GULF STURGEON
(*Acipenser oxyrinchus desotoi*)

5-Year Review:
Summary and Evaluation

Photo of Gulf Sturgeon by Ryan Hagerty, U.S. Fish and Wildlife Service

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National Marine Fisheries Service
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5-YEAR REVIEW
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1. GENERAL INFORMATION

Gulf Sturgeon is under the joint jurisdiction of the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS). USFWS is responsible for all Endangered Species Act (ESA) section 7 consultations regarding Gulf Sturgeon and critical habitat in riverine habitat units, and NMFS is responsible for all consultations regarding the species and its critical habitat in marine units (68 FR 13370). USFWS and NMFS (hereafter referred to as the Services) divide responsibility based on the action agency involved in estuarine units (68 FR 13370). Some information presented in the sections below has been drafted by USFWS or NMFS independently (identified in the section heading); in these sections each agency has conducted an independent analysis based on agency-specific policies and guidance. Otherwise, sections of the following 5-year status review were collaboratively drafted by staff from the Services.

1.1. Methodology used to complete the review

In conducting this 5-year review, we relied on the best available information pertaining to historical and contemporary distributions, life histories, genetics, habitats, and threats of this species. We announced initiation of this review and requested information in a published *Federal Register* notice with a 60-day comment period on April 11, 2019 (84 FR 14668). We received one public comment during the 60-day open comment period.

The lead recovery biologists for NMFS and USFWS gathered and synthesized information regarding the biology and status of the Gulf Sturgeon. Our information sources included:

- the Gulf Sturgeon Recovery/Management Plan (1995);
- peer-reviewed scientific publications;
- grey literature (annual reports);
- information presented at annual Gulf Sturgeon meetings and scientific conferences;
- ongoing field survey results and information shared from Gulf Sturgeon researchers (both Federal and State biologists);
- the final rule listing the Gulf Sturgeon as threatened (56 FR 49653) (September 30, 1991);
- the final rule designating critical habitat for the Gulf Sturgeon (68 FR 13370) (March 19, 2003);
- the previous 5-year status review (USFWS and NMFS 2009)

The completed draft was sent by USFWS and NMFS to six peer reviewers for review. Comments were evaluated and incorporated into this final document as appropriate (see Appendix B).

1.2. Reviewers

1.2.1. NMFS

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Melissa Price, United States Geological Survey, Wetland and Aquatic Research Center, Gainesville, Florida

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1.3. Background

1.3.1. Federal Register Notice citation announcing initiation of this review:

April 11, 2019. 84 FR 14668

1.3.2. Listing history

Original Listing: 56 FR 49653
Date listed: September 30, 1991
Entity listed: Subspecies
Classification: Threatened

1.3.3. Associated rulemakings

The Services designated critical habitat for the Gulf Sturgeon on March 19, 2003 (68 FR 13370).

1.3.4. Review History

The Services conducted a 5-year status review in September 2009, which recommended the species remain listed as threatened and indicated that the species' population trend was stable (USFWS and NMFS 2009).

1.3.5. Species' Recovery Priority Number at start of review:

1.3.5.1. NMFS

NMFS revised guidelines in 2019 (84 FR 18243) for assigning listing and recovery priorities. NMFS has assigned a recovery priority number of 7C to the Gulf Sturgeon (moderate demographic risk, uncertainty of recovery action effectiveness, and the presence of conflict with economic activities). Additional rationale for this recovery number is provided in the Recovering Threatened and Endangered Species FY 2017-2018 Report to Congress (NMFS 2019).

1.3.5.2. USFWS

At the start of this review, FWS had previously assigned the species a recovery number of 12 (a subspecies with a moderate degree of threat and a low recovery potential) to the Gulf Sturgeon (48 FR 43098).

The different priority rankings (NMFS and USFWS) reflect the fact that different criteria are used to assign priority numbers to species.

1.3.6. Recovery Plan

Name of Plan: Gulf Sturgeon (*Acipenser oxyrinchus desotoi*) Recovery/Management Plan. This plan was signed by the NMFS, USFWS, and Gulf States Marine Fisheries Commission.

Date Issued: September 22, 1995

2. 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 Distinct Population Segment (DPS)?

No.

