Carolina 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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1.0 GENERAL INFORMATION

The Carolina DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) from Albemarle Sound southward along the southern Virginia, North Carolina, and South Carolina coastal areas to Charleston Harbor. The Carolina DPS also includes: Atlantic sturgeon held in captivity (e.g., aquaria, hatcheries, and scientific institutions) that are identified as fish belonging to the Carolina DPS based on genetics 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 Carolina DPS, or is the progeny of any fish that originated from a river within the range of the Carolina 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 Carolina DPS of Atlantic sturgeon. We are required to consider new information that has become available since we listed the Carolina DPS of Atlantic sturgeon as endangered in February 2012. We reviewed and considered new information for the Carolina 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 made 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). Four of those included comments that specifically mentioned the Carolina 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 Carolina DPS: 77 FR 5914
Date listed: February 6, 2012
Entity listed: Carolina 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 Carolina DPS of Atlantic sturgeon in North Carolina and South Carolina. The designation encompasses approximately 1,939 kilometers (1,205 miles) of freshwater and tidally affected reaches of the Roanoke, Tar-Pamlico, Neuse, Northeast Cape Fear and Cape Fear, Pee Dee, Waccamaw, Bull Creek, Black, Santee (including the Rediversion Canal), North Santee, South Santee, and Cooper/West Branch Cooper (including the Tailrace Canal) rivers. All of the critical habitat units are in the geographic area occupied by the Carolina 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 Carolina 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 Carolina 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 Carolina 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 Carolina DPS.

2.3.1 Biology and Habitat for the Carolina DPS of Atlantic Sturgeon

The Carolina 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 Carolina DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) from Albemarle Sound southward along the southern Virginia, North Carolina, and South Carolina coastal areas to Charleston Harbor (77 FR 5914; February 6, 2012). At the time of listing, we identified seven rivers/river systems within the Carolina DPS where spawning is likely occurring (Roanoke; Tar-Pamlico; Neuse; Cape Fear and Northeast Cape Fear; Pee Dee, Waccamaw, Bull Creek; Black; Santee, and Cooper). Historically, both the Sampit and Ashley Rivers in South Carolina were documented to have spawning populations. Yet, the spawning population in the Sampit River is believed to be extirpated and the current status of the spawning population in the Ashley River is unknown. Both rivers may be used as nursery habitat by young Atlantic sturgeon originating from other spawning populations.

Across all DPSs, spawning is believed to occur in flowing water between the salt wedge 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 likely use the brackish waters of the rivers of the Carolina DPS in the spring through fall, as they do in other DPSs; however, this habitat use pattern has only been confirmed in the Winyah Bay, Roanoke River, Cape Fear River and to some extent the Albemarle Sound. 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 inside 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 Carolina DPS in many parts of the marine range including off the coasts of Virginia, Maryland, New Jersey, and New York (Kazyak et al. 2021).

Life history information for the Carolina DPS is somewhat inconsistent, with more information available for certain river systems (i.e., Pee Dee River, Cape Fear River), while others are data poor (e.g., Tar-Pamlico River, Chowan River, Sampit River). The spawning interval for the Carolina 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 Carolina DPS is up to approximately 60 years (Stevenson and Secor 1999).

There was no abundance estimate for the entire Carolina DPS when we listed it under the ESA. At the time of listing, the abundance for each river population within the DPS was estimated to be fewer than 300 spawning adults (total of both sexes); estimated to be less than 3% of assumed historical population sizes (ASSRT 2007). The estimate of spawning adults is based on a reasoned argument and assumption that considered the information available at that time. It 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 Carolina 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 listing, telemetry arrays have provided a fuller picture of how Atlantic sturgeon use Winyah Bay. Winyah Bay receives water from several rivers used by Atlantic sturgeon including the Sampit, Black, Pee Dee, and Waccamaw rivers, as well as Bull Creek. Winyah Bay appears to be an important aggregation area that supports individuals from all of these rivers. Research and monitoring conducted by South Carolina Department of Natural Resources (SCDNR) illustrates Winyah Bay continues to be an important nursery habitat for juvenile Atlantic sturgeon, with animals detected in the lower portions of the Black River and Sampit River and throughout the most of the Waccamaw River (SCDNR 2021). Until recently, the Sampit River was not considered particularly important habitat for Atlantic sturgeon. However, after focused sampling and tagging of young-of-year (YOY) in Winyah Bay began around 2020, the acoustic telemetry array in the Sampit River detected a previously unknown habitat hotspot for younger life stages (SCDNR 2021).

