South Atlantic Distinct Population Segment of Atlantic Sturgeon
(Acipenser oxyrinchus oxyrinchus)

5-Year Review:
Summary and Evaluation

National Marine Fisheries Service
Southeast Regional Office
St. Petersburg, Florida

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5-YEAR REVIEW
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1.0 GENERAL INFORMATION

The South Atlantic distinct population segment (DPS) of Atlantic sturgeon includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) of the ACE (Ashepoo, Combahee, and Edisto) Basin southward along the South Carolina, Georgia, and Florida coastal areas to the St. Johns River, Florida. The South Atlantic DPS also includes: Atlantic sturgeon held in captivity (e.g., aquaria, hatcheries, and scientific institutions) that are identified as fish belonging to the South Atlantic DPS based on genetic analyses, previously applied tags, previously applied marks, or documentation to verify that the fish originated from (hatched in) a river within the range of the South Atlantic DPS, or is the progeny of any fish that originated from a river within the range of the South Atlantic DPS.

1.1 Reviewers

Lead Regional or Headquarters Office: Southeast Regional Office, David Bernhart, Assistant Regional Administrator for Protected Resources, 727-824-5312

Cooperating Regional Office: Greater Atlantic Regional Fisheries Office, Jennifer Anderson, Assistant Regional Administrator for Protected Resources, 978-282-8485

1.2 Methodology used to complete the review

The Southeast Regional Office (SERO) led the 5-year review for the South Atlantic DPS of Atlantic sturgeon. We are required to consider new information that has become available since we listed the South Atlantic DPS of Atlantic sturgeon as endangered in February 2012. We reviewed and considered new information for the South Atlantic DPS specifically, as well as other new information for Atlantic sturgeon generally, when DPS-specific information was not available.

We used several methods to acquire the new information. In addition to the literature generally available (e.g., journal articles sent to us by the author, notifications of new publications via a group email list), we requested a literature search from the NOAA Central Library. We received 10 public comments in response to our Federal Register notice (83 FR 11731; March 16, 2018). Three of those included comments that were specific to the South Atlantic DPS. We also considered the information provided in the conclusions of the Atlantic States Marine Fisheries Commission (ASMFC) 2017 Atlantic Sturgeon Stock Assessment (hereafter, "Stock Assessment"). We did not request copies of the data compiled by the ASMFC or conduct our own analyses of the data. We considered all previously unpublished information in the Stock Assessment as the best available information because the Stock Assessment was peer-reviewed in accordance with the ASMFC's procedures.

1.3 Background

1.3.1 FR Notice citation announcing initiation of this review:

83 FR 11731, March 16, 2018 - Initiation of 5-Year Review for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon and the Threatened Gulf of Maine Distinct Population Segment of Atlantic Sturgeon.

83 FR 12942, March 26, 2018 - Initiation of 5-Year Review for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon and the Threatened Gulf of Maine Distinct Population Segment of Atlantic Sturgeon; Correction.

1.3.2 Listing history

Original Listing
FR notice for South Atlantic DPS: 77 FR 5914
Date listed: February 6, 2012
Entity listed: South Atlantic DPS of Atlantic Sturgeon (*A. oxyrinchus oxyrinchus*)
Classification: Endangered

1.3.3 Associated rulemakings

Critical Habitat
FR notice: 82 FR 39160
Date designated: August 17, 2017
Determination: Seven critical habitat units were designated for the South Atlantic DPS of Atlantic sturgeon in South Carolina, Georgia, and Florida. The designation encompasses approximately 2,880 kilometers (1,790 miles) of freshwater and tidally affected reaches of the Edisto, Combahee-Salkehatchie, Savannah, Ogeechee, Oconee, Ocmulgee, Altamaha, Satilla, and St. Marys rivers. All of the critical habitat units are in the geographic area occupied by the South Atlantic DPS.

1.3.4 Review History

1998 Status Review: On June 2, 1997, the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) (collectively, the Services) received a petition from the Biodiversity Legal Foundation requesting that we list Atlantic sturgeon in the United States as threatened or endangered and designate critical habitat within a reasonable period of time following the listing. In 1998, after completing a comprehensive status review, the Services published a 12-month determination in the *Federal Register* announcing that listing was not warranted at that time (63 FR 50187; September 21, 1998). We retained Atlantic sturgeon on the candidate species list (subsequently changed to the Species of Concern List [69 FR 19975; April 15, 2004]).

2003 Status and Management Workshop: NMFS sponsored a workshop with USFWS and the ASMFC titled "Status and Management of Atlantic Sturgeon," to discuss the status of Atlantic sturgeon along the Atlantic Coast and determine what obstacles, if any, were impeding their recovery. The results of the workshop indicated some riverine populations appeared to be recovering while others were declining. Fisheries bycatch and habitat degradation were noted as possible causes for continued declines.

2005 Status Review: NMFS initiated a new status review of Atlantic sturgeon based on the outcomes of the 2003 Workshop and other new information. The status review team concluded that Atlantic sturgeon of U.S. origin comprised five DPSs and recommended identifying these as the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs. The status review team further recommended that the New York Bight, Chesapeake Bay, and Carolina DPSs be considered threatened under the ESA but made no listing recommendation for the Gulf of Maine or South Atlantic DPSs because of insufficient data. A Notice of Availability of this report was published in the *Federal Register* on April 3, 2007 (72 FR 15865). NMFS considered the information provided in the 2005 Status Review and all other best available information. NMFS proposed and subsequently listed the South Atlantic DPS under the ESA as endangered.

1.3.5 Species' Recovery Priority Number at start of 5-year review

The recovery priority number for the South Atlantic DPS is 1C based on the Listing and Recovery Priority Guidelines (84 FR 18243, April 30, 2019). Additional information is available in the Recovering Threatened and Endangered Species Report to Congress 2019-2020, available at https://www.fisheries.noaa.gov/resource/document/recovering-threatened-and-endangered-species-report-congress-fy-2019-2020.

1.3.6 Name of Recovery Plan or Outline

Recovery Outline for the Atlantic Sturgeon Distinct Population Segments (available at https://www.fisheries.noaa.gov/species/atlantic-sturgeon#conservation-management)
Date issued: January 2018
Dates of previous revisions, if applicable: N/A

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate? **Yes**

2.1.2 Is the species under review listed as a DPS? **Yes**

2.1.3 Was the DPS listed prior to 1996? **No**

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy? **No**

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria? **No**

2.3 Updated Information and Current Species Status

The biology and life history information for the South Atlantic DPS was reviewed in 2007 (ASSRT 2007) and updated for the proposed and final rules when NMFS listed the DPS as endangered (75 FR 61904, October 6, 2010; 77 FR 5914, February 6, 2012). The habitat needs for the DPS were reviewed and described in the critical habitat designation (82 FR 39160, August 17, 2017) and in the supplementary document (https://repository.library.noaa.gov/view/noaa/18672). Section 2.3.1 provides a summary of the previously available information, and updates from new information that has become available since the ESA-listing and critical habitat designation for the South Atlantic DPS.

2.3.1 Biology and Habitat for the South Atlantic DPS of Atlantic Sturgeon

The South Atlantic DPS of Atlantic sturgeon has the same basic life history characteristics of all Atlantic sturgeon. Atlantic sturgeon are reliant upon fresh water for spawning, and brackish and marine waters for growth and development of the offspring as well as sustenance of adults. Atlantic sturgeon are easily distinguished from other fish species within their range because of their relatively large size, visible bony scutes, protruding snout, and heterocercal tail. Atlantic sturgeon belonging to different DPSs can only be distinguished from each other based on the unique genetic characteristics of each DPS and of each spawning river population.

The South Atlantic DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) of the ACE (Ashepoo, Combahee, and Edisto) Basin southward along the South Carolina, Georgia, and Florida coastal areas to the St. Johns River, Florida (77 FR 5914; February 6, 2012). The South Atlantic DPS historically supported eight spawning populations. At the time of listing, only six populations were believed to have contemporary spawning: the Combahee River, Edisto River, Savannah River, Ogeechee River, Altamaha River (including the Oconee and Ocmulgee tributaries), and Satilla River. The two remaining historical spawning populations in the Broad-Coosawatchie River and St. Marys River were believed extirpated. However, the capture of juvenile Atlantic sturgeon in the St. Marys River since listing suggests that spawning population is not extirpated and continues to exist, albeit at very low levels.

Likely areas for spawning have been identified in the Savannah River and Altamaha River (including the Oconee and Ocmulgee tributaries). Spawning is believed to occur in flowing water between the salt front of estuaries and the fall line of large rivers over hard substrate, such as cobble, gravel, or boulders (Gilbert 1989; Smith and Clugston 1997). River flow/discharge and water temperature play an important role in triggering spawning behavior (Bain et al. 2000;

Borodin 1925; Collins et al. 2000a; Crance 1987; Dovel and Berggren 1983; Leland 1968; Scott and Crossman 1973; Smith 1985; Smith et al. 1982; Vine et al. 2019). Our understanding of when spawning runs occur is evolving and discussed in more detail in Section 2.3.1.1.

Juvenile Atlantic sturgeon generally use the estuaries of their natal rivers as rearing habitat. Estuarine habitats are important for juveniles, serving as nursery areas by providing abundant foraging opportunities, as well as thermal and salinity refuges, for facilitating rapid growth. Atlantic sturgeon likely spend 2 to 3 years in those habitats, using and moving within the brackish waters of the natal estuary that are most suitable or their growth and development, before emigrating to the marine environment.

Subadult and adult Atlantic sturgeon also use estuarine habitats. The directed movement of subadult and adult Atlantic sturgeon in the spring is from marine waters to river estuaries. River estuaries provide foraging opportunities for subadult and adult Atlantic sturgeon in addition to providing access to spawning habitat. Subadults, non-spawning adults, and post-spawned adults use the brackish waters of the rivers of the South Atlantic DPS in the spring through fall. These include subadults and adults that are not natal to the river or to the South Atlantic DPS. The directed movement of subadult and adult Atlantic sturgeon is reversed in the fall as the fish move back into marine waters for the winter.

In the marine environment, both subadults and adults typically occur inshore of, and up to, the 50 meter (m) depth contour, and frequently travel 100s of kilometers from their natal rivers (Kazyak et al. 2021). Genetic analyses indicated the presence of Atlantic sturgeon belonging to the South Atlantic DPS in many parts of the marine range including off the coasts of Virginia, Delaware, New Jersey, New York, Rhode Island, and Massachusetts (Kazyak et al. 2021).

Life history information for the South Atlantics DPS is somewhat inconsistent, with more information available for certain river systems (i.e., Altamaha, Savannah, Edisto), while others are data poor (e.g., Ogeechee, Satilla, St. Marys). The spawning interval for the South Atlantic DPS was described as 1 to 5 years for males (Caron et al. 2002; Collins et al. 2000b; Smith 1985) and 3 to 5 years for females (Stevenson and Secor 1999; Van Eenennaam et al. 1996; Vladykov and Greeley 1963) based primarily on estimates from other spawning populations. No new information is available to change those estimates. We still believe the lifespan for Atlantic sturgeon of the South Atlantic DPS is up to approximately 60 years (Stevenson and Secor 1999).

