Bowfin

Amia calva or *Amia ocellicauda*

Louisiana

Set gillnets

Report ID 28230

July 10, 2023

Seafood Watch Standard used in this assessment: Fisheries Standard v3

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the environmental 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. 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.

Seafood Watch's science-based ratings are available at www.SeafoodWatch.org. Each rating is supported by a Seafood Watch assessment, in which the fishery or aquaculture operation is evaluated using the Seafood Watch standard.

Seafood Watch standards are built on our guiding principles, which outline the necessary environmental sustainability elements for fisheries and aquaculture operations. The guiding principles differ across standards, reflecting the different impacts of fisheries and aquaculture.

- Seafood rated Best Choice comes from sources that operate in a manner that's consistent with our guiding principles. The seafood is caught or farmed in ways that cause little or no harm to other wildlife or the environment.

- Seafood rated Good Alternative comes from sources that align with most of our guiding principles. However, one issue needs substantial improvement, or there's significant uncertainty about the impacts on wildlife or the environment.

- Seafood rated Avoid comes from sources that don't align with our guiding principles. The seafood is caught or farmed in ways that have a high risk of causing harm to wildlife or the environment. There's a critical conservation concern or many issues need substantial improvement.

Each assessment follows an eight-step process, which prioritizes rigor, impartiality, transparency and accessibility. They are conducted by Seafood Watch scientists, in collaboration with scientific, government, industry and conservation experts and are open for public comment prior to publication. Conditions in wild capture fisheries and aquaculture operations can change over time; as such assessments and ratings are updated regularly to reflect current practice.

More information on Seafood Watch guiding principles, standards, assessments and ratings are available at www.SeafoodWatch.org.

Guiding Principles

Seafood Watch defines 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.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered, or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function, or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard.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, Seafood Watch develops an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guides and online guide:

Best Choice/Green: Buy first; they're well managed and caught or farmed responsibly.

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

Avoid/Red: Take a pass on these for now; they're caught or farmed in ways that harm other marine life or the environment.

[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 is 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. Because of 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 the 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 bowfin's roles in the ecosystem and how its removal may be affecting the food web.

Overall, bowfin caught by gillnets in Louisiana is rated Yellow or a Good Alternative.

Final Seafood Recommendations

SPECIES | FISHERY	C 1 TARGET SPECIES	C 2 OTHER SPECIES	C 3 MANAGEMENT	C 4 HABITAT	OVERALL	VOLUME (MT) YEAR
Bowfin | America, North - Inland Waters | Set gillnets | United States | Louisiana	2.644	2.644	3.000	3.240	**Good Alternative (2.871)**	96

Summary

Bowfin (*Amia calva*) that is primarily caught with gillnets in shallow freshwaters of Louisiana is rated Yellow or a Good Alternative.

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 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.

[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 United States 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). Historically, it was considered the last extant species of its order (Amiiformes) and family (Amiidae) (Koch et al. 2009), but recent genetic analyses show that there are at least two *Amia* species (*A. calva* and *A. ocellicauda*), and the actual number of species remains uncertain (Brownstein et al. 2022).

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). Because of 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 have not 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 lives 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, and he protects the eggs and subsequent young until they reach approximately 102 mm (4 in) in length, about 2 to 2.5 months after the males begin building their nests (Becker 1983).

Bowfin is 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 that 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 either have a red to orange hue or are absent 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 has not 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—the 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 2020 and 2021 were 285,867 lb and 212,737 lb, respectively (NOAA 2022). For comparison, North Carolina and Michigan reported less than 1,000 lb of commercial landings of bowfin in recent years, while no other states reported commercial harvest (NOAA 2022).