Both telemetry data and genetic analysis have provided further insight into how Atlantic sturgeon are using the Pee Dee River above the Winyah Bay. Genetic (White et al. 2021) and telemetry data (SCDNR 2021) have confirmed separate spring- and fall-spawning runs. Atlantic sturgeon making spawning runs in the spring initiated migrations between late-January and mid-February of each year at water temperatures between 8.8°C and 10.8°C and at river discharge levels between 541 and 799 cubic meters per second (Denison et al. In Press). The spring cohort completely exited the river by the first week of May each year when water temperatures had risen to between 20°C and 23°C and when discharge had fallen to 170 to 368 cubic meters per second (Denison et al. In Press). Atlantic sturgeon making spawning runs in the fall began migrations as early as May when water temperatures were between 25°C and 30°C and at river discharge levels between 125 and 564 cubic meters per second (Denison et al. In Press). Individuals had completely departed the river between late-October and mid-November once water temperatures fell to between 14°C and 20°C (Denison et al. In Press). Telemetry data from these fish has also identified putative spawning staging areas, as well as potential spawning habitats (SCDNR 2021). These same data also indicate the Atlantic sturgeon making putative spawning runs in the spring use habitats lower in the river, while fall-running fish use habitats further upriver (SCDNR 2021).

The acoustic telemetry array maintained by SCDNR in the Santee River has detected an age-1 Atlantic sturgeon initially tagged in the Winyah Bay system moving to the Santee River (SCDNR 2021). SCDNR has sampled the Santee River consistently from 2014-2019. The majority (89%) of Atlantic sturgeon captured were YOY or juveniles (Post and Waldrop 2019). However, this catch composition may be an artifact of the sampling gear used, which more effectively captures these life stages. SCDNR hypothesizes the intermittent capture of YOY in the Santee River may be evidence that captured individuals are not actually natal to the Santee River, but have migrated from the Winyah Bay system during high flow events (Post and Waldrop 2019). Telemetry data from the acoustically tagged Atlantic sturgeon detected in the Santee River reveal the individuals remain primarily in the lower reaches of the river (i.e., RKM 9-30), and a few individuals were detected further upstream (Post and Waldrop 2019). No adults have been captured in the Santee River, but three adults from other river systems have been detected (Post and Waldrop 2019). No putative spawning migrations have been detected in the Santee River. Telemetry data also show several fish tagged outside the Santee River entering the river, while still other individuals tagged in the Santee River were subsequently detected on telemetry arrays outside the Santee River (Post and Waldrop 2019).

Telemetry data show acoustically tagged Atlantic sturgeon use the lower portion of the Cooper River/Charleston Harbor more frequently than upper reaches and the lower reaches are most commonly used in the spring. However, over eight sampling seasons, SCDNR has detected 20 unique Atlantic sturgeon making putative spawning runs to the base of the Pinopolis Dam on the Cooper River. Nineteen of those individuals were detected making putative spawning migrations in the fall but one individual was detected making a putative spawning migration in spring (Ruddle 2018; SCDNR 2022). SCDNR captured the first confirmed adult female Atlantic sturgeon in the Cooper River in 2020. The carcass of a second deceased female adult Atlantic sturgeon was recovered near the base of the Pinopolis Dam in 2021 (SCDNR 2021). It is worth noting the Cooper River does not fit the traditional mold for a sturgeon-spawning river; it is relatively short and sturgeon historically favored the Edisto and Santee rivers over the Cooper River for spawning. Without genetic verification, we cannot rule out the individuals detected making putative spawning runs were actually from river systems other than the Cooper River.