There was no abundance estimate for the South Atlantic DPS when we listed it under the ESA. The Atlantic Sturgeon Status Review Team (ASSRT 2007) concluded this DPS likely supported the second and third largest populations within the United States, the Altamaha River and ACE Basin, respectively. At the time of listing, the abundance of Altamaha River and ACE Basin populations was suspected to be less than 6% of their historical abundance, extrapolated from the 1890s commercial landings (ASSRT 2007). The remaining populations of the DPS were suspected to be less than 1% of their historical abundance (ASSRT 2007). In the final listing rule for the South Atlantic DPS, we reported an estimated 343 adults spawn annually in the Altamaha River and fewer than 300 adults spawning annually (total of both sexes) in the remaining spawning populations of the DPS (77 FR 5914; February 6, 2012). The estimates for the Altamaha River came from Peterson et al. (2008) and were based on potential spawning adults detected in the estuaries. The estimates for the remaining river systems stemmed from a reasoned argument and assumption based on the information available at that time. The estimate of the number of spawners outside the Altamaha River was not derived using any mathematical approach and it is not an estimate of spawning population size.

Multiple analyses have shown that Atlantic sturgeon can only sustain low levels of anthropogenic mortality (ASSRT 2007; Boreman 1997; Brown and Murphy 2010). We concluded at the time of the listing that the South Atlantic DPS is currently at risk of extinction given the combination of habitat curtailment and alteration, bycatch in commercial fisheries, and inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

2.3.1.1 New information on the species' biology and life history

Since listing, new information has been collected using acoustic telemetry to detect the presence of Atlantic sturgeon. Acoustic telemetry requires externally attaching an acoustic tag to the sturgeon or surgically implanting the tag within the sturgeon's body cavity, and then placing acoustic receivers that detect and record the unique signal of the tag when the sturgeon is within range of a receiver. Acoustic receivers are often fixed in specific locations but a receiver can also be towed or fixed to a moving object. Researchers use an array of receivers to track the movements of acoustically-tagged sturgeon in areas across the range of each DPS.

Since the listing, the existence of a spawning population in the St. Marys has been confirmed (Fox et al. 2018b). Our understanding of the timing of spawning runs in specific rivers has also improved. Telemetry data from Atlantic sturgeon detected in the Altamaha River (including the Oconee and Ocmulgee rivers) indicates those individuals likely only spawn in the fall (Ingram and Peterson 2016). Conversely, separate spring- and fall-spawning runs have been identified using telemetry data and genetic samples collected from Atlantic sturgeon in the Edisto River (Farrae et al. 2017; White et al. 2021), Savannah River (Vine et al. 2019), and Ogeechee River (White et al. 2021).

Genetic analyses have confirmed limited gene flow between the populations. Overall, the spawning populations are genetically distinct (Farrae et al. 2017; Fox et al. 2020a; Fox et al. 2019a; Fritts et al. 2016; Kazyak et al. 2021; Waldman et al. 2019; White et al. 2021). However, Kazyak et al. (2021) note that populations within the South Atlantic DPS have relatively low genetic differentiation compared to other DPSs.

There is some new information on the basic life history parameters for the South Atlantic DPS. Fox and Peterson (2019) reported that approximately 30% of river-resident juveniles in three Georgia rivers (Ogeechee, Altamaha, and Satilla) outmigrated from their natal river system by age 2. Approximately 37% of those tagged individuals did not outmigrate from their natal river system to the ocean; the status of the remaining 33% of tagged individuals was unknown.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends

There are no abundance estimates for the entire South Atlantic DPS. However, the Stock Assessment (ASMFC 2017) was a comprehensive review of the information available in 2017, and used multiple methods and analyses to assess the status of each DPS and the coast wide stock of Atlantic sturgeon. The Stock Assessment determined the South Atlantic DPS abundance is "depleted" relative to historical levels. The assessment concluded there was not enough information available to assess the abundance of the DPS since the implementation of the 1998 fishing moratorium (ASMFC 2017).

Within the South Atlantic DPS, the Altamaha (including the Oconee and Ocmulgee rivers), Savannah, and Edisto rivers are most well studied systems. Due to the relative ease of capturing river-resident juveniles, population monitoring in the South Atlantic DPS has focused largely on juvenile (e.g., age-1, age-2, and age-3) abundance and recruitment (Table 1). These activities use gillnets or trammel nets to capture juveniles and apply PIT tags, then statistical models are used to estimate the juvenile population by age, based on the percentage of tagged sturgeon that are recaptured.

While gillnet-based mark-and-recapture monitoring of juvenile abundance and recruitment is becoming a standard practice as a proxy for the status of riverine populations in the South Atlantic DPS, this approach has drawbacks. The primary concern is that the number of sturgeon captured can be influenced by a variety of factors other than the actual abundance of the population. For example, net mesh size and dimensions, river discharge (Fox et al. 2022), time of day, time of year, river temperature, density of sturgeon aggregated in the targeted holding area, overall activity level of individual sturgeon, time elapsed since the holding area was last fished, external information available to the netting crew (e.g., sonar or telemetry data acquired prior to setting nets), and fishing skills and experience of the crew (USFWS and NMFS 2022) can all influence capture rates. These external factors can affect the overall accuracy of the population estimates based on these sampling techniques. Despite these drawbacks, the current gillnet-based mark-and-recapture monitoring of juvenile abundance and recruitment remains the preferred approach. New techniques (i.e., side scan sonar), less affected by external factors, are being explored as potential complements to, or replacements of, gillnet-based mark-and-recapture monitoring.

In the St. John’s River, Florida, no evidence of a spawning population has been identified, although the river is used by non-natal migrants (Fox et al. 2018a). No juvenile recruitment estimates have been produced since listing (Table 1).

For the St. Marys River, no long-term trend information is available for the system (Table 1). The capture of several age-1 river-resident juveniles confirmed a small population of spawning Atlantic sturgeon still exists in the river (Fox et al. 2018b)

The Satilla River has a small remnant population with infrequent recruitment and a small river-resident juvenile population (Fritts et al. 2016). The Satilla River has been sampled intermittently since 2008 (Fritts et al. 2016), most recently from 2014-2017 (Fox et al. 2019a). While no long-term trend is available, the Satilla River population does not show obvious signs of recovery (Fox et al. 2019a; Fritts et al. 2016) (Table 1).

Prior to listing, Schueller and Peterson (2010) suggested the Altamaha River (including the Oconee and Ocmulgee rivers) population was likely the largest population in the South Atlantic DPS. Sampling conducted by Fox et al. (2019a) from 2014-2017 found juvenile recruitment levels are similar to those reported prior to listing (Schueller and Peterson 2010). This suggests the population is likely still the most robust in the South Atlantic DPS. Unlike other riverine populations, the Altamaha population appears to consistently produce age-1 cohorts (Fox et al. 2019a) (Table 1). Bunch (2020) also provided spawning run estimates for the Altamaha River for 2017 and 2018, the first such estimates since 2007.

The Ogeechee River population remains data deficient. Prior to listing, Farrae et al. (2009) noted the Ogeechee River is home to a relatively small population that exhibits only intermittent recruitment of small age-1 cohorts. Limited sampling conducted by Fox et al. (2019a) since listing (2014-2017) shows the population continues to produce inconsistent age-1 year classes (Fox et al. 2019a). Fox et al. (2019a) remark that while data on the historical sizes of the Ogeechee River sturgeon populations are not available, it seems unlikely that this small, coastal plain river ever supported large sturgeon populations (Table 1).

In the Savannah River, Bahr and Peterson (2016) estimated a relatively stable age-1 juvenile abundance from 2013-2015. More recently, data from Fox et al. (2020a) suggest a potential decline in age-1 juvenile abundance since 2017. Regardless, clear evidence of an overall Atlantic sturgeon population trend in the Savannah River is currently unavailable. However, Fox et al. (2020a) suggest the consistent presence of age-1 cohorts over the past several years is indicative of a population that is reliably reproducing and suggest the population may be stable (Table 1).

Limited sampling in the Combahee-Salkehatchie River was conducted prior to listing. Insufficient funding has been available to support new sampling, and no new information on the Combahee-Salkehatchie population of the Atlantic sturgeon is available (Table 1).

Takacs (In Press) provided the first estimate of juvenile abundance in the Edisto River. While estimates of juvenile abundance from other systems are often done by age class (i.e., age-1, age-2, age-3), estimates of age were not available in this study. Instead, the author estimated a "superpopulation" that is an estimate of the total number of juveniles (individuals less than or equal to 1,050 mm total length) that occupied the sampling area from May–September annually.

Table 1. Age-1 Captures and Juvenile Recruitment Estimates for Rivers of the South Atlantic DPS

River	Sampling Period	Total Number of Unique Age-1 Juveniles Captured During Sampling Period	Age-1 Abundance Extrapolation (Min.-Max.)	Reference
St. Johns	2014-2015	N/A	N/A	Fox et al 2018a
St. Marys	2013-2016	8	N/A	Fox et al. 2018b
Satilla	2008-2010	63	154 (108-231)	Fritts et al. 2016
	2014-2017	1-42	52-137 (24-272)	Fox et al. 2019
Altamaha	2004-2007	79-226	333-1,345 (246-1697)	Schueller and Peterson (2010)
	2014-2017	18-154	171-2,832 (63-5,798)	Fox et al. 2019
Ogeechee	2007	13	N/A	Farrae et al. 2009
	2014-2017	1-36	4-98 (2-238)	Fox et al. 2019
Savannah	2013-2020	48-300	353-1,075 (202-1346)	Bahr and Peterson 2016; Fox et al. 2020
Combahee-Salkehatchie	N/A	N/A	N/A	N/A
Edisto	1994-2019	N/A	N/A	Takacs (In Press)

An alternative to monitoring populations via juvenile recruitment is the genetically based, "effective population" size (N_e).[1] For the South Atlantic DPS, the 2017 Stock Assessment reported N_e for the Edisto, Savannah, Ogeechee, and Altamaha rivers (Table 2). Additional estimates of N_e have been conducted since the completion of the assessment, including for additional river systems; Table 2 reports those estimates. White et al. (2021) cautions that because the populations they considered were sampled at varying temporal scales and intensities and represented a mixture of single and mixed-cohort samples, the N_e estimates they report should be interpreted with reservation, as they technically represent a value between true N_e and the effective number of breeders. They also state that while their estimates are valuable for comparing the general magnitude of difference among populations, they should not be used to make inferences about long-term population viability (White et al. 2021).

[1] Effective population size is the number of individuals that effectively participates in producing the next generation. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/effective-population-size. More specifically, based on genetic differences between animals in a given year, or over a given period of time, scientists can estimate the number of adults needed to produce that level of genetic diversity. The effective population size is less than the total number of reproductively-active individuals in the population.

