealer who receives or purchases aquatic products from anyone other than another dealer to record all aquatic product transactions (LDWF 2018). Both paper and electronic trip tickets are available (LDWF 2018). Trip tickets must be completed when the fisher delivers the aquatic product(s) to the dealer (LDWF 2018). A report is filed with LDWF, by the 10th day of each month, of all trip tickets from the previous month.

Areas where winter fishery is allowed
Areas where winter fishery is allowed include: Assumption, Avoyelles, Iberville, Pointe Coupee, Terrebonne, Tangipahoa, and West Baton Rouge parishes, and in the areas known as Bayou Courtableau, Bayou Teche, Lake Dauterive, Lake Fausse Point, Vermilion River, Carencro Bayou, Queue de Tortue Bayou, Bayou Nez Pique, Mermentau River, Bayou Lacassine, Sabine River, and the Atchafalaya Basin Floodway that is bounded by the east and west levees of the Atchafalaya Basin and is south of US Highway 190 (LDWF 2018).

Spatial and temporal restrictions on gillnets
Gillnets are prohibited in Anacoco Lake, Lake Vernon, the portion of Anacoco Bayou between the lakes, Lake Bartholomew, Lake Bistineau, Bogue Chitto River, Bundick Lake, Caddo Lake, Caney Creek Reservoir, Lake Charles, Lake Claiborne, Lake Concordia, Cross Lake, Cypress Lake, Black Bayou Reservoir, Chicot Lake, D'Arbonne Lake, John K. Kelly-Grand Bayou Reservoir, Moss Lake, Nantachie Lake, Prien Lake, Spring Bayou, Tchefuncte River, and Toledo Bend Reservoir (LDWF 2018).

In Lacassine Bayou (the portion that flows through Lacassine National Refuge), gillnets are prohibited 1 March to 30 November (LDWF 2018). In False River Lake, Lake Bruin, Lake Providence, and Poverty Point Lake, net mesh must be 3.5 inches square or 7 inches stretched; nets are only permitted 1 October through sunset on the last day of February of the following year (LDWF 2018). Nets may not be set within 500 ft of the mouth of any inlet or pass or within 500 ft of any water control structures, dams, or weirs (LDWF 2018). Nets may not be used in freshwater impoundments to harvest fish during water draw-down periods, unless expressly

specified by LDWF (LDWF 2018). Impoundment closures begin the day when the draw-down control structure opens and lasts until the lake is full again (LDWF 2018).

Trip Ticket Requirements:

- The fisherman's name and license number
- The dealer's name and license number
- Date of sale
- Gear and vessel used
- Primary location where the fish were caught
- Duration of the fishing trip
- Species identification
- Quantity and units of each species
- Size and condition of each species
- Unit price for each species

Factor 3.2 - Bycatch Strategy

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

LOUISIANA, SET GILLNETS

Moderately Effective

There is limited Information on bycatch in this fishery. LDWF has a minimum mesh size in place for gillnets as well as seasonal and locational closures (LDWF 2018). The minimum size of legal freshwater gillnets limits the susceptibility of smaller sized bowfin and forage species (e.g., gizzard shad and threadfin shad) to the commercial fishery (H. Blanchet, personal communication 2019).

There is no information available on "ghost fishing" from lost or discarded gillnets in Louisiana. Gillnets are among the most common derelict fishing gear and the ability to ghost fish depends on many factors (NOAA 2015). For example, gillnets deployed in shallow water with dynamic currents—which are conditions in bowfin habitat (Koch et al. 2009)—ball up more quickly and tend not to be effective at ghost fishing (NOAA 2015). Anecdotally, gear loss in the bowfin fishery is considered infrequent and unlikely because nets are expensive and are pulled from the water daily (D. Wilson, personal communication 2018). Gillnets have a high likelihood of ghost fishing in general, but there is no demonstrated concern in Louisiana and it's likely that lost nets would not effectively ghost fish in bowfin habitat. The fishery is not thought to have interactions with species of concern (D. Morris, personal communication 2018) (D. Wilson, personal communication 2018). Most species that encounter bowfin gillnets are retained (H. Blanchet, personal communication 2019).

There are mesh size restrictions and fishing closures that are presumably aimed at reducing bycatch, but the effectiveness of these measures is unknown. Therefore, the score is "moderate" concern.

Factor 3.3 - Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population

assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

LOUISIANA, SET GILLNETS

Moderately Effective

There are no stock assessments for bowfin in Louisiana and bycatch is not monitored. Louisiana Department of Wildlife and Fisheries uses fishery-dependent data to monitor and oversee the bowfin fishery, and trip tickets provide information on sold bycatch species (H. Blanchet, personal communication 2019) (D. Morris, personal communication 2018). There is generalized fishery-independent monitoring through gillnet surveys and electrofishing, which provides information on long-term CPUE and length data for bowfin and other species (H. Blanchet, personal communication 2019). Managers rely on spatial closures, minimum size limits, and gear restrictions to protect spawning stocks (LDWF 2018) (H. Blanchet, personal communication 2019).