In the Cape Fear River, sampling work in the Cape Fear River was conducted around the time of listing, from (2011 to 2013). This project collected and acoustically tagged several subadults and adults. Telemetry data collected from those individuals found habitat use patterns similar to those detected in other river systems (Post et al. 2014). Individuals tended to use more of the river from its mouth to RKM 70 in the spring (March-May). During warmer months (June-August) the area of the river used by sturgeon was compressed and shifted further upriver (Post et al. 2014). During these warmer months, individuals moved less in general. As the water cooled in the fall, animals began to roam more, using more of the river. Once the cold of winter arrived, all acoustically-tagged fish had either left the system or moved into the lower estuary (Post et al. 2014).

Post et al. (2014) reported subadults and adults using the lower Roanoke River from 2011-2013, with one acoustically tagged individual detected further upriver near Hamilton, North Carolina. Smith et al. (2015) confirmed fall spawning in the Roanoke River via the collection of eggs.

No directed research was conducted in North Carolina between 2014 and 2021, then directed research began again in 2021 with an emphasis on the Cape Fear River and the Roanoke River. The recent sampling has been conducted during both the fall and spring. Adult male Atlantic sturgeon in spawning condition were captured and tagged in the Cape Fear River during spring, but to date no adults have been captured in the Cape Fear River during the fall. Subadults have been captured and tagged during both the spring and fall. Several of these fish were recaptured between early summer and late fall, an indication of long residence times near the salt/freshwater interface. Additionally, a number of the captured subadults had been originally tagged in Georgia or South Carolina river systems (Scharf 2021). High inter-annual return rates of acoustically tagged subadults to the Cape Fear River demonstrates fish have fidelity to this system. This suggests the Cape Fear basin may be the natal system of these fish, or is at least a highly important foraging area (Post et al. 2014).

In the Roanoke River, unlike the Cape Fear River, no adults have been captured to date during spring, but fall sampling has captured both adult males and one female in post-spawning condition. Subadults have been captured and tagged during both the spring and fall (Scharf 2021). Trained fisheries biologists with the North Carolina Wildlife Resources Commission (NCWRC) have also observed large Atlantic sturgeon far upstream in the Roanoke River. In May 2022, they observed an Atlantic sturgeon very close to the area Smith et al. (2015) reported collecting Atlantic sturgeon eggs several years prior. NCWRC biologists observed another large Atlantic sturgeon in October 2022 near Roanoke Rapids (J. McCargo, NC Wildlife Resource Commission to A. Herndon, NMFS; pers. comm.). Given the size of the animals, their locations in the river, and the time of year, it is likely they were adults making a spawning run.

Without directed research in the Neuse, Tar-Pamlico, and Chowan rivers, anecdotal observations reported by the public and trained biologists have taken on a greater importance in these river systems. In the Neuse River, NCWRC biologists have observed adult-sized Atlantic sturgeon very far upriver in both the spring (April) and fall (September) (J. McCargo, NC Wildlife Resource Commission to A. Herndon, NMFS; pers. comm.). An angler in the Tar River provided a photo-verified report of a large sturgeon far upriver in April. Given the size of the animal, the location in the river, and the time of year, its likely this individual was an adult making a putative spawning run.

No new information is available since the time of listing on Atlantic sturgeon use of the Chowan River.

Currently, there are no directed research programs focused solely on the habitat use in the sounds. However, directed research in the Albemarle Sound did occur around the time of listing (2011-2013). That research effort found the western Albemarle Sound was used by all life stages (i.e., YOY, juveniles, subadults, and adults) during at least some portion of the year (Post et al. 2014). Telemetry data collected from juvenile and subadult Atlantic sturgeon acoustically tagged in Albemarle Sound revealed three general movement patterns: individuals remaining in western Albemarle Sound year round; individuals moving to eastern Albemarle Sound (near Oregon Inlet) in winter but back to western Albemarle Sound in summer; and individuals leaving Albemarle Sound to enter the Atlantic Ocean (Post et al. 2014). These seasonal movements were

consistent with the pattern of Atlantic sturgeon bycatch by fisheries-independent sampling occurring in Albemarle Sound from 1990-2015 (Hoos et al. 2017). Aside from movements within Albemarle Sound, Post et al. (2014) also identified Oregon Inlet as a critical passageway for migrating adults and subadults as they make their way from the Albemarle Sound into the Atlantic Ocean and back. The same telemetry array used to detect the movement of fish tagged in the Albemarle Sound also detected fish from other river systems entering the sound from the Atlantic Ocean (Post et al. 2014).