Table 2. Estimates of Effective Population Size by Rivers

River	Effective Population Size (N_e) (95% CI)	Sample Size	Collection Years	Reference
Edisto	55.4 (36.8-90.6)	109	1996-2005	ASMFC (2017)
	Fall Run – 48.0 (44.7-51.5)	1,154	1996-2004	Farrae et al. (2017)
	Fall Run (82 (60.3-122.1)	373	1996, 1998, 2001-2003, 2005	White et al. (2021)
	Spring Run – 13.3 (12.1-14.6)	198	1998, 2003	Farrae et al. (2017)
	Spring Run – 16.4 (12.8-20.6)	123	1998, 2003	White et al. (2021)
	60.0 (51.9-69.0)	145	1996, 1998, 2005	Waldman et al. (2018)
Savannah	126.5 (88.1-205)	98	2000-2013	ASMFC (2017)
	123 (103.1-149.4)	161	2013, 2014, 2017	Waldman et al. (2018)
	154.5 (99.6-287.7)	134	2000, 2007, 2208, 2013, 2017, 2018	White et al. (2021)
Ogeechee	32.2 (26.9-38.8)	115	2003-2015	ASMFC (2017)
	26 23.9–28.2	200	2007-2009, 2014-2017	Waldman et al. (2018)
	23.9 (22.2-25.7)	197	2007-2009, 2014-2017	Fox et al. (2019a)
	Spring Run – 31.1 (24.3-40.2)	92	2003, 2007, 2009, 2014, 2015, 2016	White et al. (2021)
	Fall Run – 56.5 (36.3-103.6)	55	2003, 2004, 2008, 2009, 2015, 2016	White et al. (2021)
Altamaha	111.9 (67.5-216.3)	186	2005-2015	ASMFC (2017)
	149 (128.7–174.3)	245	2005, 2011, 2014, 2016-2017	Waldman et al. (2018)
	142.1 (124.2-164.0)	268	2005, 2011, 2014-2017	Fox et al. (2019a)
	141.7 (73.4-399)	189	2005, 2010, 2011, 2018	White et al. (2021)
Satilla	21 (18.7–23.2)	68	2015-2016	Waldman et al. (2018)
	11.4 (9.1-13.9)	74	2010, 2014, 2016	White et al. (2021)
St. Marys	1 (1.3–2.0)	14	2014-2015	Waldman et al. (2018)

The estimates of effective population size, as well as new genetic analyses for sturgeon collected in mixed aggregations (Kazyak et al. 2021; Waldman et al. 2019), continue to support that the South Atlantic DPS is primarily comprised of Atlantic sturgeon that originate from the Altamaha, Edisto, and Savannah rivers. Section 2.3.1.5 provides additional results of genetic analyses for sturgeon captured from mixed aggregation areas within the marine range.

Hightower et al. (2015) estimated survival rates primarily for adults, but some subadults were included in their estimates for the Altamaha River and the Ashepoo-Combahee-Edisto (ACE) river basin. Apparent monthly survival exceeded 98% for the ACE (0.989; 95% CI=0.979–0.993), and Altamaha River (0.985; 95% CI=0.973–0.994); annual survival rates in the two regions were slightly lower 87.1% in the ACE Basin and 84.2% in the Altamaha River (Hightower et al. 2015). Survival estimates for other rivers in the South Atlantic DPS are not currently available.

The Stock Assessment considered the survival rate for the South Atlantic DPS as whole. The Stock Assessment estimated the mean survival rates of 83% and 59% for acoustically-tagged adults and acoustically-tagged juveniles from the South Atlantic DPS, respectively.[2] The ASMFC also concluded that there is a relatively low likelihood (40% probability) that mortality

[2] ASMFC (2017) actually estimated the morality rate for the DPS (Z=0.15 [95% CI=0.01-0.87]) which we converted to a survival rate (1-Z = survival rate).

for the South Atlantic DPS exceeds the mortality threshold used for the Stock Assessment (ASMFC 2017).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.)

The results of recent genetic analyses have confirmed limited gene flow between the riverine populations and overall, the spawning populations are genetically distinct (Kazyak et al. 2021; Waldman et al. 2019; White et al. 2021)

Kazyak et al. (2021) presented the first comprehensive mixed stock analysis of Atlantic sturgeon in the Southeast, since listing. The analysis considered Atlantic sturgeon genetic samples collected in both riverine/estuarine and marine environments along the East Coast. Kazyak et al. (2021) confirmed that while Atlantic sturgeon are making long-distance migrations, stock composition is best assessed at a regional level, with relatively little mixing of stocks in the Southeast. Of the 513 samples assigned to the “South” region (Cape Hatteras, NC to FL) the most common DPS was South Atlantic (91.2%, n=468) followed by Carolina DPS (6.2%; n=32), with only 2.6% (n=13) of the samples originating from other DPSs (Kazyak et al. 2021).

Within the South Atlantic DPS, the relative proportion of individuals that assigned to each riverine population in the DPS corresponded roughly to the overall abundance of the population (Kazyak et al. 2021). For example, the greatest proportion of individuals were from the Altamaha River population, which is thought to currently host one of the largest populations of Atlantic sturgeon (Kazyak et al. 2021; Peterson et al. 2008). Kazyak et al. (2021) reported individuals from the fall-spawn Edisto population were the next most abundant, followed by individuals from the Savannah, Ogeechee, and Satilla rivers, respectively. However, Kazyak et al. (2021) note that assignments to specific populations within the South Atlantic DPS should be viewed with some caution, because populations within this area have the lowest levels of genetic differentiation observed in the species (ASSRT 2007).

White et al. (2021) noted that the riverine populations of the South Atlantic DPS seem to be more closely related to one another than riverine populations of the mid and northern DPSs. Of note is that rivers in the South Atlantic DPS have relatively undefined, braided channels that lead to common estuaries, and most rivers are connected by the Intracoastal Waterway (Kazyak et al. 2021). This may facilitate interaction between riverine populations.

As noted in Section 2.3.1.1., genetic evidence also supports dual spawning runs (fall and spring) in the Edisto River (Farrae et al. 2017) and the Ogeechee River (White et al. 2021). White et al. (2021) also found evidence of a potential dual spawning run in the Satilla River, but data limitations prevented them from confirming it and an alternative hypothesis (i.e., the presence of non-natal individuals or other genetic phenomena) could explain the genetic differences they noted.

While not inclusive of all the spawning rivers in the South Atlantic DPS, the estimates reported in Table 2 suggest there is a risk for inbreeding depression ($N_e < 100$) in four of those rivers (Edisto, Ogeechee, Satilla, and St. Marys rivers) and loss of evolutionary potential ($N_e < 1000$) in all six (ASMFC 2017; Frankham et al. 2014).[3] However, White et al. (2021) report, that while historical comparisons are not available, the South Atlantic DPS river populations they surveyed (i.e., Edisto River (Spring), Edisto River (Fall), Savannah River, Ogeechee River (Spring), Ogeechee River (Fall), Altamaha River, and Satilla River) showed reasonably high levels of contemporary genetic diversity and low inbreeding despite relatively recent and severe demographic bottleneck events and small estimated effective population sizes. We do not have information to inform whether the South Atlantic DPS is negatively affected by the reduced genetic variation.

2.3.1.4 Taxonomic classification or changes in nomenclature

There are no changes in taxonomic classification or changes in nomenclature for the South Atlantic DPS of Atlantic sturgeon. Additional genetic analyses conducted by ASMFC (2017), Kazyak et al. (2021), and White et al. (2021) continue to support the existing genetic designations of the Atlantic sturgeon DPSs, first suggested in 2007. This information also indicates the initial listing continues to accurately describe the geographic groups of Atlantic sturgeon encountered along the U.S. Atlantic coast (ASMFC 2017). As described in Section 2.3.1.5, there is additional, new information that supports our conclusion in the listing rule that the South Atlantic DPS persists in an ecological setting unusual or unique for the taxon, and loss of the DPS would result in a significant gap in the range of the taxon.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.)

New information is available that better informs the marine range of the South Atlantic DPS. Based on genetic analyses, Atlantic sturgeon belonging to the South Atlantic DPS have been identified among individuals captured off the coasts of Massachusetts, Rhode Island, New Jersey, Delaware and Virginia (Kazyak et al. 2021) and even proposed offshore wind lease areas near New York (Kazyak et al. 2020). However, the South Atlantic DPS was most prevalent in southern marine waters, bays, and sounds (Dunton et al. 2012; Waldman et al. 2013; Wirgin et al. 2015a; Wirgin et al. 2015b; Wirgin et al. 2012; Wirgin et al. 2018).

Kazyak et al. (2021) also provides further evidence that the river of origin influences the distribution of Atlantic sturgeon in the marine environment. Atlantic sturgeon that originate from each of the five DPSs and from the Canadian rivers were represented in the 1,704 samples analyzed for the study. However, there were statistically significant differences in the spatial distribution of each DPS, and individuals were most likely to be assigned to a DPS in the same general region where they were collected. For the South Atlantic DPS, the results support the findings of previous genetic analyses that Atlantic sturgeon belonging to the DPS are most prevalent in the waters off North Carolina (south of Cape Hatteras), South Carolina, Georgia, and Florida (Kazyak et al. 2021).

[3] Generally, a minimum N_e of 100 individuals is considered the threshold required to limit the loss in total fitness from in-breeding depression to <10%; while an N_e greater than 1,000 is the recommended minimum to maintain evolutionary potential (ASMFC 2017; Frankham et al. 2014). N_e is useful for defining abundance levels where populations are at risk of loss of genetic fitness.

Data collected from telemetry arrays continue to enhance our understanding of when Atlantic sturgeon occur in offshore waters and the depths they prefer. Multiple studies have reinforced our understanding that Atlantic sturgeon occur further offshore in the late fall and winter months than in the spring and summer (Arendt et al. 2017; Rothermel et al. 2020; Rulifson et al. 2020; Williams et al. 2019). Additionally, acoustic telemetry arrays off South Carolina/Georgia (Arendt et al. 2017) and Gray's Reef National Marine Sanctuary (Williams et al. 2019) have detected tagged Atlantic sturgeon as far as 19 miles (31 kilometers) offshore, though approximately 80% of detections were recorded within 14 miles from shore (Arendt et al. 2017). Williams et al. (2019) reported detections occurring in waters 70 ft. (21 meters) or shallower, which is consistent with previously observed depth range preferences for Atlantic sturgeon.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem)

Since listing, Litts and Kaeser (2016) mapped almost 600 river miles (961 river kilometers) of benthic habitat in the Savannah, Oconee, Ocmulgee, and Altamaha rivers. The authors determined the Ocmulgee and Oconee rivers had the greatest overall percentage of "hard substrates" respectively, followed by the Savannah River and the Altamaha River (Litts and Kaeser 2016). Bunch (2020) used side scan sonar to refine the hard substrate areas identified by Litts and Kaeser (2016) in the Ocmulgee, Oconee, and Altamaha rivers to determine where Atlantic sturgeon were most likely to occur during putative spawning runs.

We designated critical habitat for the South Atlantic DPS in the Edisto River (including the North Fork Edisto River, South Fork Edisto River, North Edisto River and South Edisto River, Combahee River, Salkehatchie River, Savannah River, Ogeechee River, Altamaha River (including the Oconee River and Ocmulgee River), Satilla River and St. Marys River based on the best available information (82 FR 39160; August 17, 2017). In total, these designations encompass approximately 1,791 miles (2,883 kilometers) of aquatic habitat that is essential to the recovery of the South Atlantic DPS.

As described in Section 2.3.1.5, there is new information describing the distribution of South Atlantic DPS Atlantic sturgeon, particularly in marine waters. We did not designate critical habitat in marine waters, bays, or sounds despite evidence that Atlantic sturgeon belonging to the South Atlantic DPS are prevalent in certain areas because we are required to designate critical habitat based on the physical or biological features that are essential, and not based solely on the presence of the listed species. The available information was too limited to inform what the physical or biological features are in the marine environment, bays, or sounds that are essential to the South Atlantic DPS. Section 2.3.2 provides information for on-going and emerging threats to designated critical habitat and the habitats that are otherwise used by the South Atlantic DPS.