Because some data is collected to monitor the stock, data-limited management strategies are in place, and regulations are used to constrain fishing mortality, a score of "moderate" concern is awarded.

Justification:

Many parts of the state are off limits for bowfin harvest during the spawning season and gillnets are prohibited in the areas mentioned in Section 3.1.

Figure 8 Primary area of bowfin harvests in Louisiana. Area outside primary bowfin harvest is closed to fishing during winter spawning season.

Factor 3.4 - Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

LOUISIANA, SET GILLNETS

Highly Effective

The Louisiana Department of Wildlife and Fisheries Enforcement Division is responsible for the enforcement of LDWF regulations. There are more than 200 agents currently in the division (LDWF 2018b). Between 1 January 2010 and 30 May 2018, 50 bowfin violations occurred in Louisiana, a majority of which involved the taking of undersized fish (D. Morris, personal communication 2018). Six of these incidents warranted a warning, and the rest were deemed criminal offenses (D. Morris, personal communication 2018). With regular enforcement by LDWF agents and the trip ticket program, Enforcement of Management Regulations is assessed as "highly effective."

Factor 3.5 - Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

LOUISIANA, SET GILLNETS

Highly Effective

The Louisiana Wildlife and Fisheries Commission (LWFC), which sets the possession limits, quotas, seasons, size limits, and daily take limits, is made up of seven board members appointed by the Governor (GSMFC 2015). Task forces have been set up for shrimp, blue crab, oyster, and finfish (in-process) to inform LWFC's decisions (LDWF 2018). Representatives from respective industries and relevant state agencies make up each task force (LDWF 2018). Task force meetings as well as monthly LWFC meetings are open to the public (LDWF 2018). LDWF has a comments section available on their website in addition to a sign-up for text and/or email alerts for seasonal openings/closings, regulatory changes, and task force and LWFC meetings (LDWF 2018). Because LDWF provides multiple ways stakeholders may participate in the regulatory process, stakeholder inclusion is assessed as "highly effective."

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2=Red or High Concern*

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

Region / Method	Gear Type and Substrate	Mitigation of Gear Impacts	EBFM	Score
Louisiana / Set gillnets	3	+0.5	Moderate Concern	Green (3.240)

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*
- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management

Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*
- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

LOUISIANA, SET GILLNETS

3

Bowfin are rarely detected in less vegetated areas and show a strong preference to shallow water with high percent coverage of submerged aquatic vegetation (Midwood et al. 2017). Because bowfin inhabit shallow water, gillnets are likely to contact bottom habitat. It is assumed that gillnets targeting bowfin are set over vegetated areas; this assumption is supported by anecdotal evidence (D. Wilson, personal communication 2018). Using the Seafood Watch matrix for sensitivity and recovery of bottom habitats to gear impacts, we award a score of 3 for the bowfin gillnet fishery because, although it is assumed to occur in biogenic habitats, those habitats are highly productive backwater areas where submersed vegetation is capable of recovering from disturbance and many species are capable of spreading from broken fragments (H. Blanchet, personal communication 2019).

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

LOUISIANA, SET GILLNETS

+0.5

In Louisiana, gillnets, seines, hoop nets, and trammel nets are entirely banned from numerous lakes, reservoirs, and portions of rivers, and restricted seasonally in others (described fully in Criterion 3.1) (LDWF 2018). We are not able to quantify the proportion of habitat that is protected from gillnets, but these measures are reasonably expected to be effective in mitigating the fishery's impact on bottom habitats and we award +0.5 mitigation credit.

Factor 4.3 - Ecosystem-Based Fisheries Management

LOUISIANA, SET GILLNETS

Moderate Concern

Bowfin is a predator feeding mostly on other fish, including catfish and gizzard shad, crayfish, and grass shrimp, but may also include small rodents, snakes, frogs, turtles, leeches, and large insects in its diet (Becker 1983) (Davis 2006). Overall, it's considered a generalist species with "complex foraging ecology" (Nawrocki et al. 2016). Although it is a predator, bowfin is known to be prey to wood storks and alligators (Davis 2006). Bowfin may be an important factor in controlling smaller fish populations; however, research on this species is limited and the ecological role it plays is not fully understood (Davis 2006) (Midwood et al. 2018).