Similar to Winyah Bay in South Carolina, the Albemarle Sound is located at the confluence of several rivers, including the Chowan and Roanoke, and is an important aggregation area for Atlantic sturgeon. Because of the Albemarle Sound's location, sturgeon occurring there may represent one or more spawning populations. However, limited genetic information was available at the time of listing, impeding our ability to differentiate individuals found in the Sound into riverine-specific populations. Instead, individuals from this area are currently grouped into a single "Albemarle Sound Complex" population. We are working with our conservation partners to increase the genetic information available from the rivers flowing to the Albemarle Sound to improve the resolution.

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 Carolina DPS. However, the Stock Assessment (ASMFC 2017) was a comprehensive review of the available information, and used multiple methods and analyses to assess the status of each DPS and the coastwide stock of Atlantic sturgeon. The Stock Assessment determined the Carolina DPS abundance (at the time of the 2017 Assessment) is "depleted" relative to historical levels. The assessment also concluded there was 67% probability the abundance of the Carolina DPS had increased since the implementation of the 1998 fishing moratorium (ASMFC 2017).

Within the Carolina DPS, Winyah Bay (including the Sampit, Black, and Waccamaw rivers and Bull Creek) and the Pee Dee River are the most well studied systems. Due to the relative ease of capturing river-resident juveniles, population monitoring of the Carolina DPS is focused largely on juvenile (e.g., age-1, age-2, and age-3) abundance and recruitment. These activities use gillnets or trammel nets to capture juveniles and apply PIT tags. However, to date there have not been enough individuals of the appropriate age classes captured and tagged 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 Carolina 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 Cooper River, adult Atlantic sturgeon making putative spawning runs have been detected in recent years (SCDNR 2021); however, no YOY or age-1 life stages have been observed. The lack of these life stages suggests any eggs/larvae produced in the Cooper River are not surviving. No juvenile recruitment estimates have been produced since listing.

As noted in Section 2.3.1.1, age-1 individuals have been detected in the lower Santee River, but it is unclear whether these animals are native to this river system or Winyah Bay. SCDNR has also captured juvenile/subadult Atlantic sturgeon residing in the lower Santee River but no juvenile recruitment estimates have been produced since listing.

SCDNR began monitoring juvenile abundance in Winyah Bay, with the intention of estimating juvenile recruitment. Those efforts are currently underway but insufficient data have been collected to provide current recruitment/abundance estimates. Crane and Takacs (2022) provided the first estimate of juvenile abundance in Winyah Bay, which only spans a single year (2021). While estimates of juvenile abundance from other systems are often done by age class (i.e., age-1, age-2, age-3), limited recaptures of presumed YOY (potentially age-1) individuals, along with additional complications of accurately ageing captured individuals, frustrated efforts to estimate abundance by age. Instead, the authors 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–October annually. Daily encounter histories resulted in a larger estimated superpopulation size of Atlantic Sturgeon ≤1,050 mm TL (2,564 [95% CI = 1,885–3,539]) compared to monthly encounter histories (1,484 [95% CI = 887–2,719]) (Crane and Takacs 2022).

Similarly, the juvenile abundance monitoring in the Cape Fear and Northeast Cape Fear rivers, as well as the Roanoke River, is in its nascency and no juvenile abundance estimates have been produced for either system. However, exploratory sampling for river-resident juvenile Atlantic sturgeon (age-0 and age-1 individuals) in the Cape Fear River revealed good potential for abundance estimation using a mark-recapture approach in the next five years. The high catch rate of juveniles provides confidence that additional sampling effort will produce sample sizes that enable precise estimates of abundance, and an index of recruitment.

No juvenile abundance monitoring is currently occurring in the Neuse, Tar-Pamlico or Chowan river systems. While establishing juvenile abundance monitoring programs in these systems is a future goal for NOAA Fisheries, there is currently no timeline for when these programs will begin. There are currently no efforts planned to estimate juvenile recruitment in Pamlico or Albemarle sounds.