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

Section 4(a)(1) of the ESA requires the Services to determine whether a species is endangered or threatened because of any of the following factors (or threats) alone or in combination:

A. The present or threatened destruction, modification, or curtailment of its habitat or range;
B. Overutilization for commercial, recreational, scientific, or educational purposes;
C. Disease or predation;
D. Inadequacy of existing regulatory mechanisms to address identified threats; or
E. Other natural or human factors.

New information relative to each of these factors and the status of the South Atlantic DPS are described below.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range

Summary of Factor A: We described in the ESA-listing rule that dams, dredging, and water quality (e.g., dissolved oxygen levels, water temperature, and contaminants) and water quantity are threats that affect the habitat or range of the South Atlantic DPS. We anticipated that potential changes in water quality/quantity because of global climate change will likely affect the South Atlantic DPS and those effects are likely to be more severe in areas that are already subject to poor water quality because of eutrophication.

New information is available for the effects of these threats to the South Atlantic DPS, and the actions taken to address the threats. Since the listing, we have consulted with the United States Army Corp of Engineers (USACE) and the Bureau of Ocean Energy Management (BOEM) Marine Minerals Program under Section 7 of the ESA to consider the effects of on-going activities in the Southeast United States from the North Carolina/Virginia Border through and including Key West, Florida and the Islands of Puerto Rico and the U.S. Virgin Islands. The activities considered included: dredging (maintenance dredging, dredging/sand mining in borrow sites, and restoration dredging/muck dredging to improve water quality); dredge material placement (sand placement for beach nourishment, nearshore placement, placement in in ocean dredged material disposal site (ODMDS), upland placement, transportation of materials between dredging and material placement locations); geotechnical and geophysical (G&G) surveys, conducted by USACE, necessary to complete dredging and material placement projects (NMFS 2020).

There is also new information describing the behavior of Atlantic sturgeon in the James River during dredging operations. The results of Reine et al. (2014) and Balazik et al. (2020) show that hydraulic-cutterhead dredging in the James River federal navigational channel does not pose a barrier, either via the sound or turbidity plume produced by dredging, to Atlantic sturgeon movements within the river. Even spawning adults made their usual upriver movements past the dredge activity to the spawning grounds. Both studies demonstrated that the sturgeon were neither avoiding nor attracted to the dredge activity. While the James River is not within the range of the South Atlantic DPS, we have no reason to believe Atlantic sturgeon from the South Atlantic DPS will behave any differently when exposed to similar dredging operations under similar conditions. The study results, and our assumption about the behavior of fish from the South Atlantic DPS, support the conclusions of NMFS (2020) that the effects of regular, on-going maintenance dredging in rivers of Southeast are unlikely to pose a barrier to Atlantic sturgeon from South Atlantic DPS within rivers where these activities occur. However, takes (e.g., capture and killing) of Atlantic sturgeon might occur in the dredge gear. The biological opinion describes the anticipated observed and unobserved lethal take of Atlantic sturgeon belonging to the South Atlantic DPS at 73 Atlantic sturgeon from dredging entrainment every 3 years (NMFS 2020). Our consultation with the USACE on the effects of the ongoing maintenance dredging, dredge material placement, and G&G surveys concluded that the proposed activities may adversely affect but would not jeopardize the continued existence of the South Atlantic DPS, and were not likely to adversely affect the DPS's designated critical habitat. Additional information is available at https://www.fisheries.noaa.gov/content/endangered-species-act-section-7-biological-opinions-southeast.

In addition to maintenance dredging, we continue to monitor impacts from port deepenings within the South Atlantic DPS. Port deepenings are required to ensure the next generation of large shipping vessels can access ports efficiently. However, these deepenings can reduce dissolved oxygen concentrations in the bottom of the water column, reduce tidal exchange in the estuary, and induce upstream movement of the fresh water/salt water interface. These environmental changes can affect the distribution of Atlantic sturgeon within river systems and force them into less suitable habitats, an effect documented in shortnose sturgeon during a previous port deepening of the Savannah River (Collins et al. 2001; Hall et al. 1991). Larger vessels calling upon deeper ports may also increase threats from vessel strikes.

Within the South Atlantic DPS, the New Savannah Bluff Lock and Dam on the Savannah River is a known barrier that curtails the range of the Atlantic sturgeon. The dam blocks access to approximately 20 river miles (32 river kilometers) of additional habitat. As part of the ESA Section 7 consultation for the Savannah Harbor Expansion Project, we issued a biological opinion requiring the USACE to construct a fish passage structure at the New Savannah Bluff Lock and Dam that is capable of allowing Atlantic sturgeon of passing upstream of the lock and dam (NMFS 2017). A design for the fish passage structure was completed and its construction was slated to begin in 2020 before litigation halted construction. Construction remains suspended while the issue is resolved in court. Anecdotal reports suggest Atlantic sturgeon may travel to the base of the Juliette Dam on the Ocmulgee River and the Sinclair Dam on the Oconee River. We are still investigating these reports and it is currently unclear whether these dams are blocking upstream passage for Atlantic sturgeon in these river systems.

We continue to consult with federal agencies on other actions that may affect Atlantic sturgeon belonging to the South Atlantic DPS. A list of our most frequently requested biological opinions is available at https://www.fisheries.noaa.gov/content/endangered-species-act-section-7-biological-opinions-southeast.

Since listing, we designated critical habitat for the South Atlantic DPS (82 FR 39106; August 17, 2017). As part of the designation, we determined that an essential feature of critical habitat for the South Atlantic DPS is water between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, and dissolved oxygen values that, combined, support the DPS's spawning, survival, growth, development, and recruitment. We did not establish specific water quality criteria for this feature of the critical habitat designation because temperature and dissolved oxygen concentrations are ephemeral by nature, fluctuating daily and seasonally in estuaries and rivers. However, based on the work of the EPA (2003), we provided specific dissolved oxygen concentration and temperature values, along with estimates of the general duration these conditions should be met, as examples and guidance to inform the combinations of temperature and dissolved oxygen that support successful Atlantic sturgeon reproduction and recruitment.

The South Atlantic DPS represents the southern end of the known range of Atlantic sturgeon. Given their location, individuals from the South Atlantic DPS experience different climatic conditions than individuals from northern DPSs. For example, each year as water temperatures naturally increase in the summer, concomitant decreases in dissolved oxygen concentration are also noted across many rivers systems within the South Atlantic DPS (Fritts and Peterson 2010). Clinal differences in other life history characteristics such as spawning timing (Kynard 1997), growth rates, and age at maturity (Scott and Crossman 1973; Smith et al. 1982; Young et al. 1988) have been noted across different populations of Atlantic sturgeon. It is possible that similar clinal differences in low dissolved oxygen/high water temperature tolerance exist, given the frequency with which Atlantic sturgeon in the South Atlantic DPS are exposed to low concentrations during the summer. If so, Atlantic sturgeon from the South Atlantic DPS may have a higher tolerance for lower dissolved oxygen concentrations and higher water temperatures than Atlantic sturgeon from more northern DPSs.

Water allocation issues continue to pose a threat to the South Atlantic DPS. Taking water from one basin within the DPS and transferring it to another fundamentally and irreversibly alters natural water flows in both the originating and receiving basins. This transfer can affect dissolved oxygen levels, temperature, and the ability of the basin of origin to assimilate pollutants (GWC 2006). Water is also withdrawn directly from river systems to meet industrial and municipal needs. For example, over 630 million gallons per day are permitted to be withdrawn from the Savannah River for power generation, municipal uses, and industrial uses in the state of Georgia (https://epd.georgia.gov/watershed-protection-branch-lists), exclusive of South Carolina water needs. The removal of large amounts of water from the system alters flows, temperature, and dissolved oxygen. Water shortages and "water wars" have already occurred in the Southeast and will likely be compounded in the future by human population growth and potentially by climate change.

Since listing, more information has become available regarding the potential effect of climate change on Atlantic sturgeon, but there is still relatively little information available specific to the South Atlantic DPS. Hare et al. (2016) evaluated the vulnerability of Atlantic sturgeon to climate change on the Northeast U.S. Shelf. Based on their comprehensive assessment, Hare et al. (2016) determined that Atlantic sturgeons are highly vulnerable to climate change. Contributing factors include their low potential to change distribution in response to climate change (e.g., spawning locations are specific to a DPS within a specific geographic region), and their exposure to climate change throughout their range, including in estuarine and marine waters. Hare et al.

(2016) did not evaluate vulnerability to climate change by DPS. However, we believe the same factors that broadly contribute to the vulnerability of Atlantic sturgeon to climate change will affect the South Atlantic DPS specifically. Shein et al. (2019) conducted a vulnerability assessment for Atlantic sturgeon occurring near Gray's Reef National Marine Sanctuary, which is located very close to river systems of the South Atlantic DPS. The authors also concluded that Atlantic sturgeon likely to be from the South Atlantic DPS have a moderate to high relative vulnerability to climate change due to life history stages spent in estuaries and rivers where climate stressors are anticipated to be felt acutely (i.e., changes in precipitation patterns will affect river flow) (Shein et al. 2019). New information is also becoming available on the environmental cues (i.e., river discharge, water temperature) that may trigger specific spawning behaviors in fish of the South Atlantic DPS (Vine et al. 2019). Climate change is likely to affect these environmental factors, which may ultimately lead to impacts to timing, duration, and success of spawning of fish from the South Atlantic DPS.

Conclusion of Factor A: Maintenance dredging continues to be a stressor for the South Atlantic DPS throughout its range, particularly in the areas nearest to and within the rivers that support spawning habitat. The new information suggests that dredging may pose less of a stressor with respect to being a barrier to sturgeon movements. However, takes of Atlantic sturgeon in dredge gear still occur. Port deepenings are also leading to environmental changes that may reduce suitable habitats, and may increase the risk of vessels strikes, both of which can affect the South Atlantic DPS. Blocked access to historical spawning habitat continues to be an issue in the Savannah River, while water quality continues to be a stressor across the entire South Atlantic DPS. New information suggests that the DPS will be more negatively affected by climate change than what we anticipated when we listed the DPS as endangered.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

Summary of Factor B: A moratorium on the possession and retention of Atlantic sturgeon had already terminated directed harvest of Atlantic sturgeon when we listed the five DPSs. However, bycatch in federal- and state-regulated fisheries continued to occur and we considered fisheries bycatch to be one of the primary threats to the South Atlantic DPS. For example, Wirgin et al. (2015b) found that the South Atlantic DPS was the second-largest contributor to marine bycatch of Atlantic sturgeon in several U.S. commercial fisheries.

We completed several biological opinions after the ESA-listings that document our conclusions on the anticipated effects of the federally-managed fisheries on the Atlantic sturgeon DPSs. Table 3 reports the biological opinions for federal fisheries or fisheries operating under federal gear regulations, along with authorized incidental takes for Atlantic sturgeon from the South Atlantic DPS. In all instances, the biological opinions concluded the anticipated level of take would not decrease the likelihood that the South Atlantic DPS will continue to persist into the future and will retain sufficient resilience to allow for its potential recovery. The take estimates for opinions completed before 2021 are not directly comparable to those completed later because the approach for distributing the total take among the DPSs changed based on the new information in Kazyak et al. (2021).

Table 3. Federal Fisheries Authorizing the Incidental Take of Atlantic Sturgeon from the South Atlantic DPS.