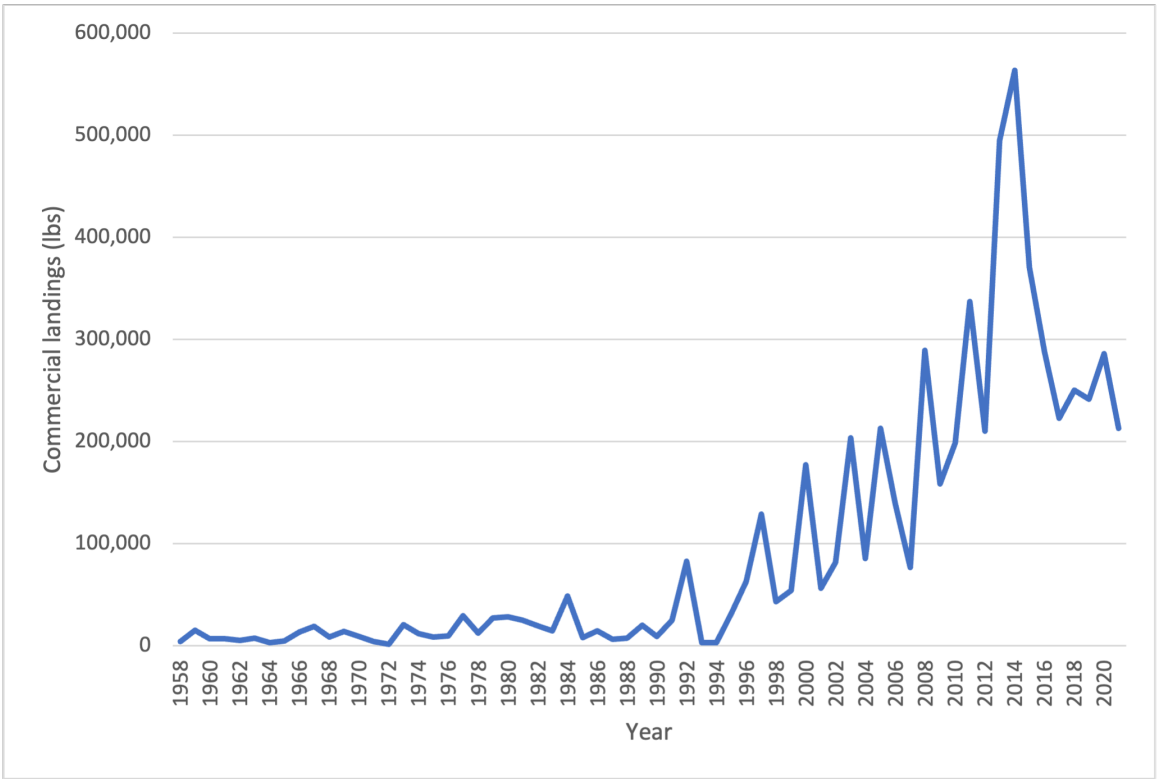

Figure 3: Louisiana commercial bowfin landings in pounds, 1958 to 2021. Data source: NOAA 2022.

Importance to the US/North American market.

In 2014, 563,236 lb of Louisiana bowfin brought in $412,913, which was the highest amount since 1958 (NOAA 2022). Commercial bowfin landings in the state were valued at $260,250 and $179,309 in 2020 and 2021, respectively (NOAA 2022).

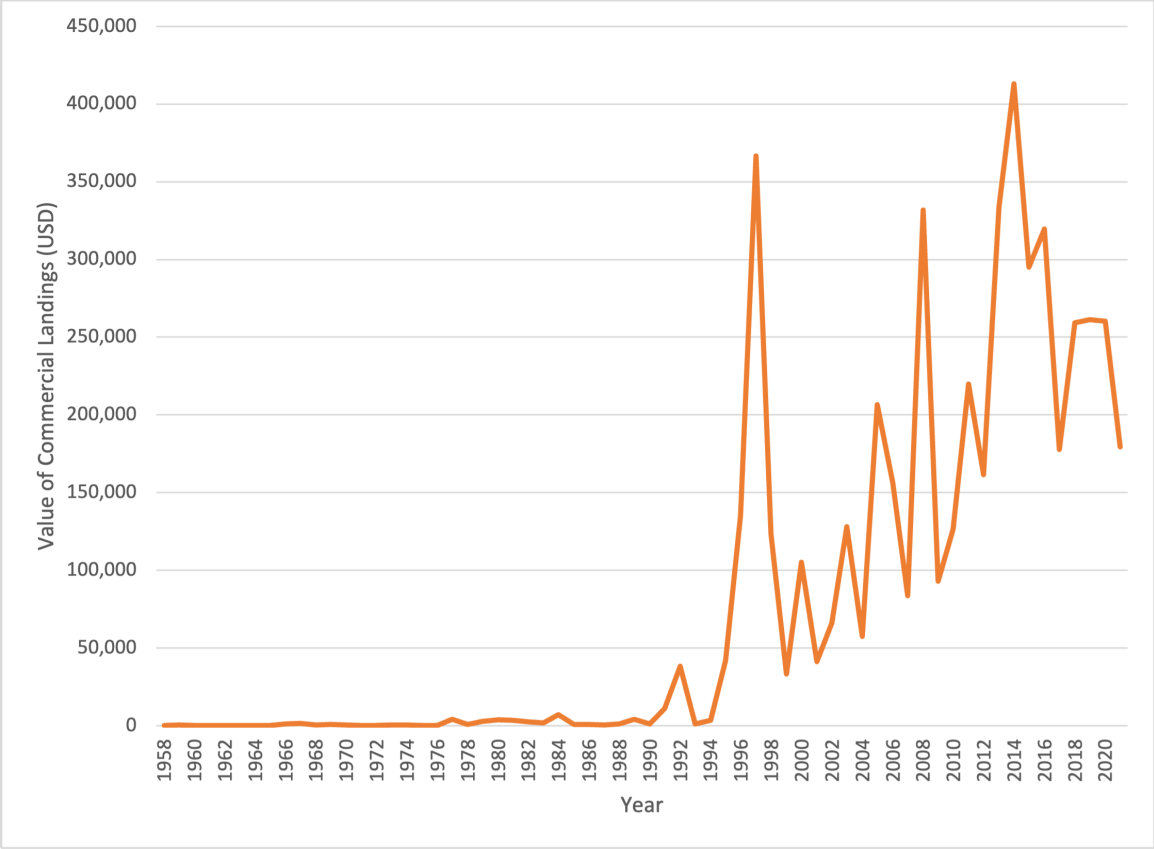

Figure 4: Louisiana commercial bowfin landings (USD), 1958 to 2021. Data source: NOAA 2022.

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.

Guiding principles

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

Criterion 1 Summary

BOWFIN			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
America, North - Inland Waters | Set gillnets | United States | Louisiana	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

Criterion 1 Assessments

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

America, North - Inland Waters | Set gillnets | United States | Louisiana

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). But, recent genetic analysis indicates that there are at least two extant species in the *Amia* genus: *A. calva* and *A. ocellicauda*, both of which occur in Louisiana (Brownstein et al. 2022). Based on the concentration of landings in the Atchafalaya Basin (LDWF 2018c), and the range of the two *Amia* species (Brownstein et al. 2022), the fishery likely catches *A. ocellicauda.* The IUCN assessment is outdated and does not account for updated information on species diversity within the *Amia* genus. Therefore, a productivity-susceptibility analysis (PSA) was performed (see Justification). Bowfin is not highly vulnerable to fishing pressure and abundance is assessed a moderate concern.