2.1.3. Is there relevant new information for this species regarding the application of the DPS policy?

Yes, new information regarding the application of the DPS policy is available. Both genetics and tagging data indicate that Gulf Sturgeon spawning river fidelity is high and spawning in non-natal rivers (i.e., straying) is low –summarized in Sulak et al. (2016). Regional groupings have been identified – East (Suwannee, Apalachicola, Choctawhatchee, Yellow, Escambia) and West (Pascagoula and Pearl) – based on genetic discreteness of each population (Stabile et al. 1996). In addition, Rudd et al. (2014) reported low straying between groupings, which together provide evidence that may support either a population-based or regional grouping-based DPS classification in the future.

2.1.4. Is there relevant new information that would lead you to consider listing this species as a DPS in accordance with the 1996 policy?

At this time, we are unable to resolve differences in recovery status among conceptual groupings of adjacent populations (i.e., potential DPS units) that would suggest applying the DPS policy as a strategy to improve the prospects for recovery of Gulf Sturgeon. Differences in the recovery status of regional groupings- should they become clearer in the future- might suggest we reevaluate the species according to the DPS policy.

2.2. Recovery Criteria

2.2.1. Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes.

2.2.2. Adequacy of recovery criteria

2.2.2.1. Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

The recovery criteria reflect the best available information for both the short and long-term recovery criteria. Major efforts are currently underway to validate and implement a long-term monitoring program in Florida rivers using standardized, side scan sonar (SSS) surveys to reveal trends over time (i.e., short-term criteria), and to estimate rates of mortality and recruitment for all seven populations that will enable an assessment of population trajectory (i.e., stable, increasing, or decreasing; long-term criteria). These efforts may provide data that support alternative recovery criteria that better reflect the biology of the species and its habitat. However, some items listed in the plan as recovery criteria are not true recovery criteria, but rather are statements that support criteria. For more information see the discussions below.

2.2.2.2. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria?

No. The recovery actions outlined in the 1995 Recovery Plan address threats relative to listing factors (e.g., habitat modification, overutilization). The Plan, however, lacks criteria that would measure progress towards reducing these threats. We summarize new information about threats and progress towards reducing threats in section 2.3.2.

2.2.3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

1. ***Short-term Objective*** *– to prevent further reduction of existing wild populations of Gulf Sturgeon within the range of the subspecies. This objective will apply to all management units within the range of the subspecies. Ongoing recovery actions will continue and additional actions will be initiated as needed.*

Criteria

A. Management units will be defined using an ecosystem approach based on river drainages. The approach may also incorporate genetic affinities among populations in different river drainages.

The Services designated critical habitat for the Gulf Sturgeon in 2003 (68 FR68 13370). In the critical habitat rule we recognized seven extant reproducing populations that are associated with seven river drainages (Pearl, Pascagoula, Escambia, Yellow, Choctawhatchee, Apalachicola, and Suwannee). The Services have since recognized and treated these seven populations as management units, and the body of research that has appeared since critical habitat was designated continues to support this construct (see references in Sulak et al. 2016). We therefore consider this criterion met.

B. A baseline population index for each management unit will be determined by fishery independent catch-per-unit-effort (CPUE) levels.

The Services are currently working toward meeting this criterion by developing, validating, and implementing a long-term fishery independent monitoring program that provides “CPUE-type” data for most Gulf Sturgeon populations. This monitoring program involves standardized annual surveys using SSS, a remote sensing tool that generates imagery of targeted riverine areas (i.e., index reaches) that can be processed, reviewed, and analyzed to generate counts of Gulf Sturgeon ≥90 cm fork length. These data are independent of any fishery or fishing effort, and represent indices of abundance that are assumed to track true population abundance over time. Count data are effort-based in that total area scanned, geography of index reaches, time of year and water conditions may influence the count of sturgeon. At present, 5 of the 7 populations are being monitored with sonar surveys, all of which are in Florida. A multi-day pilot survey was conducted in the Pearl River in 2016, but failed to provide the data needed to identify a fixed "index reach" because only a few large sturgeon were encountered. We are awaiting results from ongoing telemetry investigations involving large sturgeon in both the Pearl and Pascagoula rivers to aid in identifying an index reach in each river to monitor. Sonar monitoring was first initiated in 2012 (Table 2), and has since been conducted annually or semi-annually for purposes of establishing a baseline population index.

Research is currently underway to test the assumptions associated with the sonar count index, refine statistical methods for analyzing these data for purposes of revealing long-term trends, and identify efficiencies in survey design. We anticipate this criterion to be fully met within the next five years.