Fishery/Action	Anticipated Incidental Take of Atlantic Sturgeon from the South Atlantic DPS	Year Biological Opinion Completed
Southeastern U.S. Shrimp Fishery	103 total over 5 years; up to 24 over which may be mortalities	2021
Highly Migratory Species – Atlantic Shark and Smoothound Fisheries	63 total over 3 years; up to 12 of which may be mortalities	2012
Highly Migratory Species – Tuna, Swordfish, Billfish and Shark Fisheries	75 total over 3 years; up to 19 of which may be mortalities	2020
Coastal Migratory Pelagic Fishery in the Atlantic and Gulf of Mexico	Up to 10 total over 3 years; no mortalities anticipated	2015
Northeast multispecies, monkfish, spiny dogfish, Atlantic bluefish, Northeast skate complex, mackerel/squid/butterfish, and summer flounder/scup/black sea bass fisheries	79 total over 5 years; up to 9 of which may be mortalities	2021
Northeast Atlantic Sea Scallop Fishery	Up to 5 total over 5 years; 1 of which may be a mortality every 20 years	2021
NMFS Gear Regulations in the Virginia Pound Net Fishery	Up to 3 total every year; up to 2 mortalities may occur every 10 years.	2018

Scientific research not deliberately targeting sturgeon does occasionally capture Atlantic sturgeon during the course of the normal research activities. Biological opinions considering the potential impacts from these activities on Atlantic sturgeon from the South Atlantic DPS have also been completed and are reported in Table 4.

Table 4. Research Activities that may Incidentally Capture Atlantic Sturgeon from the South Atlantic DPS.

Research Activity	Anticipated Incidental Take of Atlantic Sturgeon from the South Atlantic DPS	Year Biological Opinion Completed
Continued Authorization and Implementation of National Marine Fisheries Service' s Integrated Fisheries Independent Monitoring Activities in the Southeast Region	Up to 30 over 5 years; up to 5 of which may be mortalities	2016
United States Fish and Wildlife Service Funding of Georgia Department of Natural Resources to Collect, Analyze and Report Biological and Fisheries Information to Describe the Conditions or Health of Recreationally Important Finfish	Up to 16 over 5 years; no mortalities are anticipated	2017
Marine Recreational Fishery Statistical Data Collection Survey in the State of Florida	Up to 1 every 3 years; no mortalities are anticipated	2019
Fisheries and Ecosystem Research to be Conducted and Funded by the Northeast Fisheries Science Center and the Issuance of a Letter of Authorization under the Marine Mammal Protection Act for the Incidental Take of Marine Mammals Pursuant to those Research Activities from 2021-2026	Up to 33 every 5 years; up to 2 of which may be mortalities	2021

Research for gear modifications that could reduce the capture of Atlantic sturgeon in the federally managed gillnet fisheries has been conducted but management measures have not been implemented based on the results. Additional research into gear modifications began in 2022 under ESA permit number 24387. Research has also been conducted to test a modified gillnet for the state-managed fishery for striped bass in the James River. The raised footrope design had reduced sturgeon bycatch by 64.3% and increased landings of striped bass (i.e., the targeted species) by 45.6% compared to the conventional fishing gear (Hager et al. 2021). While not specific to Atlantic sturgeon from South Atlantic DPS, we anticipate these gear modifications will also benefit individuals from South Atlantic DPS.

NOAA Fisheries also issues permits under Section 10(a)(1)(B) of the ESA. These "Incidental Take Permits (ITPs)" are required for any take of an endangered or threatened species incidental to, and not the purpose of, an otherwise lawful activity. These permits are issued for non-federal activities. They are commonly issued for state-managed commercial fisheries where Atlantic sturgeon may be incidentally captured during otherwise legal fishing targeting other species. ITPs must be requested and include a conservation plan prepared by the applicant that describes measures designed to monitor, minimize, and mitigate the incidental take of ESA-listed species. We can issue an ITP if: the following conditions are met: the associated taking will occur incidental to an otherwise legal activity, the permit applicant will minimize and mitigate the impacts of such taking to the maximum extent practicable, the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild, and the applicant ensures that the minimization and mitigation measures will be implemented. There are currently two ITPs for the anticipated incidental take of Atlantic sturgeon belonging to the South Atlantic DPS for some state-managed fisheries in North Carolina and Georgia. The state of South Carolina has also submitted an application for a Section 10(a)(1)(B) permit for the incidental capture of Atlantic sturgeon in their state shad fishery; that application is under review. Details for each of the permits are available at https://www.fisheries.noaa.gov/national/endangered-species-conservation/incidental-take-permits.

There are anecdotal as well as documented reports of Atlantic sturgeon caught on recreational fishing gear. All state waters in which Atlantic sturgeon occur require that the fish be immediately released from the gear. In addition, NOAA Fisheries provides information on safely releasing Atlantic sturgeon from recreational fishing gear. Based on social media posts and voluntary reports to us, recreational fishers generally comply with the regulations and guidance; however, there have been instances of angler confusion regarding what to do with an incidentally captured Atlantic sturgeon.

Aside from the incidental capture of Atlantic sturgeon during activities targeting other species, NOAA Fisheries also issues a handful of ESA Section 10(a)(1)(A) permits authorizing the *purposeful or direct* take of Atlantic sturgeon for scientific purposes or to enhance their propagation or survival. The process for issuing these scientific research permits considers the number of permits that have already been issued and the take allowance on each permit. Requested take for live, wild sturgeon typically includes activities such as capture and temporary retention of the sturgeon to obtain data (e.g., length and weight measurements), to collect samples (e.g., fin clips for genetic analysis, fin spine samples for ageing), and to apply external and/or internal tags. Guidelines for when and how to conduct the procedures were made available before the ESA-listing (see Damon-Randall et al. (2010) and Kahn and Mohead (2010)). Studies conducted by Crossman et al. (2013) demonstrated internally placed acoustic tags are safe for sturgeon. Similarly, Matsche (2011) and Matsche (2013) provided evidence that laparoscopy, another commonly used surgical procedure for wild Atlantic sturgeon, is also safe. Since the ESA-listing, electronarcosis has become the preferred anesthetic for these surgical procedures because it has faster induction and recovery times, and reduced physiological effects compared to MS-222, the previously preferred anesthetic (Balazik et al. 2013; Matsche 2011; Matsche 2013). Balazik (2015) reported electronarcosis did not affect sturgeon spawning behavior when it is used for brief invasive procedures of wild-caught Atlantic sturgeon during the spawning season.

There are currently two active Section 10(a)(1)(A) permits that authorize directed scientific research on Atlantic sturgeon from South Atlantic DPS specifically. There is also a single Section 10(a)(1)(A) permit authorizing retention of captive bred Atlantic sturgeon from the South Atlantic DPS of scientific and research purposes. In addition, we possess a permit to salvage opportinistically found dead Atlantic sturgeon or mortalities from other actions (e.g., permitted research, fisheries bycatch, hatchery operations). By maximizing the use of these salvaged specimens through our large network of sturgeon researchers, we provide opportunities to obtain new information while reducing the need for taking (e.g., capture, collecting, sampling) living, wild specimens.

No permits authorizing the capture of wild Atlantic sturgeon and keeping them for the purpose of public display or for scientific research have been issued. Some Atlantic sturgeon that were brought into captivity before the ESA-listing are on public display for educational purposes or are housed for scientific research. All of the broodstock for these captive breeding research facilities originated from the South Atlantic DPS.

Conclusion for Factor B: The available information continues to support our conclusion in the listing rule that overutilization of the South Atlantic DPS is not occurring because of educational or scientific purposes. However, overutilization in terms of bycatch remains one of the primary stressors for the DPS. Based on the best available information, bycatch in federally-managed fisheries remains the highest enumerated take of Atlantic sturgeon belonging to the South Atlantic DPS among all known stressors. All of the Atlantic sturgeon that are killed as bycatch in federally-managed fisheries are subadults or adults. Bycatch in state-managed fisheries can take the earlier, juvenile, life stages depending on where and when those fisheries occur. There continues to be limited information by which to estimate the number of Atlantic sturgeon belonging to the South Atlantic DPS that are taken and killed because of fisheries bycatch. The lack of information hinders our ability to fully address this stressor.

2.3.2.3 Disease or predation

Summary of Factor C: We described in the listing rule that very little is known about natural predators of Atlantic sturgeon. After reviewing the limited information, we concluded that neither disease nor predation are considered primary factors affecting the continued persistence of the South Atlantic DPS of Atlantic sturgeon.

Hilton et al. (2016) reviewed diseases and parasites known to affect Atlantic sturgeon. There is no new information for the South Atlantic DPS.

Predation of early Atlantic sturgeon life stages by introduced, non-native, catfish species has been document in the Satilla River (Flowers et al. 2011) but the extent of the predation, is unknown (Hilton et al. 2016). The ASMFC reviewed but did not find new information that supports or refutes these discussions (ASMFC 2017). Bunch et al. (2021) report predation of Atlantic sturgeon eggs by common carp (*Cyprinus carpio),* striped bass (*Morone saxatilis)* and blue catfish (*Ictalurus furcatus)* in the Pamunkey River (Chesapeake Bay DPS). The amount Atlantic sturgeon egg predation in river systems of the South Atlantic DPS is currently unknown, though all three species identified by Bunch et al. (2021) exist in the DPS.

Conclusion for Factor C: The new, best available, information does not change our determination from the listing rule that neither disease nor predation are primary factors affecting the continued persistence of the South Atlantic DPS of Atlantic sturgeon. On-going work may provide further insight into the risk to Atlantic sturgeon early life stages from predation by the introduced catfish species.

2.3.2.4 Inadequacy of existing regulatory mechanisms

Summary of Factor D: The inadequacy of existing regulatory mechanisms was considered a primary stressor when we listed the South Atlantic DPS. We determined the failure of the South Atlantic DPS population to rebound despite harvest prohibitions established in the 1990s, along with the ongoing impacts from bycatch, habitat modification, were evidence the existing regulatory mechanisms and protective efforts to control or mitigate for these impacts were inadequate at the time of listing (77 FR 5914; February 6, 2012).

In general, the three fundamental regulatory mechanisms under authority of the ESA for addressing threats to listed species are through rulemaking, Section 7 consultation, and permitting. By statute, all endangered species, such as the South Atlantic DPS, are protected by a suite of prohibitions in Section 9 of the ESA. We have not conducted rulemaking to address any specific threat to Atlantic sturgeon from the South Atlantic DPS, beyond the Section 9 prohibitions. However, all biological opinions described in Section 2.3.2.1 and 2.3.2.2 include non-discretionary measures that must be enacted by the federal action agencies to ensure incidental takes of Atlantic sturgeon are minimized. While only applicable to the federal actions subject to those biological opinions, these requirements provide further protections for Atlantic sturgeon.

Information about bycatch of Atlantic sturgeon in state-managed fisheries remains meager. The relatively limited information on bycatch that is available is often from self-reporting by fishermen. As noted in the Stock Assessment, Atlantic sturgeon are not well-monitored by the existing fishery-independent and dependent data collection programs (ASMFC 2017). South Atlantic DPS Atlantic sturgeon are taken in Georgia's commercial shad state fisheries, South Carolina's commercial shad state fishery, and North Carolina's inshore gillnet state fisheries. The existing regulatory mechanism for addressing Atlantic sturgeon bycatch in state-managed fisheries is through issuance of an ESA Section 10 ITP (see Section 2.3.2.2). We have issued ITPs for the incidental take of Atlantic sturgeon (all DPSs) in the North Carolina commercial inshore gillnet fishery, and in the Georgia commercial shad fishery. As noted in Section 2.3.2.2, we are also currently reviewing a Section 10(a)(1)(B) permit application from the state of South Carolina requesting a permit for the incidental capture of Atlantic sturgeon in their commercial shad gill net fishery.