An alternative to monitoring populations via juvenile recruitment is the genetically based, "effective population" size (N_e).[1] For the Carolina DPS, the 2017 Stock Assessment reported N_e for the Albemarle Sound Complex; Waldman et al. (2019) also provided an N_e estimate for Albemarle Sound (Table 1). White et al. (2021) provided an estimate of N_e for the Pee Dee River, but caution 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).

Table 1. Estimates of Effective Population Size by River

River	Effective Population Size (N_e) (95% CI)	Sample Size	Collection Years	Reference
Albemarle Sound	14.2 (11.8-17.1)	37	1998-2008	ASMFC (2017)
	19.0 (16.5–20.6)	88	1998, 2006-2011, 2013-2014	Waldman et al. (2019)
	29.5 (24.2-36.3)	71	1998, 2006-2009, 2012, 2015 2016	White et al. (2021)
Pee Dee	Fall Run – 82 (60.3-122.1)	50	2011, 2012, 2017-2019	White et al. (2021)
	Spring Run – 16.4 (12.8-20.6)	66	2012, 2017-2019	White et al. (2021)

The Stock Assessment considered the survival rate for the Carolina DPS as whole. The Stock Assessment estimated the mean survival rates of 78%, 33%, and 72% for all acoustically tagged fish, acoustically tagged adults, and acoustically tagged juveniles from the Carolina DPS, respectively. The ASMFC also concluded it was relatively likely (75% probability) that mortality for the Carolina 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. Overall, the mixed stock analysis noted relatively little mixing of stocks in the Southeast, but did identify more mixing around the Mid-

[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.

Atlantic. 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). However, the Carolina DPS made up a far greater proportion of samples from the "MID" region (Cape Hatteras, NC to and Cape Cod, MA). Of the 1,150 samples assigned to the MID region, the most common DPS was New York Bight (37.5%, n=432) followed by Carolina DPS (30.7%; n=353) (Kazyak et al. 2021).

The relative proportions of individuals that assigned to each riverine population in the Carolina DPS was largely dictated by where an individual was captured. For example, of the individuals captured in the MID region in riverine/estuarine environments, 60.9% assigned to the Carolina DPS, while only 6.0% of individuals captured offshore assigned to the Carolina DPS. Conversely, individuals from the New York Bight (54.0%) and Chesapeake Bay DPSs (21.6%) were more prevalent offshore (Kazyak et al. 2021). Of note is that a large number of the total samples in the MID region considered by Kazyak et al. (2021) were from the sounds of North Carolina. Thus, it is likely the analysis overestimated the total proportion of Atlantic sturgeon from the Carolina DPS that occur within the MID region.

As noted in Section 2.3.1.1., genetic evidence also supports dual spawning runs (fall and spring) in the Pee Dee River (White et al. 2021).

While limited to the Albemarle Sound and Pee Dee populations, the estimates reported in Table 1 suggest there is a risk for inbreeding depression ($N_e < 100$) and loss of evolutionary potential ($N_e < 1000$) for these populations (ASMFC 2017; Frankham et al. 2014).[2] However, White et al. (2021), stated that while historic comparisons are currently not available, all 18 populations surveyed showed reasonably high levels of contemporary genetic diversity and low inbreeding despite relatively recent and severe demographic bottleneck events. Section 2.3.1.5 provides additional results of genetic analyses for sturgeon captured from mixed aggregation areas within the marine range.

2.3.1.4 Taxonomic classification or changes in nomenclature

There are no changes in taxonomic classification or changes in nomenclature for the Carolina 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 Carolina 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] 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.

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 Carolina DPS. Based on genetic analyses, Atlantic sturgeon belonging to the Carolina DPS have been identified among individuals captured off the coasts of New York, New Jersey, Maryland and Virginia (Kazyak et al. 2021). 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 Carolina DPS, the results suggest that Atlantic sturgeon occurring offshore in the Mid-Atlantic region (Cape Hatteras, NC to and Cape Cod, MA) make up a relatively small proportions of all individuals (6%). Conversely, individuals from the Carolina DPS accounted for almost 61% of animals captured in riverine/estuarine habitats of the Mid-Atlantic (Kazyak et al. 2021).