Justification:

Productivity Attributes	Value	Score (1 = low; 2 = medium; 5 = high)	Reference
Average age at maturity (years)	2.5	1	(Koch et al. 2009)
Average maximum age (years)	Up to 33 years	3	(Lackmann et al. 2022)
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)	N/A	—	
Quality of habitat	Moderately altered	2	(Kesel 1989)(Davis 2006) (Kearney et al. 2011)
Productivity Subscore		**1.875**	

Susceptibility Attribute	Information	Score (1 = low; 2 = medium; 3 = high)	Reference
Areal overlap	Bowfin is fished commercially in Louisiana, Michigan, Virginia, and North Carolina.*	3	{NOAA 2018}
Vertical overlap	Bowfin prefers 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		**2.325**	

Productivity-Susceptibility Score	**2.987**
Vulnerability Rating (high, medium, or low)	**Medium**

* Bowfin is only commercially harvested in 5 states, though its range extends into 32 of the United States and 2 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.

** There are anecdotal accounts that fishers are catching bowfin with less roe than when the fishery began, and there is a possibility that recent declining landings may be attributed to a change in age structure as a result of the targeting of older individuals (Sinopoli and Stewart 2021). But, there are currently no data to confirm whether or not declining yields are due to a decrease in demand, a decrease in effort, or a change in populations (Sinopoli and Stewart 2021), and we do not have enough information to override the default score for the Selectivity attribute and score "3" for a fishery that targets "BOFFFFs" (big old fat fecund female fish) (Hixon et al. 2014).

Factor 1.2 - Fishing Mortality

America, North - Inland Waters | Set gillnets | United States | Louisiana

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 then, with the highest commercial landings recorded in 2014 at 563,239 lb, although landings returned to short-term average levels in the ensuing years (NOAA 2022). 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). But, 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), which indicates that 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 matures early, is not as long-lived, spawns annually, and exhibits 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

Criterion 2 score(s) overview

This table(s) provides an overview of the Criterion 2 subscore, discards+bait modifier, and final Criterion 2 score for each fishery. A separate table is provided for each species/stock that we want an overall rating for.

BOWFIN			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
America, North - Inland Waters | Set gillnets | United States | Louisiana	2.644	1.000: < 100%	Yellow (2.644)

Criterion 2 main assessed species/stocks table(s)

This table(s) provides a list of all species/stocks included in this assessment for each 'fishery' (as defined by a region/method combination). The text following this table(s) provides an explanation of the reasons the listed species were selected for inclusion in the assessment.

AMERICA, NORTH - INLAND WATERS | SET GILLNETS | UNITED STATES | LOUISIANA			
SUB SCORE: 2.644	DISCARD RATE: 1.000	**SCORE: 2.644**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Bowfin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Buffalofish (unspecified)	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Blue catfish	2.330: Moderate Concern	5.000: 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 (pers. comm., D. Morris 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, because fishers target different species with gillnets in the same areas where bowfin are caught (pers. comm., D. Morris 2018). Catch data are confidential in cases when there are fewer than three harvesters or dealers. But, LDWF reviewed this data and found that only blue catfish and buffalofish exceeded 5% of gillnet landings that contained bowfin during the primary fishing months of December to February (pers. comm., H. Blanchet 2019). Most species caught with bowfin have markets and are therefore retained (pers. comm., H. Blanchet 2019). Because most fish that are caught with bowfin are landed, and blue catfish and buffalofish 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 the 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 (pers. comm., H. Blanchet 2019). Although this monitoring cannot completely describe the potential bycatch in the bowfin fishery, it does provide insight about the 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, which is an area of bowfin harvest (LDWF 2019) (pers. comm., H. Blanchet 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 is too small to be captured in the gillnets used for bowfin (pers. comm., H. Blanchet 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 (pers. comm., H. Blanchet 2019). Buffalofish limits 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)

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

Blue catfish

Factor 2.1 - Abundance

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderate Concern

Blue catfish is native to the Mississippi, Missouri, and Ohio River basins, and has been introduced to other parts of the United States, where it is considered a nuisance (Fuller and Neilson 2019). But, the bowfin fishery occurs within the native range of blue catfish, so abundance is not scored according to the Seafood Watch invasive species criteria. Blue catfish has been assessed by the International Union for the Conservation of Nature (IUCN) as a species of "Least Concern" (NatureServe 2013b), but the data used in the assessment are now more than 10 years old. Therefore, a productivity-susceptibility analysis (PSA) was performed (see Justification). Blue catfish is not highly vulnerable to fishing pressure, so abundance is assessed a moderate concern.