With respect to the federally-managed fisheries and as described in Section 2.3.2.2, we anticipate that Atlantic sturgeon belonging to the South Atlantic DPS are likely to be killed annually as a result of operation of the federally-managed fisheries described in Table 3. There have been some studies of relatively limited scope since the ESA-listing that investigated gillnet gear modifications to reduce sturgeon takes, and a single study to examine post-release mortality for sturgeon captured in gillnet gear (Bouyoucos et al. 2013; Fox et al. 2019b; Fox et al. 2013; Hager et al. 2021; He and Jones 2013). No regulatory measures have been implemented because of these studies.

Section 2.3.2.5 provides new information for the threat of vessel strikes to the South Atlantic DPS when the fish are in rivers, bays, and sounds. We have not conducted rulemaking to address the threat of vessel strikes for Atlantic sturgeon because we do not know what measures are necessary to reduce the number of or impact from vessel strikes. Methods which have been used for other species, such as reducing vessel speed or posting a lookout, are not practical in rivers where vessels may need to maintain a certain speed to safely operate, and where sturgeon are not visible below the surface.

Conclusion for Factor D: An inadequacy of existing regulatory mechanisms continues to be a stressor for the South Atlantic DPS. The existing regulatory mechanisms are not being fully utilized to address primary threats (e.g., bycatch in state- and federally-managed fisheries). A lack of critical information for the DPS (e.g., abundance) and the full extent of threats (e.g., the total number of South Atlantic DPS Atlantic sturgeon that are struck and killed by vessels or captured in fisheries) is hindering our ability to fully utilize the existing regulatory mechanisms.

2.3.2.5 Other natural or manmade factors affecting its continued existence

Summary of Factor E: At the time of listing, impingement and entrainment, vessel strikes, and artificial propagation were identified as potential other natural or manmade threats to the South Atlantic DPS. Information remains limited on the impacts of impingement/entrainment of Atlantic sturgeon. EPA issued final regulations (40 CFR 122 and 125; Rule) under Section 316(b) of the Clean Water Act that established requirements for cooling water intake structures (CWIS) at existing facilities. A part of those new requirements establishes that the owner or operator of a CWIS must monitor intakes to determine the level of impingement/entrainment, if any, of aquatic species, including any life stages of Atlantic sturgeon. To date, information regarding impingement/entrainment of Atlantic sturgeon collected from these CWIS, and elsewhere, remains limited.

New information suggests vessel strikes of Atlantic sturgeon occur more frequently and in more areas than what we anticipated when the South Atlantic DPS was listed as endangered. Multiple studies have shown that Atlantic sturgeon may not move away from vessels or avoid areas with vessel activity (Balazik et al. 2020; Balazik et al. 2017; Barber 2017; DiJohnson 2019; Reine et al. 2014). The best available information indicates sturgeon are struck by small (e.g., recreational) as well as large vessels. However, examination of the salvaged carcasses suggest that most fatalities are the result of the sturgeon being struck by a large vessel causing either blunt trauma injuries (e.g., broken scutes, bruising, damaged soft tissues) or propeller injuries (e.g., decapitation, complete transection of other parts of the sturgeon body, or deep slices nearly through the body depth of large sturgeon) (Balazik et al. 2012).

We have minimum counts of the number of South Atlantic DPS Atlantic sturgeon that are struck and killed by vessels because we can only count the sturgeon that are found dead with evidence of a vessel strike. New information from river systems outside the South Atlantic DPS suggests most Atlantic sturgeon carcasses are not found and, when found, many are not reported to us or to our sturgeon salvage co-investigators (Balazik et al. 2012; Fox et al. 2020b). Additionally, the geomorphology of the river systems in the South Atlantic DPS can make it difficult for sturgeon carcasses to be detected, potentially further compounding the issue of underreporting. In 2018, we augmented our efforts to increase public awareness regarding our desire to receive reports of sturgeon carcasses when found. Since then, the number of dead sturgeon reported in rivers of the South Atlantic has steadily increased, some of which show signs of vessel strikes. While it is unclear whether the increase in reported carcasses showing signs of vessels strikes reflects an actual increase in vessel struck sturgeon, or just an increase in reports, it is clear the number vessel struck Atlantic sturgeon from the South Atlantic DPS is greater than previously thought.

At the time of listing, we considered artificial propagation of Atlantic sturgeon for use in restoration of extirpated riverine populations or recovery of severely depleted wild riverine populations as both a potential threat to the species and a tool for recovery. There have been no artificial propagation programs for Atlantic sturgeon since the listings. However, we have received a number of reports from members of the Atlantic sturgeon scientific community regarding the advertised sale for the hobbyist aquarium trade of non-native, non-ESA listed, sturgeon species of the genus Acipenser. Hybridization between Acipenser species is known to occur (Ludwig et al. 2009), and hybridization has even occurred between an Acipenser species and American paddlefish (*Polyodon spathula*) (Káldy et al. 2020). There is no current information that any non-ESA listed Acipenser species has been intentionally or accidentally released into habitat used by the South Atlantic DPS of Atlantic sturgeon. However, the known risk of hybridization as well as other potential threats (such as competition for habitat or food resources) is a concern and a potential threat to the South Atlantic DPS that we were not aware of when we listed the DPS as endangered.

Conclusion for Factor E: Data remain limited on the impacts of impingement/entrainment, and artificial propagation, on the South Atlantic DPS. New information confirms that vessel strikes are a threat to the South Atlantic DPS and that the number of strikes is greater than what we anticipated when we listed the DPS. However, the impacts of vessels strikes on condition of the DPS as a whole, is not currently understood. The sale and trade of non-native Acipenser species poses a potential threat to the South Atlantic DPS.

2.4 Synthesis

Our recommended classification for the South Atlantic DPS of Atlantic sturgeon is "endangered" because the status of the DPS has not improved from what it was when we listed the DPS in 2012. The new information further supports our 2012 listing determination. Atlantic sturgeon belonging to the South Atlantic DPS are captured and killed because of fishery interactions, vessel strikes, and dredging. Their habitat, including critical habitat, continues to be lost or altered because of anthropogenic activities.

The number of spawning adults for the Altamaha River was recently estimated for the first time in a decade (Bunch 2020), but no other spawning run estimates are currently available. New genetic analyses estimating effective population sizes suggest there is a risk for inbreeding depression ($N_e < 100$) in the Edisto, Ogeechee, Satilla, and St. Marys rivers and loss of evolutionary potential ($N_e < 1000$) in the Savannah, Altamaha, Edisto, Ogeechee, Satilla, and St. Marys rivers (Table 2). At the time of listing the St. Marys River, population was thought to be extirpated, but a small extant population remains. At the time of listing, we estimated that abundances of most river populations in the South Atlantic DPS were less than 1% of their historical levels, while the Altamaha River population was suspected to be closer to 6% of its historical abundance. The information available since the time of listing show a mixed trend with some river systems remaining data poor, while others show some potential signs of recovery.

New information available since the listing has informed our understanding of which physical features in marine waters and estuaries are preferred by the South Atlantic DPS. The studies reporting this information demonstrate that the fish are selective of specific habitats with certain features that are often dynamic and only occur at specific times of the year. We have used this information, for example, to implement conservation measures to protect the South Atlantic DPS from dredge activities in certain rivers during times of year when environmental conditions are stressful. This information is also important for identifying and addressing existing and emerging threats to the DPS. The new information also indicates that all parts of the DPS's range and its designated critical habitat do not have equal value or provides different value to the DPS depending on the life stage present and time of year considered.

Certain river populations (i.e., St. Marys, Satilla, Ogeechee, and Combahee-Salkehatchie) within the South Atlantic DPS remain data poor. This has consequences for our suggestions of proactive conservation measures and our Section 7 consultations, which remains one of our most powerful tools to address the threats to the DPS.

3.0 RESULTS

3.1 Recommended Classification: No change is needed

3.2 New Recovery Priority Number: No change is needed

The South Atlantic DPS's demographic risk is "High" because of its productivity (i.e., relatively few adults compared to historical levels and irregular spawning success), abundance (i.e., riverine populations vary significantly and abundance is generally low in the DPS, overall), and spatial distribution (i.e., riverine populations and connectivity vary, creating inconsistent population coverage across the DPS and potentially limited ability to repopulate extirpated river populations). Meeting any one of these risk conditions ranks the South Atlantic DPS as at high demographic risk.

The South Atlantic DPS' potential to recover is, however, also "High" because man-made threats that have a major impact on the species' ability to persist have been identified (e.g., bycatch in fisheries, dams blocking access to spawning habitat, dredging, vessel strikes), the DPS' response to those threats are well understood, management or protective actions to address major threats are primarily under U.S. jurisdiction or authority, and management or protective actions are technically feasible even if they require further testing (e.g., gear modifications to minimize dredge or fishing gear interactions).

The DPS is in conflict with construction and other developmental projects such as port deepening projects and changes to the Savannah River because of continued industrialization and commercial shipping, along with water withdrawals. Therefore, based on the Listing and Recovery Priority Guidelines (84 FR 18243, April 30, 2019), the recovery priority number for the South Atlantic DPS is 1C, and is unchanged.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

NMFS, along with our conservation partners when appropriate, should identify what information is necessary to better inform Section 7 consultations that consider effects to the South Atlantic DPS and its designated critical habitat, and assess how to acquire the information within reasonable timeframes. Information needed regarding bycatch, vessel strike frequency, critical habitat destruction and alteration from federal activities, and climate change should be given the highest priority.

NMFS should develop a recovery plan for the South Atlantic DPS, with external individual expert advice or a recovery team, as needed.

NMFS should have at least one sturgeon expert at either the Northeast Fisheries Science Center or Southeast Fisheries Science Center to support the agency's scientific needs for the Atlantic sturgeon DPSs (e.g., for more frequent estimates of Atlantic sturgeon bycatch in the federally-managed fisheries) as it does for the other ESA-listed species, including other fish, whales, and sea turtles.

Juvenile recruitment and abundance sampling should continue, particularly in river systems with long-term datasets. Establishing an “index” system to systematically monitor juvenile recruitment and abundance across specific river systems over discrete periods should be considered.

NMFS and our conservation partners should seek to better understand survival and mortality rates of the South Atlantic DPS. As this information becomes available, NMFS should consider whether an elasticity analysis specifically considering the South Atlantic DPS, similar to Gross et al. (2002), should be pursued. We should also evaluate whether a population viability analysis (PVA) being developed for the closely related Gulf sturgeon could be modified to use with the South Atlantic DPS.

NMFS, along with our conservation partners, should support efforts to determine what combination of environmental variables (e.g., water temperature and river flow) most likely affect successful spawning and recruitment.

NMFS, along with our conservation partners, should support efforts to determine if individuals from the South Atlantic DPS have a higher tolerance for high water temperatures and low dissolved oxygen concentrations, than individuals from DPSs further north.

NMFS, along with our conservation partners when appropriate, should continue outreach efforts to inform the public of threats faced by sturgeon and our desire for the public to report sturgeon sightings/mortalities via the sturgeon reporting hotline.

NMFS should conduct a river-by-river threats assessment, with help from external experts, for each river within the South Atlantic DPS.

NMFS, along with our conservation partners, should continue to explore the use of side-scan sonar as population monitoring and habitat detection tool. NMFS should also promote work to increase the accuracy of side-scan sonar data in estimating sturgeon abundance.