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. While not specific to the Carolina DPS, we have no reason to believe the behavior of individuals from this DPS would be significantly different.

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

The biological opinion for the Yadkin-Pee Dee Hydroelectric Project was issued in 2015, which required a spawning and incubation habitat assessment be conducted in the Great Pee Dee River. The effort mapped an 88-mile long stretch of river from Blewett Falls Hydroelectric Dam (river mile 188.2) to Florence, South Carolina (river mile 100.2); breaking the river into 2 reaches and 5 sub-reaches (HDR 2018). That exercise identified several potential locations with habitat suitable for sturgeon spawning. Similarly, the biological opinion for the Santee-Cooper Hydroelectric Project established requirements to map habitat in the Santee River. Santee-Cooper Hydroelectric Project received its operating license from FERC in January 2023; the mapping is slated to begin in the spring of 2023.

In the Cooper River, the Santee Cooper Jefferies Hydroelectric Station has been required to provide a weekly average flow of 4,500 cubic feet per second (cfs), since 1985. Beginning in

late-2016 and early-2017, the station modified its schedule of generation from constant discharge to "hydro peaking."[3] Under this new flow regime, the average weekly flow has remained the same, but the river now experiences periods of high flow, followed by low flow, which in turn has negatively affected dissolved oxygen levels downstream (SCDNR 2020). These changes likely have a negative impact on sturgeon in the river.

Since listing, the privately-owned, low-head, Milburnie Dam on the Neuse River has been removed. Its removal opened approximately 15 miles of additional habitat.

We designated critical habitat for the Carolina DPS in Roanoke River, Tar - Pamlico River, Neuse River, Cape Fear and Northeast Cape Fear River, Pee Dee River (including the Waccamaw River and Bull Creek), Black River (SC), Santee River (including the Rediversion Canal, North Santee River, and South Santee River) and Cooper River (including the Tailrace Canal and West Branch Cooper River) based on the best available information (82 FR 39160; August 17, 2017). In total, these designations encompass approximately 1,210 miles (1,946 kilometers) of aquatic habitat that is essential to the recovery of the Carolina DPS.

As described in Section 2.3.1.5, there is new information describing the distribution of Carolina 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 Carolina 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 Carolina 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 Carolina 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 Carolina DPS are described below.

[3] *Hydro peaking* is the practice of releasing water in pulses, instead of a steady flow, to increase energy production during times of day when energy demands are the highest.

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, water quality (e.g., dissolved oxygen levels, water temperature, and contaminants), and water quantity are threats that affect the habitat or range of the Carolina DPS. We anticipated that potential changes in water quality/quantity because of global climate change will likely affect the Carolina DPS and those effects are likely to be more severe in areas that are already subject to poor water quality.

New information is available for the effects of these threats to the Carolina DPS, and the actions taken to address the threats. Since 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, 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 Carolina DPS, we have no reason to believe Atlantic sturgeon from the Carolina 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 Carolina 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 Carolina 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 Carolina DPS at 47 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 Carolina DPS, and were not likely to adversely affect the DPSs designated critical habitat. Additional information is available at https://www.fisheries.noaa.gov/content/endangered-species-act-section-7-biological-opinions-southeast.

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

We also continue to monitor impacts from port deepenings within the Carolina 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 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 Carolina DPS, a series of three locks and dams on the Cape Fear River, NC, and three hydroelectric dams in the Santee-Cooper River system, continue to curtail the range of the Atlantic sturgeon. Fish passage has been built at the lowest lock and dam on the Cape Fear River, but the remaining two locks and dams continue to block access to upstream habitat. Fish passage suitable for sturgeon does not exist anywhere on the Santee-Cooper River system. At the time of listing, we estimated only 38% of the historical habitat in the Santee-Cooper River system remained available to Atlantic sturgeon today; we still believe that assessment is accurate.

Since listing, we also designated critical habitat for the Carolina DPS (82 FR 39106; August 17, 2017). As part of the designation, we determined that an essential feature of critical habitat for the Carolina 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.

Water allocation issues continue to pose a threat to the Carolina 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, in 2021, 9 inter-basin transfers allowing the movement of over 178 million gallons of per day from basins supporting Atlantic sturgeon were authorized by North Carolina Department of Environmental Quality (NCDEQ 2021). 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 climate change.