Justification:

Productivity Attributes	Value	Score (1 = low; 2 = medium; 3 = high)	Reference
Average age at maturity (years)	2–3	1	(Froese and Pauly 2018)
Average maximum age (years)	20	2	(USFWS 2020)
Fecundity (eggs/yr)	20,000	2	(Froese and Pauly 2018)
Average maximum size (cm)	165	2	(USFWS 2020)
Average size at maturity (cm)	60	2	(USFWS 2020)
Reproductive strategy	Demersal egg layer or brooder	2	(Froese and Pauly 2018)
Trophic level	2.9	2	(Schmitt et al. 2018)
Density dependence (invertebrates only)	N/A	N/A	
Quality of habitat	Moderately compromised	2	(Kesel 1989)(Davis 2006)(Kearney et al. 2011)
Productivity Subscore		**1.88**	

Susceptibility Attribute	Information	Score (1 = low; 2 = medium; 3 = high)	Reference
Areal overlap	Blue catfish is fished commercially in many U.S. states.	3	(NOAA 2022)
Vertical overlap	Depth range 0–15 m (default score when unknown)	3	(Froese and Pauly 2018)
Selectivity of fishery	Blue catfish is targeted, or incidentally encountered, but conditions under high risk do not apply	2	
Post-capture mortality	Default score for retained species	3	
Susceptibility Subscore		**2.33**	

Productivity-Susceptibility Score	**2.98**
Vulnerability Rating (high, medium, or low)	**Medium**

Factor 2.2 - Fishing Mortality

America, North - Inland Waters | Set gillnets | United States | Louisiana

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 a 10-year period (2007 to 2016) and have been stable over this time (Figure 5). On average, gillnets are responsible for just 2% of commercial landings (Figure 6) {NOAA 2018}. Blue catfish is part of a targeted fishery and is 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:

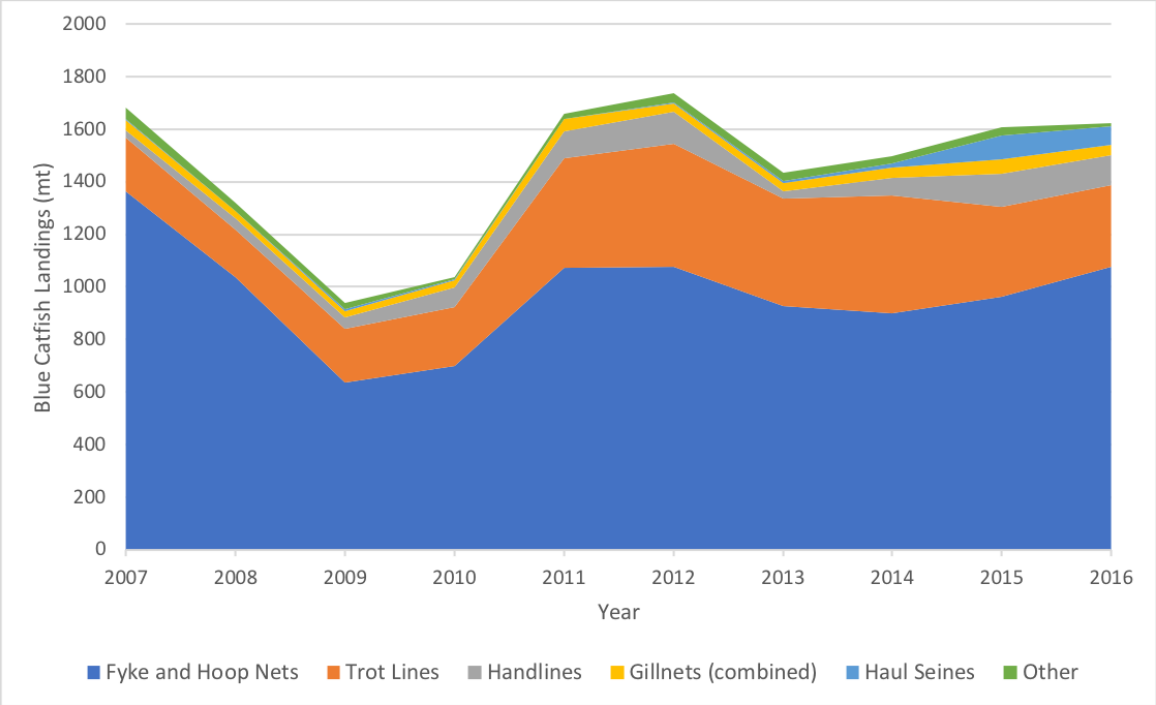

Figure 5: Commercial landings (mt) of blue catfish in Louisiana by gear from 2007 to 2016. Data source: {NOAA 2018}.