The Louisiana Department of Wildlife and Fisheries (LDWF) currently uses spatial management and winter fishing closures to protect bowfin during the primary part of the spawning season (February to early March in Louisiana) (Davis 2006); some areas are closed to fishing December through February (LDWF 2018). The minimum size limit likely protects bowfin from experiencing growth overfishing and possibly limits recruitment overfishing (Koch et al. 2009). Bowfin is a top predator; detrimental food web impacts may be possible, but some policies are in place that may protect ecosystem functioning. We award a score of "moderate" concern.

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Appendix A: Extra By Catch Species

<u>BLUE CATFISH</u>

Factor 2.1 - Abundance

LOUISIANA, SET GILLNETS

Moderate Concern

Blue catfish (*Ictalurus furcatus*) has been assessed by the International Union for Conservation of Nature (IUCN) as a species of "Least Concern" (NatureServe 2013b). It is native to the Mississippi, Missouri, and Ohio River basins, and has been introduced to other parts of the US where it is considered a nuisance (Fuller and Neilson 2019). However, the bowfin fishery occurs within the native range of blue catfish, so abundance is not scored according to the Seafood Watch invasive species criteria. There is no quantitative stock assessment for this species and a score of "moderate" concern is awarded based on the IUCN rating.

Factor 2.2 - Fishing Mortality

LOUISIANA, SET GILLNETS

Low Concern

The commercial blue catfish fishery in Louisiana is the leading producer of catfish in the country; fyke and hoop nets are the primary gear for this fishery (NOAA 2018). Landings in Louisiana have averaged 1,463 MT over the last 10 years (2008 to 2017) and have been stable over this time (Figure 6). On average, gillnets are responsible for just 2% of commercial landings (Figure 7) (NOAA 2018). Blue catfish are part of a targeted fishery and are retained in the bowfin gillnet fishery. The bowfin fishery is not a substantial contributor to fishing mortality because the fishery accounts for 2% (at most) of blue catfish landings. Therefore, a score of "low" concern is awarded.
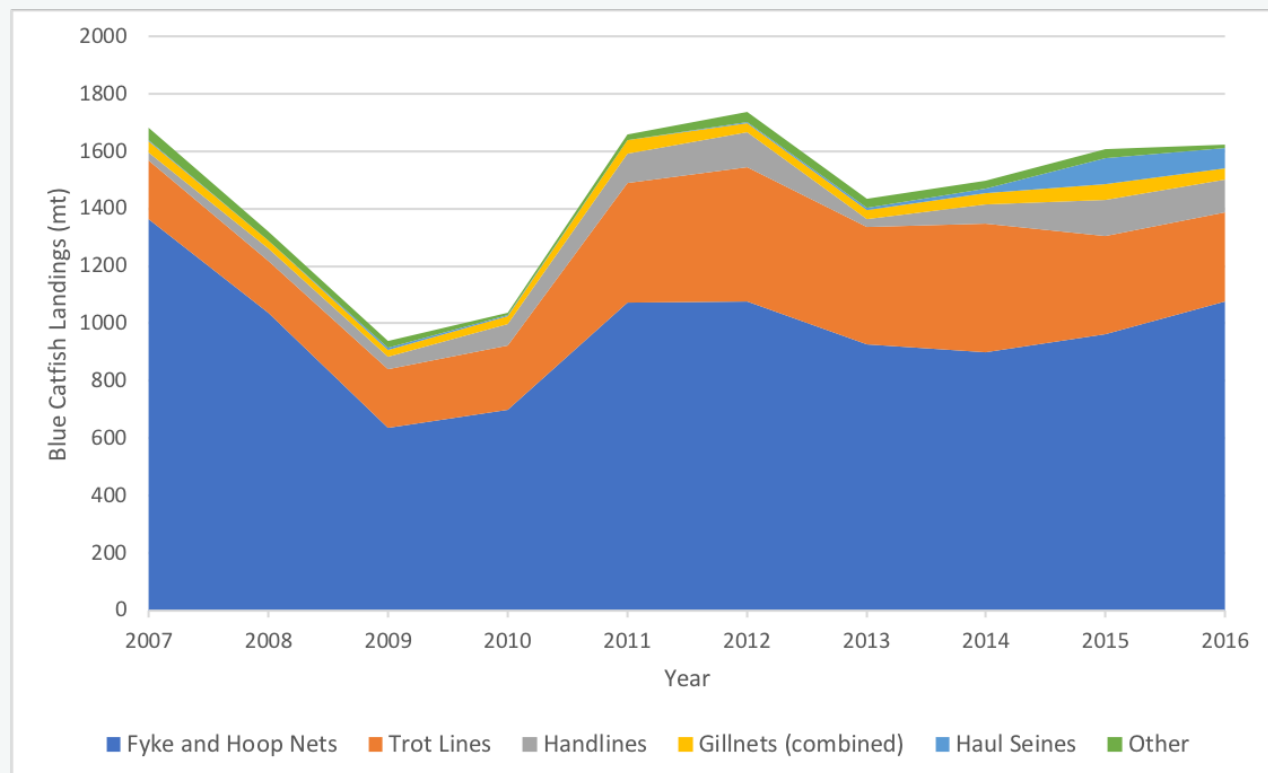
Justification:

Figure 6 Commercial landings (mt) of blue catfish in Louisiana by gear from 2007-2016. Data source: NOAA 2018.
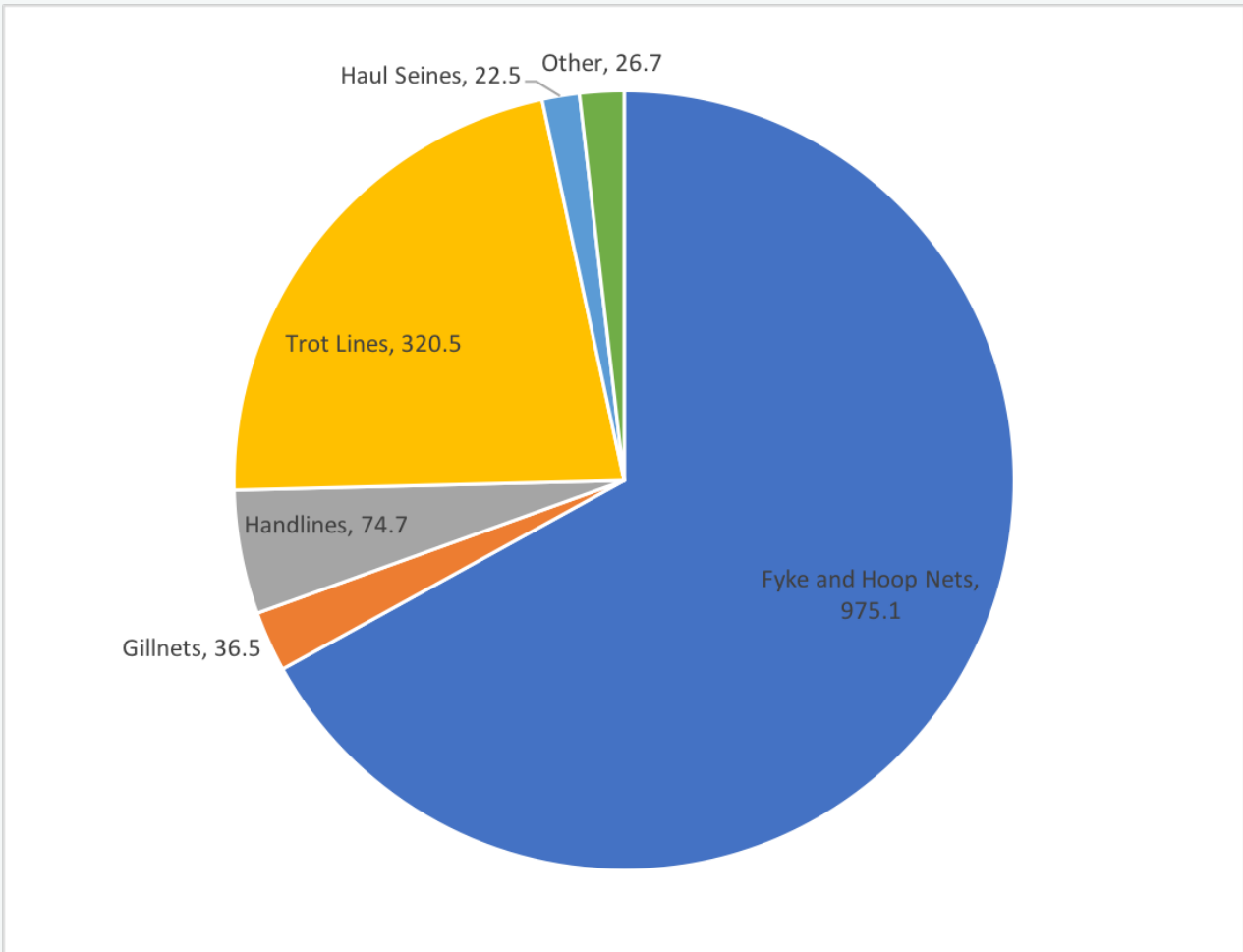

Figure 7 Average annual commercial landings (mt) of blue catfish in Louisiana from 2007-2016. Data source: NOAA 2018.

Factor 2.3 - Discard Rate

LOUISIANA, SET GILLNETS

< 100%

There is no information on discards for the bowfin gillnet fishery in Louisiana. Studies from other fisheries indicate average discard rates between 3 to 31% for bottom gillnets (Kelleher 2005). The amount of discards is unlikely to exceed total landings and we use a modifying factor of "1" for Factor 2.3.