At the time of listing, we identified water quality as a threat to the Carolina DPS. Industrialization associated with paper and steel mills has degraded water quality in the Winyah Bay system, which includes the Waccamaw, Pee Dee, and Sampit rivers (NMFS and USFWS, 1998). Concentrated animal feeding operations (e.g., farms that produce hogs, turkeys, and chickens) have also degraded the water quality in the Winyah Bay system and the Cape Fear River, and, to a lesser extent, the Tar-Pamlico and Neuse rivers (Glasgow et al. 2001; Paerl et al. 1998; Qian et al. 2000). These systems suffer from seasonal hypoxia/anoxia. Water quality in the Cape Fear River is further degraded by industrial development including the Port of Wilmington and numerous industrial point-source discharges. Threats from degraded water quality continue to affect the Carolina DPS.

Since listing, more information has become available regarding the effects of climate change on Atlantic sturgeon, generally. Hare et al. (2016) evaluated the vulnerability of Atlantic sturgeon to climate change on the Northeast Shelf of the United States. 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. While Hare et al. (2016) did not evaluate vulnerability to climate change by DPS, we believe the same factors that broadly contribute to the vulnerability of Atlantic sturgeon to climate change will affect the Carolina DPS. There is currently no information specifically considering the impacts of climate change on the Carolina DPS. However, new information is becoming available on the environmental cues (i.e., river discharge, water temperature) that may trigger specific spawning behaviors in fish of the Carolina DPS (Denison et al. In Press). 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 Carolina DPS.

Conclusion of Factor A: Maintenance dredging continues to be a stressor for the Carolina 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 Carolina DPS. Blocked access to historical spawning habitat continues to be an issue in the Cape Fear and Santee-Cooper river systems, while water quality continues to be a stressor across the entire Carolina 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 Carolina DPS.

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 2 reports the biological opinions for federal fisheries or fisheries operating under federal gear regulations, along with authorized incidental takes for Atlantic sturgeon from the Carolina DPS. In all instances, the biological opinions concluded the anticipated level of take would not decrease the likelihood that the Carolina 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 2. Federal Fisheries Authorizing the Incidental Take of Atlantic Sturgeon from the Carolina DPS.

Fishery/Action	Anticipated Incidental Take of Atlantic Sturgeon from the Carolina DPS	Year Biological Opinion Completed
Southeastern U.S. Shrimp Fishery	66 total over 5 years; up to 15 of which may be mortalities	2021
Highly Migratory Species – Atlantic Shark and Smoothound Fisheries	18 total over 3 years; up to 6 of which may be mortalities	2012
Highly Migratory Species – Tuna, Swordfish, Billfish and Shark Fisheries	10 total over 3 years; up to 5 of which may be mortalities	2020
Coastal Migratory Pelagic Fishery in the Atlantic and Gulf of Mexico	Up to 4 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	36 total over 5 years; up to 4 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 1 total every year; up to 1 mortalities may occur every 10 years.	2018

Scientific research not deliberately targeting sturgeon does occasional 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 Carolina DPS have also been completed and are reported in Table 3. The state of North Carolina and the U.S. Fish and Wildlife Service have begun the Section 7 consultation process with NOAA Fisheries to address the incidental take of Atlantic sturgeon in the state's fisheries independent monitoring programs.

Table 3. Research Activities that may Incidentally Capture Atlantic Sturgeon from the Carolina DPS.

Research Activity	Anticipated Incidental Take of Atlantic Sturgeon from the Carolina 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 6 over 5 years; up to 1 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 3 over 5 years; no mortalities are anticipated	2017
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 15 every 5 years; up to 1 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 the Carolina DPS, we anticipate these gear modifications will also benefit individuals from the Carolina 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 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 permits for the anticipated incidental take of Atlantic sturgeon belonging to the Carolina 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 Carolina DPS specifically. In addition, NOAA Fisheries posseses 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; none of those individuals was from the Carolina DPS.

Conclusion for Factor B: The available information continues to support our conclusion in the listing rule that overutilization of the Carolina DPS is not occurring because of educational or scientific purposes. However, overutilization via 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 Carolina 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 Carolina DPS that are taken and killed as 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 Carolina DPS of Atlantic sturgeon. We believe that assessment is still accurate.