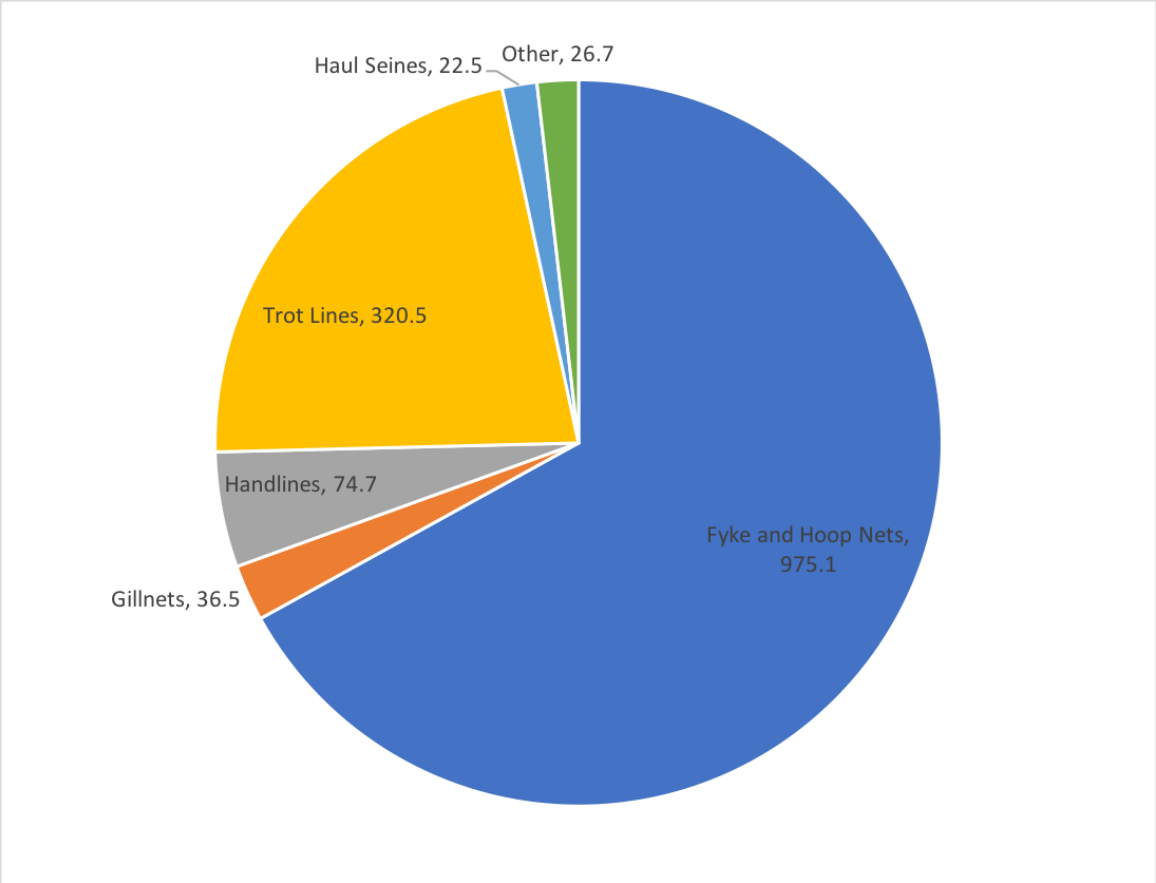

Figure 6: Average annual commercial landings (mt) of blue catfish in Louisiana from 2007 to 2016. Data source: {NOAA 2018}.

Buffalofish (unspecified)

Factor 2.1 - Abundance

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderate Concern

Three species of buffalofish are captured and retained in the bowfin fishery. Smallmouth buffalo (*Ictiobus bubalus*) likely accounts for the majority of buffalofish landings with bowfin, but landings of buffalofish are not reported to the species level (pers. comm., H. Blanchet 2019). Bigmouth buffalo (*I. cyprinellus*) and black buffalo (*I. niger*) are also caught. There are no stock assessments for any of the three buffalofish species in Louisiana. Each species is assessed by the IUCN as "Least Concern," and populations appear stable (NatureServe 2013d)(NatureServe & Lyons 2019) (NatureServe & Soto Galera 2019). There is limited information on the health of buffalofish populations in Louisiana. Based on the IUCN status of all three species, a score of moderate concern is awarded.

Factor 2.2 - Fishing Mortality

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderate Concern

Buffalofish is retained in the bowfin gillnet fishery and targeted in commercial fisheries with multiple gears (pers. comm., H. Blanchet 2019). Over a 10-year period (2007–16), commercial fishers landed an annual average of 1,361 mt of all three species combined; set gillnets were responsible for approximately 38% of landings, on average {NOAA 2018}. Annually, an average of 160 mt of buffalofish were landed in winter gillnet fisheries (the primary bowfin season) (pers. comm., D. Morris 2018). Commercial landings of buffalofish have remained relatively stable (Figure 7), but there are no reference points for buffalofish, so the sustainability of fishing levels is unknown. Therefore, a score of moderate concern is awarded.

Justification:

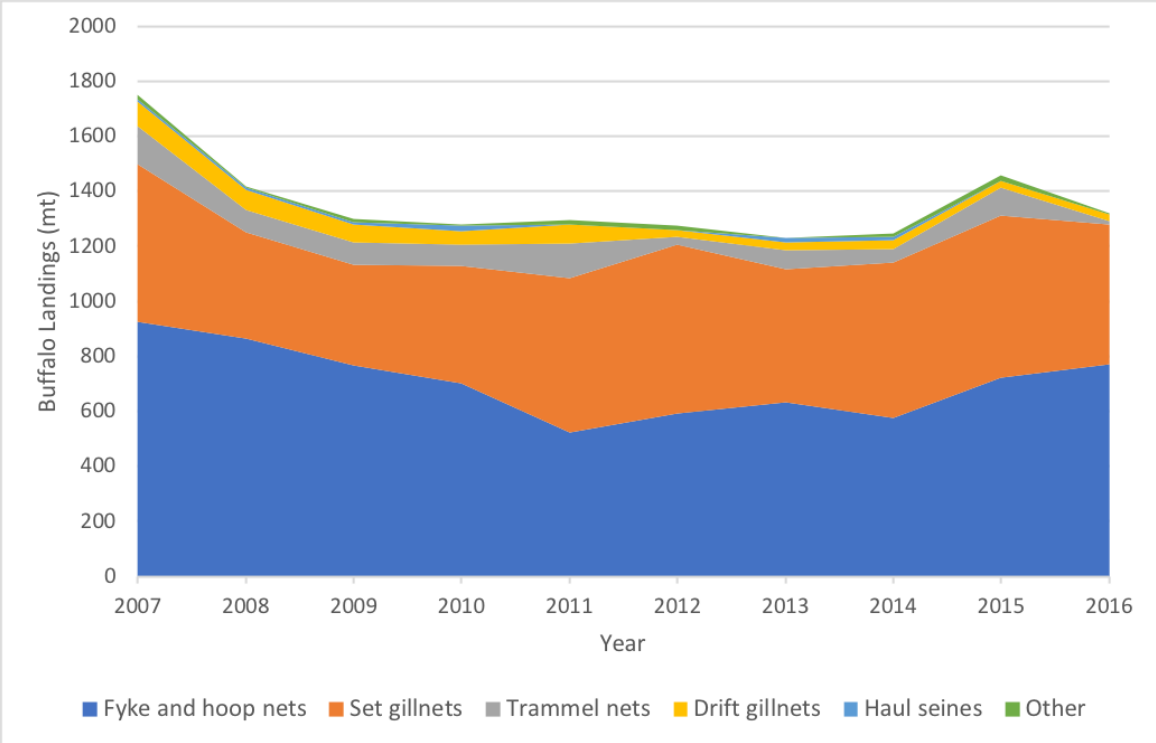

Figure 1: Commercial landings (mt) of buffalofish (bigmouth, smallmouth, and black buffalo combined) in Louisiana by gear from 2007 to 2016. Data source: {NOAA 2018}.

Factor 2.3 - Discard Rate/Landings

America, North - Inland Waters | Set gillnets | United States | Louisiana

< 100%

There is no information on discards for the bowfin gillnet fishery in Louisiana. Studies from other fisheries indicate average discard rates between 3% and 31% for bottom gillnets (Kelleher 2005). The amount of discards is unlikely to exceed total landings, so 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.

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:

Criterion 3 Summary

FISHERY	MANAGEMENT STRATEGY	BYCATCH STRATEGY	RESEARCH AND MONITORING	ENFORCEMENT	INCLUSION	SCORE
America, North - Inland Waters | Set gillnets | United States | Louisiana	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	Highly effective	**Yellow (3.000)**

Seafood Watch conducted a ratings review of this report in December 2022. All reports undergo a rating review at least every 3 years to determine if new information has become available that would suggest that the rating is no longer accurate. Since we published the report in 2019, scientists have published papers on bowfin species diversity (Wright et al. 2022)(Brownstein et al. 2022), management review of bowfishing in

the U.S. (Scarnecchia and Schooley 2020), and bowfin maximum age (Lackmann et al. 2022). Some of the concerns regarding management of bowfin across the U.S. expressed in recent peer-reviewed literature include:

- Scarnecchia and Schooley (2020) argue that management of species exhibiting sexual dimorphism should avoid excessive harvest of females, especially older and larger females. The authors also state that a minimum size limit does not meet the goal of avoiding age and size truncation and the selective harvest of females.
- Lackmann et al. (2022) note that an understanding of life history and exploitation rates of bowfin is required for sustainable management.
- Wright et al. (2022) caution that regional bowfin populations may represent geographically restricted species, and there is a potential for negative impacts to recruitment and genetic diversity as a result of overexploitation.

In addition, an essay in American Fisheries Society highlights the failure of reactive management measures in other caviar fisheries and the importance of proactive regulations, including defined management areas and fishing seasons, effort limits, and length, sex, and gear regulations (Sinopoli and Stewart 2021).

Although Seafood Watch recognizes that there is uncertainty in the effectiveness of bowfin management in Louisiana, current policies still exceed the threshold for an ineffective score for Factor 3.1. Specifically, the minimum size limit likely protects bowfin from experiencing overfishing (Koch et al. 2009) and we have no evidence to suggest that the fishery targets larger and older females. Although Sinopoli and Stewart (2021) express concern about the potential overharvest of distinct populations, the recent genetic analysis suggests that *A. ocellicauda* and *A. calva* populations may overlap in eastern Louisiana (Figure 8) (Brownstein et al. 2022), whereas the majority of bowfin landings in Louisiana occur in the Atchafalaya Basin in central Louisiana (LDWF 2018c). While there is an evolving understanding of species diversity within the *Amia* genus (Wright et al. 2022) and of bowfin longevity (Lackmann et al. 2022), the proactive regulations on gear, size, fishing areas, and fishing seasons in the Louisiana bowfin fishery (see Factors 3.1 and 4.3) are expected to be effective at protecting bowfin populations in the state.