NMFS, along with our conservation partners, should explore whether environmental DNA (eDNA) can be used to effectively detect and monitor South Atlantic DPS Atlantic sturgeon populations.

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW

South Atlantic Distinct Population Segment of Atlantic Sturgeon
(Acipenser oxyrinchus oxyrinchus)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

- [ ] Downlist to Threatened
- [ ] Uplist to Endangered
- [ ] Delist
- [x] No change is needed

Review Conducted By (Name and Office):

Andrew Herndon, Southeast Regional Office

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

for
Approve AMENDOLA.KIMBERLY.BARBARA.1365830769 Digitally signed by AMENDOLA.KIMBERLY.BARBARA.1365830769 Date: 2023.08.18 15:36:19 -04'00' Date: 8/18/23

Cooperating Regional Administrator, NOAA Fisheries

[ ] Concur [ ] Do Not Concur [ ] N/A

Signature____ Date: _______

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

[x] Concur [ ] Do Not Concur

Signature COIT.JANET.LOUISE.1605731623 Digitally signed by COIT.JANET.LOUISE.1605731623 Date: 2023.09.14 15:42:23 -04'00' Date: _______

5.0 REFERENCES

Arendt, M., W. C. Post, B. Frazier, M. Taliercio, D. J. Farrae, T. Darden, P. Geer, and C. Kalinowsky. 2017. Temporal and spatial distribution of Atlantic sturgeon (*Acipenser oxyrinchus*) in U.S. territorial waters off South Carolina and Georgia: Final (2013-2017) report to the National Marine Fisheries Service, National Oceanic and Atmospheric Administration. South Carolina Department of Natural Resources, Marine Resources Division and Georgia Department of Natural Resources, Grant Number NA13NMF4720045, Charleston, SC.

ASMFC. 2017. Atlantic Sturgeon Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission, Arlington, VA.

ASSRT. 2007. Status Review of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Regional Office, Atlantic Sturgeon Status Review Team, Gloucester, Massachusetts.

Bahr, D. L., and D. L. Peterson. 2016. Recruitment of juvenile Atlantic sturgeon in the Savannah River, Georgia. Transactions of the American Fisheries Society 145(6):1171-1178.

Bain, M., N. Haley, D. Peterson, J. R. Waldman, and K. Arend. 2000. Harvest and habitats of Atlantic sturgeon *Acipenser oxyrinchus* Mitchill, 1815 in the Hudson River estuary: lessons for sturgeon conservation. Boletín. Instituto Español de Oceanografía 16:43-53.

Balazik, M., M. Barber, S. Altman, K. Reine, A. Katzenmeyer, A. Bunch, and G. Garman. 2020. Dredging activity and associated sound have negligible effects on adult Atlantic sturgeon migration to spawning habitat in a large coastal river. PLOS ONE 15(3):e0230029.

Balazik, M., M. Barber, and G. Garman. 2017. Vessel related threats to reproductively active Atlantic sturgeon in a large coastal river system. Final Report. NOAA-NMFS Award No. NA16NMF4720358. .

Balazik, M., B. Langford, G. Garman, M. Fine, J. Stewart, R. Latour, and S. McIninch. 2013. Comparison of MS-222 and Electronarcosis as Anesthetics on Cortisol Levels in Juvenile Atlantic Sturgeon. Transactions of the American Fisheries Society 142:1640-1643.

Balazik, M. T. 2015. Capture and Brief Invasive Procedures Using Electronarcosis Does Not Appear to Affect Postrelease Habits in Male Atlantic Sturgeon During the Spawning Season. North American Journal of Fisheries Management 35(2):398-402.

Balazik, M. T., K. J. Reine, A. J. Spells, C. A. Fredrickson, M. L. Fine, G. C. Garman, and S. P. McIninch. 2012. The potential for vessel interactions with adult Atlantic sturgeon in the James River, Virginia. North American Journal of Fisheries Management 32(6):1062-1069.

Barber, M. R. 2017. Effects of Hydraulic Dredging and Vessel Operation on Atlantic Sturgeon Behavior in a Large Coastal River. Virginia Commonwealth University, Richmond, VA.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48(1):399-405.

Borodin, N. 1925. Biological observations on the Atlantic sturgeon (*Acipenser sturio*). Transactions of the American Fisheries Society 55(1):184-190.

Bouyoucos, I., P. Bushnell, and R. Brill. 2013. Potential for electropositive metal to reduce the interactions of Atlantic sturgeon with fishing gear. Conserv Biol 28(1):278-82.

Brown, J. J., and G. W. Murphy. 2010. Atlantic Sturgeon Vessel Strike Mortalities in the Delaware Estuary. Fisheries 35:72-83.

Bunch, A. J., K. B. Carlson, F. J. Hoogakker, L. V. Plough, and H. K. Evans. 2021. Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus Mitchill, 1815) early life stage consumption evidenced by high-throughput DNA sequencing. Journal of Applied Ichthyology 37(1):12-19.

Bunch, C. J. 2020. Using Side-Scan Sonar to Quantify the Spawning Runs of Atlantic Sturgeon in the Altamaha River, Georgia. University of GA, Athens, GA.

Caron, F., D. Hastin, and R. Fortin. 2002. Biological Characteristics of Adult Atlantic Sturgeon (Acipenser oxyrinchus) in the St Lawrence River Estuary and the Effectiveness of Management Rules. Journal of Applied Ichthyology 18:580-585.

Collins, M., B. Post, and D. Russ. 2001. Distribution of Shortnose Sturgeon in the Lower Savannah River - Results of Research Conducted 1999-2000 - Final Report to Georgia Ports Authority. South Carolina Department of Natural Resources, Charleston, SC.

Collins, M. R., S. G. Rogers, T. I. J. Smith, and M. L. Moser. 2000a. Primary factors affecting sturgeon populations in the southeastern United States: fishing mortality and degradation of essential habitats. Bulletin of Marine Science 66(3):917-928.

Collins, M. R., T. I. J. Smith, W. C. Post, and O. Pashuk. 2000b. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions of the American Fisheries Society 129(4):982-988.

Crance, J. H. 1987. Habitat suitability index curves for anadromous fishes. In: Common strategies of anadromous and catadromous fishes: proceedings of an International Symposium held in Boston, Massachusetts, USA, March 9-13, 1986. Pages 554 *in* M. J. Dadswell, editor. American Fisheries Society, Bethesda, Maryland.

Damon-Randall, K., R. Bohl, S. Bolden, D. Fox, C. Hager, B. Hickson, E. Hilton, J. Mohler, E. Robbins, T. Savoy, and S. Albert. 2010. Atlantic Sturgeon Research Techniques. . U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts

DiJohnson, A. M. 2019. Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) behavioral responses to vessel traffic and habitat use in the Delaware River, USA. Master's Thesis. Delaware State University, Dover, DE.

Dovel, W. L., and T. J. Berggren. 1983. Atlantic sturgeon of the Hudson Estuary, New York. New York Fish and Game Journal 30(2):140-172.

Dunton, K. J., D. Chapman, A. Jordaan, K. Feldheim, S. J. O'Leary, K. A. McKown, and M. G. Frisk. 2012. Genetic mixed-stock analysis of Atlantic sturgeon Acipenser oxyrinchus

oxyrinchus in a heavily exploited marine habitat indicates the need for routine genetic monitoring. Journal of Fish Biology 80(1):207-217.

EPA. 2003. Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. Region III Chesapeake Bay Program Office and Region III Water Protection Division, Washington, DC.

Farrae, D., P. Schueller, and D. Peterson. 2009. Abundance of Juvenile Atlantic Sturgeon in the Ogeechee River, Georgia. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 63:172-176.

Farrae, D. J., W. C. Post, and T. L. Darden. 2017. Genetic characterization of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus, in the Edisto River, South Carolina and identification of genetically discrete fall and spring spawning. Conservation Genetics 18(4):813-823.

Flowers, H. J., T. Bonvechio, and D. Peterson. 2011. Observation of Atlantic Sturgeon Predation by a Flathead Catfish. Transactions of the American Fisheries Society 140:250-252.

Fox, A., N. Hancock, A. Marbury, A. Kaeser, and D. Peterson. 2022. Recruitment and survival of juvenile Gulf sturgeon (Acipenser oxyrinchus desotoi) in the Apalachicola River in Florida. Fishery Bulletin- National Oceanic and Atmospheric Administration 119:243-254.

Fox, A. G., A. Cummins, D. L. Bahr, M. Baker, and D. Peterson. 2020a. Assessment of the Atlantic and Shortnose Sturgeon populations in the Savannah River, Georgia - Final Report. Warnell School of Forestry and Natural Resources - University of Georgia, Athens, GA.

Fox, A. G., D. Peterson, I. Wirgin, and A. Cummins. 2019a. Quantifying Annual Recruitment and Nursery Habitats of Atlantic Sturgeon in Georgia. National Marine Fisheries Service.

Fox, A. G., and D. L. Peterson. 2019. Movement and Out-Migration of Juvenile Atlantic Sturgeon in Georgia, USA. Transactions of the American Fisheries Society 148(5):952-962.

Fox, A. G., E. S. Stowe, K. J. Dunton, and D. L. Peterson. 2018a. Seasonal occurrence of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) in the St. Johns River, Florida. Fishery Bulletin 116(3):219-227.

Fox, A. G., I. I. Wirgin, and D. L. Peterson. 2018b. Occurrence of Atlantic Sturgeon in the St. Marys River, Georgia. Marine and Coastal Fisheries 10(6):606-618.

Fox, D., K. Dunton, and L. Bonacci. 2019b. Conservation engineering within the Monkfish Gillnet Fishery: Reducing negative fishery interaction through gear modifications and assessing post-release mortality and behavior of the endangered Atlantic sturgeon. NOAA-NMFS Saltonstall-Kennedy Grant Program Award No. NA14NMF4270036. .

Fox, D., E. Hale, and J. Sweka. 2020b. Examination of Atlantic sturgeon vessel strikes in the Delaware River Estuary. Final Report. NOAA-NMFS Award No. NA16NMF4720357. .

Fox, D. A., J. L. Armstrong, L. M. Brown, and K. Wark. 2013. Year Three, the Influence of Sink Gillnet Profile on Bycatch of Atlantic Sturgeon in the Mid-Atlantic Monkfish Fishery. .

Frankham, R., C. J. A. Bradshaw, and B. W. Brook. 2014. Genetics in conservation management: revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170:56-63.

Fritts, M., and D. Peterson. 2010. Status of Atlantic sturgeon and shortnose sturgeon in the St. Marys and Satilla Rivers, Georgia. Final report ot the National Marine Fisheries Service. Warnell School of Forestry and Natural Resources - University of Georgia.

Fritts, M. W., C. Grunwald, I. Wirgin, T. L. King, and D. L. Peterson. 2016. Status and Genetic Character of Atlantic Sturgeon in the Satilla River, Georgia. Transactions of the American Fisheries Society 145(1):69-82.

Gilbert, C. R. 1989. Species profiles : life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic Bight) : Atlantic and shortnose sturgeons. Coastal Ecology Group, Waterways Experiment Station, U.S. Dept. of the Interior, Fish and Wildlife Service, Research and Development, National Wetlands Research Center, Vicksburg, MS, Washington, DC.

Gross, M., J. Repka, C. Robertson, D. H. Secor, and W. Winkle. 2002. Sturgeon Conservation: Insights From Elasticity Analysis. American Fisheries Society Symposium 28.