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

Predation of early Atlantic sturgeon life stages by introduced, non-native, catfish species has been suggested. The extent of the predation, if it occurs, 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 of Atlantic sturgeon egg predation in river systems of the Carolina DPS is currently unknown, though all three species identified by Bunch et al. (2021) exist in the DPS.

Conclusion for Factor C: The latest information does not change our determination from the listing rule that neither disease nor predation are primary factors affecting the continued persistence of the Carolina DPS. 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 Carolina DPS. We determined the failure of the Carolina DPS population to rebound despite harvest prohibitions established in the 1990s, along with the ongoing impacts from bycatch, habitat modification, degraded water quality, 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 ESA-listed species are through rulemaking, Section 7 consultation, and permitting. By statute, all endangered species, such as the Carolina 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 Carolina DPS, beyond 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 self-reported 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). Carolina 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 Carolina DPS are likely to be killed annually because of the operation of the federally-managed fisheries described in Table 2. 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. 2019; 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 Carolina 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 Carolina 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 Carolina DPS Atlantic sturgeon that are struck and killed by vessels or captured in fisheries) are 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 Carolina 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 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 Carolina DPS was listed as endangered. For example, Post et al. (2014) reported that from 2011-2014, of 10 subadult fish that were captured within North Carolina state waters with physical abnormalities or injuries, 5 (50%) showed signs of boat propeller damage (such as deep lacerations along the back, or missing and cracked scutes), and 3 (30%) had missing eyes or fins that may have been indicative of vessel strikes. 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 that 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 Carolina 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 Carolina 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. 2020). Additionally, the geomorphology of the river systems in the Carolina 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 within rivers of the Carolina DPS 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 Carolina 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 Carolina 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 Carolina 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 Carolina DPS. New information confirms that vessel strikes are a threat to the Carolina 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 Carolina DPS.

2.4 Synthesis

Our recommended classification for the Carolina 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 Carolina DPS are captured and killed as a result of fishery interactions, vessel strikes, and dredging. Their habitat, including critical habitat, continues to be lost or altered because of anthropogenic activities.

Genetic analyses of effective population sizes are only available for the Pee Dee and Albemarle Sound Complex populations of the Carolina DPS and both suggest there is a risk for inbreeding depression ($N_e < 100$) and loss of evolutionary potential (Table 1). At the time of listing, the abundance for each river population within the DPS was estimated to have fewer than 300 spawning adults (total of both sexes); estimated to be less than 3% of what they were historically (ASSRT 2007). The information available since the time of listing remains limited for most river, with the exception of the Pee Dee River.

New information available since the listing has informed our understanding of which physical features in marine waters and estuaries are preferred by the Carolina 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 Carolina 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., Santee, Black, Neuse, Tar-Pamlico and Chowan) within the Carolina 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 Carolina 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 Carolina DPS as at high demographic risk.

The Carolina 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 federally-managed 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. Therefore, based on the Listing and Recovery Priority Guidelines (84 FR 18243, April 30, 2019), the recovery priority number for the Carolina 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 Carolina 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 Carolina 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 Carolina DPS. As this information becomes available, NMFS should consider whether an elasticity analysis specifically considering the Carolina 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 Carolina 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 and our conservation partners should seek information to determine if individuals from the Carolina DPS have a higher tolerance for high water temperatures and low dissolved oxygen concentrations, than individuals for 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 Carolina DPS.

NMFS, along with our conservation partners, should continue to support the use of side-scan sonar as population monitoring and habitat detection tool. We 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 Carolina DPS Atlantic sturgeon populations.

NMFS, along with our conservation partners, should support efforts to determine how individuals from the Carolina DPS of Atlantic sturgeon are using offshore habitats that may be used for offshore wind installations.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW

Carolina 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
- ☒ 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 13:01:32 -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

☒ Concur ☐ Do Not Concur

Signature COIT.JANET.LOUISE.1605731623 Digitally signed by COIT.JANET.LOUISE.1605731623 Date: 2023.09.14 15:40:13 -04'00' Date: _____