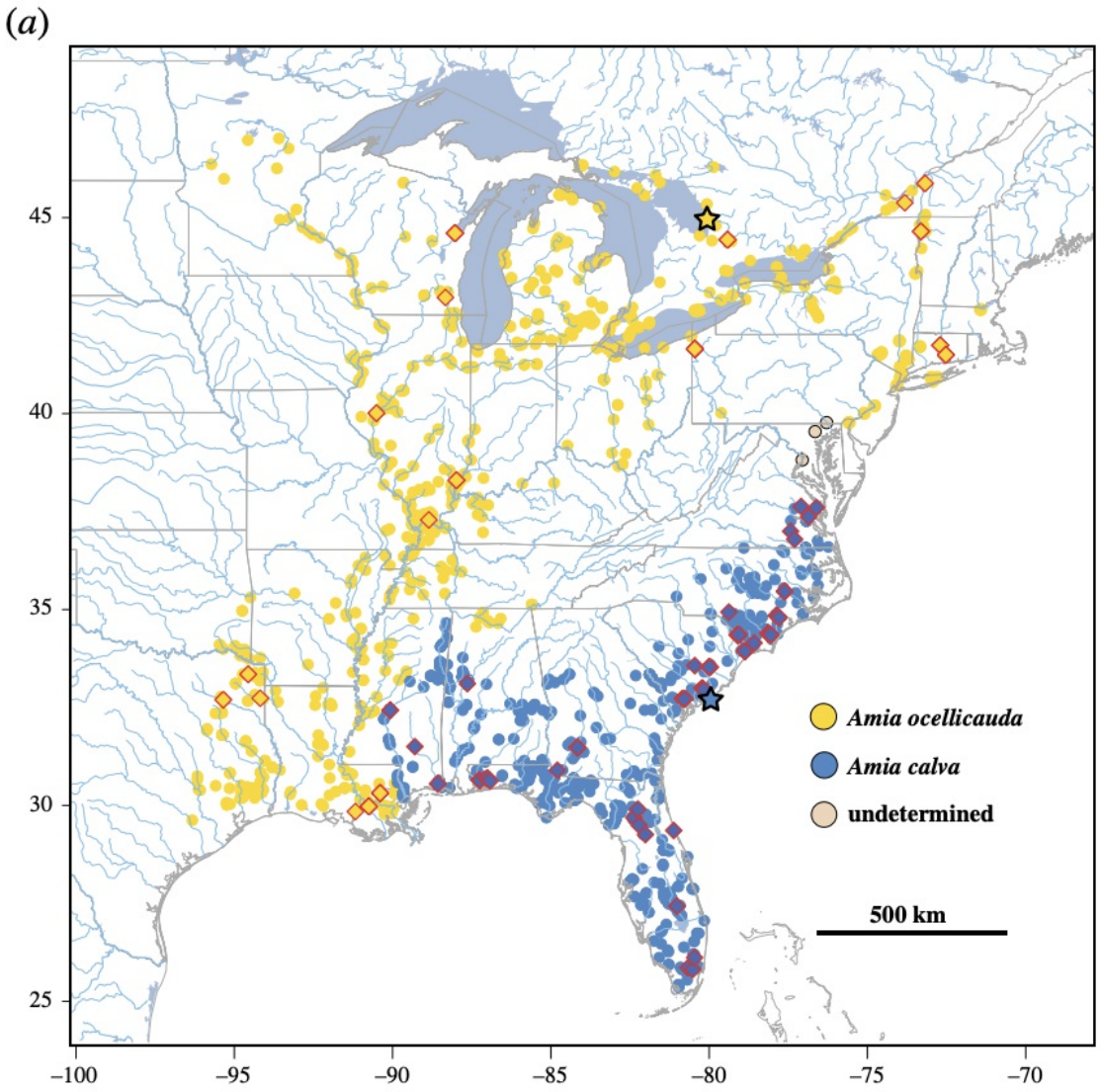

Figure 8: Identification of hidden bowfin species diversity. Map of eastern North America showing museum specimen collection records of *Amia calva* (blue), *Amia ocellicauda* (yellow), and undetermined (tan), retrieved from fishnet2.net. Stars indicate type localities. Diamonds indicate specimens sampled in the ddRAD phylogenetic analysis (Brownstein et al. 2022).

Criterion 3 Assessment

SCORING GUIDELINES

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.

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.

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.

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.

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.

Factor 3.1 - Management Strategy And Implementation

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderately Effective

The Louisiana Department of Wildlife and Fisheries (LDWF) is the managing body over fisheries in Louisiana waters. A fishing license is required for all commercial fishers, 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., fishers cannot remove the eggs until the trip is completed) (Davis 2006). Bowfin season is closed from December through February, except in several parishes and rivers (see Justification). The legal length limits for blue catfish and buffalofish are 12 in TL and 16 in TL, respectively, and a trip ticket program is used to monitor the fishery (see Justification) {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 (pers. comm., H. Blanchet 2019)(LDWF 2018)(LDWF 2018a). The main retained species are not of conservation concern and/or are not highly vulnerable (NatureServe 2013b)(NatureServe 2013d)(NatureServe & Lyons 2019)(NatureServe & Soto Galera 2019). Although there are measures in place that are expected to be effective (e.g., spatial management, seasonal closures, gear restrictions, and minimum size limits), their 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 for commercial fishers; the program 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 the winter fishery is allowed

Areas where the 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 U.S. 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 the Lacassine National Refuge), gillnets are prohibited from March 1 to November 30 (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 from October 1 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 drawdown periods, unless expressly specified by LDWF (LDWF 2018). Impoundment closures begin the day when the drawdown control structure opens and lasts until the lake is full again (LDWF 2018).