GWC. 2006. Interbasin Transfer Fact Sheet. Georgia Water Coalition, http://www.garivers.org/gawater/pdf%20files/IBT%20fact%20sheet02-06.pdf.

Hager, C., J. C. Levesque, R. J. Dickey, and J. E. Kahn. 2021. Raised-Footrope Gill-Net Modification Significantly Reduces Subadult Atlantic Sturgeon Bycatch. North American Journal of Fisheries Management 41(1):19-25.

Hall, J. W., T. I. J. Smith, and S. D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon, *Acipenser brevirostrum* in the Savannah River. Copeia (3):695-702.

Hare, J. A., W. E. Morrison, M. W. Nelson, M. M. Stachura, E. J. Teeters, R. B. Griffis, M. A. Alexander, J. D. Scott, L. Alade, R. J. Bell, A. S. Chute, K. L. Curti, T. H. Curtis, D. Kircheis, J. F. Kocik, S. M. Lucey, C. T. McCandless, L. M. Milke, D. E. Richardson, E. Robillard, H. J. Walsh, M. C. McManus, K. E. Marancik, and C. A. Griswold. 2016. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLOS ONE 11(2):e0146756.

He, P., and N. Jones. 2013. Design and Test of a Low Profile Gillnet to Reduce Atlantic Sturgeon and Sea Turtle Bycatch in Mid-Atlantic Monkfish Fishery - FINAL REPORT.

Hightower, J. E., M. Loeffler, W. C. Post, and D. L. Peterson. 2015. Estimated Survival of Subadult and Adult Atlantic Sturgeon in Four River Basins in the Southeastern United States. Marine and Coastal Fisheries 7(1):514-522.

Hilton, E. J., B. Kynard, M. T. Balazik, A. Z. Horodysky, and C. B. Dillman. 2016. Review of the biology, fisheries, and conservation status of the Atlantic Sturgeon, (Acipenser oxyrinchus oxyrinchus Mitchill, 1815) Journal of Applied Ichthyology 32(S1):30-66.

Ingram, E. C., and D. L. Peterson. 2016. Annual Spawning Migrations of Adult Atlantic Sturgeon in the Altamaha River, Georgia. Marine and Coastal Fisheries 8(1):595-606.

Kahn, J. E., and M. Mohead. 2010. A Protocol for Use of Shortnose, Atlantic, Gulf, and Green Sturgeons. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

Káldy, J., A. Mozsár, G. Fazekas, M. Farkas, D. L. Fazekas, G. L. Fazekas, K. Goda, Z. Gyöngy, B. Kovács, K. Semmens, M. Bercsényi, M. Molnár, and E. Patakiné Várkonyi. 2020. Hybridization of Russian Sturgeon (Acipenser gueldenstaedtii, Brandt and Ratzeberg, 1833) and American Paddlefish (Polyodon spathula, Walbaum 1792) and Evaluation of Their Progeny. Genes (Basel) 11(7).

Kazyak, D., A. Aunins, R. Johnson, B. Lubinski, M. Eackles, and T. King. 2020. Using advanced population genomics to better understand the relationship between offshore and spawning habitat use for Atlantic sturgeon. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 62:70.

Kazyak, D. C., S. L. White, B. A. Lubinski, R. Johnson, and M. Eackles. 2021. Stock composition of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) encountered in marine and estuarine environments on the U.S. Atlantic Coast. Conservation Genetics 22(5):767-781.

Leland, J. G. 1968. A survey of the sturgeon fishery of South Carolina. Bears Bluff Laboratories, Wadmalaw Island, S.C.

Litts, T. L., and A. J. Kaeser. 2016. Mapping potential spawning substrate for Shortnose and Atlantic sturgeon in coastal plain rivers of Georgia using low-cost side-scan sonar. Journal of the Southeastern Association of Fish and Wildlife Agencies 3:80-88.

Ludwig, A., S. Lippold, L. Debus, and R. Reinartz. 2009. First evidence of hybridization between endangered sterlets (Acipenser ruthenus) and exotic Siberian sturgeons (Acipenser baerii) in the Danube River. Biological Invasions 11(3):753-760.

Matsche, M. A. 2011. Evaluation of tricaine methanesulfonate (MS-222) as a surgical anesthetic for Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus. Journal of Applied Ichthyology 27(2):600-610.

Matsche, M. A. 2013. Relative physiological effects of laparoscopic surgery and anesthesia with tricaine methanesulfonate (MS-222) in Atlantic sturgeon Acipenser oxyrinchus oxyrinchus. Journal of Applied Ichthyology 29(3):510-519.

NMFS. 2017. Amendment to the Biological Opinion for the Deepening of the Savannah Harbor Federal Navigational Channel in association with the Savannah Harbor Expansion Project (SHEP). NOAA Fisheries, St Petersburg, FL.

NMFS. 2020. South Atlantic Regional Biological Opinion for Dredging and Material Placement Activities in the Southeast United States (2020 SARBO). NOAA Fisheries, St. Petersburg, FL.

Peterson, D. L., P. Schueller, R. DeVries, J. Fleming, C. Grunwald, and I. Wirgin. 2008. Annual Run Size and Genetic Characteristics of Atlantic Sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society 137(2):393-401.

Reine, K., D. Clarke, M. Balzaik, S. O'Haire, C. Dickerson, C. Frederickson, G. Garman, C. Hager, A. Spells, and C. Turner. 2014. Assessing impacts of navigation dredging on

Atlantic sturgeon (*Acipenser oxyrinchus*): Final report. U.S. Department of Defense, Army Corps of Engineers, Engineer Research and Development Center, ERDC/EL TR-14-12.

Rothermel, E. R., M. T. Balazik, J. E. Best, M. W. Breece, D. A. Fox, B. I. Gahagan, D. E. Haulsee, A. L. Higgs, M. H. P. O'Brien, M. J. Oliver, I. A. Park, and D. H. Secor. 2020. Comparative migration ecology of striped bass and Atlantic sturgeon in the US Southern mid-Atlantic bight flyway. PLOS ONE 15(6):e0234442.

Rulifson, R. A., C. W. Bangley, J. L. Cudney, A. Dell'Apa, K. J. Dunton, M. G. Frisk, M. S. Loeffler, M. T. Balazik, C. Hager, T. Savoy, H. M. Brundage, and W. C. Post. 2020. Seasonal Presence of Atlantic Sturgeon and Sharks at Cape Hatteras, a Large Continental Shelf Constriction to Coastal Migration. Marine and Coastal Fisheries 12(5):308-321.

Schueller, P., and D. L. Peterson. 2010. Abundance and Recruitment of Juvenile Atlantic Sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society 139(5):1526-1535.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada., Fisheries Research Board of Canada Bulletin.

Shein, K., J. Cavanaugh, H. Scalliet, S. Hutto, K. Roberson, B. Shortland, and L. Wenzel. 2019. Rapid vulnerability assessment for Gray’s Reef National Marine Sanctuary. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.

Smith, T. I. J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Environmental Biology of Fishes 14(1):61-72.

Smith, T. I. J., and J. P. Clugston. 1997. Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48(1-4):335-346.

Smith, T. I. J., D. E. Marchette, and R. A. Smiley. 1982. Life history, ecology, culture and management of Atlantic sturgeon, Acipenser oxyrhynchus, Mitchill, in South Carolina. Final Report to U.S. Fish and Wildlife Service Resources Department.

Stevenson, J. C., and D. H. Secor. 1999. Age determination and growth of Hudson River Atlantic sturgeon (*Acipenser oxyrinchus*). Fishery Bulletin 97:153-166.

Takacs, M. In Press. Abundance and Recruitment of Juvenile Atlantic Sturgeon (*Acipenser oxyrinchus*) in the Edisto River, SC. Coastal Carolina University

USFWS, and NMFS. 2022. Gulf Sturgeon (Acipenser oxyrinchus desotoi) 5-Year Review: Summary and Evaluation.

Van Eenennaam, J., S. Doroshov, G. Moberg, J. Watson, D. Moore, and J. Linares. 1996. Reproductive conditions of the Atlantic sturgeon (*Acipenser oxyrinchus*) in the Hudson River. Estuaries and Coasts 19(4):769-777.

Vine, J. R., S. C. Holbrook, W. C. Post, and B. K. Peoples. 2019. Identifying Environmental Cues for Atlantic Sturgeon and Shortnose Sturgeon Spawning Migrations in the Savannah River. Transactions of the American Fisheries Society 148(3):671-681.

Vladykov, V. D., and J. R. Greeley. 1963. Order Acipenseroidei. Pages 24-60 *in* H. B. Bigelow, editor. Fishes of the Western North Atlantic, Part 3, First edition. Sears Foundation for Marine Research, Yale University, New Haven, CT.

Waldman, J., S. E. Alter, D. Peterson, L. Maceda, N. K. Roy, and I. Wirgin. 2018. Contemporary and historical effective population sizes of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus. Conservation Genetics.

Waldman, J., S. E. Alter, D. Peterson, L. Maceda, N. K. Roy, and I. Wirgin. 2019. Contemporary and historical effective population sizes of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus. Conservation Genetics 20(2):167-184.

Waldman, J. R., T. King, T. Savoy, L. Maceda, C. Grunwald, and I. Wirgin. 2013. Stock Origins of Subadult and Adult Atlantic Sturgeon, Acipenser oxyrinchus, in a Non-natal Estuary, Long Island Sound. Estuaries and Coasts 36(2):257-267.

White, S. L., D. C. Kazyak, T. L. Darden, D. J. Farrae, B. A. Lubinski, R. L. Johnson, M. S. Eackles, M. T. Balazik, H. M. Brundage, A. G. Fox, D. A. Fox, C. H. Hager, J. E. Kahn, and I. I. Wirgin. 2021. Establishment of a microsatellite genetic baseline for North American Atlantic sturgeon (Acipenser o. oxyrhinchus) and range-wide analysis of population genetics. Conservation Genetics.

Williams, B. L., K. K. W. Roberson, J. R. Young, and M. S. Kendall. 2019. Using Acoustic Telemetry to Understand Connectivity of Gray's Reef National Sanctuary to the U.S. Atlantic Coastal Ocean.

Wirgin, I., M. W. Breece, D. A. Fox, L. Maceda, K. W. Wark, and T. King. 2015a. Origin of Atlantic Sturgeon Collected off the Delaware Coast during Spring Months. North American Journal of Fisheries Management 35(1):20-30.

Wirgin, I., L. Maceda, C. Grunwald, and T. L. King. 2015b. Population origin of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus by-catch in U.S. Atlantic coast fisheries. J Fish Biol 86(4):1251-70.

Wirgin, I., L. Maceda, J. Waldman, S. Wehrell, M. Dadswell, and T. King. 2012. Stock Origin of Migratory Atlantic Sturgeon in Minas Basin, Inner Bay of Fundy, Canada, Determined by Microsatellite and Mitochondrial DNA Analyses. Transactions of the American Fisheries Society 141.

Wirgin, I., N. K. Roy, L. Maceda, and M. T. Mattson. 2018. DPS and population origin of subadult Atlantic Sturgeon in the Hudson River. Fisheries Research 207:165-170.

Young, J. R., T. B. Hoff, W. P. Dey, and J. G. Hoff. 1988. Management recommendations for a Hudson River Atlantic sturgeon fishery based on an age-structured population model. Fisheries Research in the Hudson River. State of University of New York Press, Albany, New York.