Trip ticket requirements

- The fisher'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

America, North - Inland Waters | Set gillnets | United States | Louisiana

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 location 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 (pers. comm., H. Blanchet 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 (pers. comm., D. Wilson 2018). Gillnets have a high likelihood of ghost fishing in general, but there is no demonstrated concern in Louisiana, and it is likely that lost nets would not effectively ghost fish in bowfin habitat. The fishery is not thought to have interactions with species of concern (pers. comm., D. Morris 2018) (pers. comm., D. Wilson 2018). Most species that encounter bowfin gillnets are retained (pers. comm., H. Blanchet 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

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderately Effective

There are no stock assessments for bowfin in Louisiana, and bycatch is not monitored. LDWF uses fishery-dependent data to monitor and oversee the bowfin fishery, and trip tickets provide information on sold bycatch species (pers. comm., H. Blanchet 2019) (pers. comm., D. Morris 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 (pers. comm., H. Blanchet 2019). Managers rely on spatial closures, minimum size limits, and gear restrictions to protect spawning stocks (LDWF 2018) (pers. comm., H. Blanchet 2019). Because some data are 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 (Figure 9), and gillnets are prohibited in the areas mentioned in Factor 3.1.

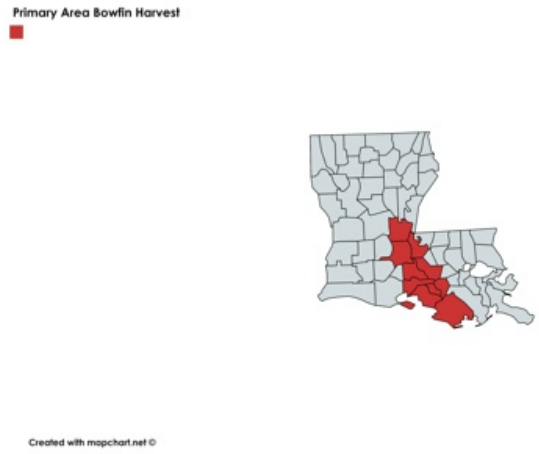

Figure 9: Primary area of bowfin harvests in Louisiana. Area outside the primary bowfin harvests are closed to fishing during the winter spawning season.

Factor 3.4 - Enforcement Of Management Regulations

America, North - Inland Waters | Set gillnets | United States | Louisiana

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 January 1, 2010 and May 30, 2018, 50 bowfin violations occurred in Louisiana, a majority of which involved the taking of undersized fish (pers. comm., D. Morris 2018). Six of these incidents warranted a warning, and the rest were deemed criminal offenses (pers. comm., D. Morris 2018). With regular enforcement by LDWF agents and the trip ticket program, the enforcement of management regulations is deemed highly effective.

Factor 3.5 - Stakeholder Inclusion

America, North - Inland Waters | Set gillnets | United States | Louisiana

Highly effective

The Louisiana Wildlife and Fisheries Commission (LWFC), which sets the possession limits, quotas, seasons, size limits, and daily take limits, comprises 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 the respective industries and relevant state agencies compose 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 its 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 through which stakeholders may participate in the regulatory process, stakeholder inclusion is deemed 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***

Guiding principles

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

FISHERY	FISHING GEAR ON THE SUBSTRATE	MITIGATION OF GEAR IMPACTS	ECOSYSTEM-BASED FISHERIES MGMT	SCORE
America, North - Inland Waters | Set gillnets | United States | Louisiana	Score: 3	+.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 - Impact of Fishing Gear on the Habitat/Substrate

America, North - Inland Waters | Set gillnets | United States | Louisiana

Score: 3

Bowfin is rarely detected in less vegetated areas and shows a strong preference for shallow water with a high rate of coverage by submerged aquatic vegetation (Midwood et al. 2017). Because bowfin inhabits 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 (pers. comm., D. Wilson 2018). Using the Seafood Watch matrix for the 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 (pers. comm., H. Blanchet 2019).

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

America, North - Inland Waters | Set gillnets | United States | Louisiana

+.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 (see Factor 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, so we award a +0.5 mitigation credit.

Factor 4.3 - Ecosystem-based Fisheries Management

America, North - Inland Waters | Set gillnets | United States | Louisiana

Moderate Concern

Bowfin is a predator that feeds 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, bowfin is considered a generalist species with a "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 that 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 it 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. Therefore, we award a score of moderate concern.

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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Appendix A: Updates to the Louisiana Bowfin Report

Updates to the June 3, 2019 Louisiana Bowfin Report were made on December 15, 2022:

Overall ratings for bowfin caught by gillnet in Louisiana remain unchanged, but we have outlined the individual criterion updates below (there were no score changes for any criterion).

Seafood Watch made the following updates:

- C1.1
    - Updated the productivity-susceptibility analysis (PSA) maximum age attribute from 13 years to 33 years, based on a recent analysis of bowfin otoliths (Lackmann et al. 2022).
    - Added new information on bowfin species diversity (Brownstein et al. 2022).
- C2.1
    - Added the updated IUCN assessments for black buffalo and smallmouth buffalo (NatureServe & Lyons 2019)(NatureServe & Soto Galera 2019). The IUCN status remains "Least Concern" for both species.
- C3
    - Added new information to the Criterion 3 Synthesis from recent peer-reviewed publications on bowfin species diversity (Brownstein et al. 2022), "rough fish" and bowfishing management (Scarnecchia and Schooley 2020), and bowfin maximum age (Lackmann et al. 2022).

Appendix B: Rating Review Summary Table

Criteria	Previous Report (2019)	Current Review (2022)
Who conducted the stock assessment?	No stock assessment has been conducted.	Same as previous
When was the stock assessment conducted?	N/A	Same as previous
Where/what are the catch composition data sources?	Louisiana Department of Wildlife and Fisheries (LDWF)	Same as previous
Who manages the fishery?	LDWF	Same as previous
What is the date of the published management plan?	No management plan in place.	Same as previous
Are there any amendments?	N/A	Same as previous