The Services previously acknowledged the problems inherent with using a capture-based CPUE metric (i.e., number of sturgeon caught per hour) as a short-term recovery monitoring tool. These problems stem from the fact that the number of sturgeon captured in a net in any system can be influenced by a wide variety of factors other than the actual abundance of the population, including but not limited to the following: net mesh size and dimensions, river discharge (Fox et al. 2021), time of day, time of year, river temperature, density of sturgeon aggregated in the targeted holding area, 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. The influence of so many external factors makes it highly unlikely a CPUE-metric based on fish captured per hour could serve as a reliable index of population abundance for long-term monitoring.

In lieu of capture-based metrics, researchers have instead employed mark-recapture models and age-structured population models to assess population status over the last few decades (Morrow et al. 1999, Sulak and Clugston 1999, Pine et al. 2001, Pine and Allen 2005, Flowers 2008, Pine and Martell 2009). Information that has emerged from these and other studies is synthesized and reviewed in Sulak et al. (2016). Considering this information, and the recent results of an investigation of population level effects of Hurricane Michael on the Apalachicola population (Dula 2021), four Gulf Sturgeon populations appear to be stable or slowly increasing: Suwannee, Choctawhatchee, Yellow, and Escambia. Baseline population sonar count index values obtained for these systems also supports these trends (Table 2). Note- when interpreting sonar count trends from the Yellow and Escambia rivers, the inclusion of annual counts made in the adjacent Blackwater River system must occur, as adults from both the Yellow and Escambia often utilize the Blackwater during summer residency. Pooling annual counts made in the 3 systems is likely the most robust way to assess trends in the Pensacola Bay population complex. The Suwannee population has increased to a relatively high level of abundance and may be showing signs of population growth rate reduction (Appendix A, Table 1; Sulak et al. 2016). Sulak et al. (2016) suggested that increased straying (i.e., relocating to another river system) and presumably decreased population growth may be an indication of the population reaching contemporary carrying capacity (i.e., the biomass and/or population size supported by current (not historic) ecological conditions occurring in a given system).

C. *Change from the baseline level will be determined by fishery independent CPUE over a three to five-year period. This time frame will be sufficient to detect a problem and to provide trend information. The data will be assessed annually.*

   The Services are working toward evaluating this criterion through ongoing analysis of the sonar count data obtained thus far. Results of this effort will help determine whether changes from the baseline can be detected over a three to five year period, or whether monitoring must take place over a longer time frame. In a recently completed study of the population level effects of Hurricane Michael, a ~33% reduction in the adult population (estimated via telemetry and mark recapture work) was also confirmed by the SSS monitoring occurring in the system, suggesting the index is capable of detecting problems such as mass mortality events (Dula 2021).

   Seven rivers continue to support reproducing populations of Gulf Sturgeon (Sulak et al. 2016). Population estimates necessary to evaluate a change from baseline over a three to five-year period are not available. It should be noted that the feasibility of statistically detecting such a change over a short period of time (i.e., 3-5 years) is extremely low given the slow rate of change in Gulf Sturgeon population abundances over time and relatively low precision of abundance estimates, unless significant, mass mortality events occur. However, surveys have occurred on rivers throughout the range and population estimates have been reported (see Appendix A, Table 1).

D. *The short-term objective will be considered achieved for a management unit when the CPUE is not declining (within statistically valid limits) from the baseline level.*

   Monitoring of Gulf Sturgeon CPUE has not been consistently conducted (with the exception of recent SSS surveys) and we are unable to verify trends in CPUE over time. We are currently analyzing data collected via sonar monitoring to determine whether changes from baseline can be detected within statistically valid limits given the data we have thus far collected. Because current SSS methods have not been verified and traditional CPUE methods have not been consistently conducted, we cannot assess management unit declines at this time.

2. ***Long-term Objective A*** *– to establish population levels that would allow delisting of the Gulf Sturgeon by management units. Management units could be delisted by 2023 if required criteria are met. While this objective will be sought for all management units, it is recognized that it may not be achievable for all management units.*

Management units are not listed entities under the ESA and therefore they cannot be delisted. However, management units are similar to recovery parameters used in more recent anadromous fish recovery plans. Some NMFS recovery plans (2014; 2016) use ‘diversity groups' or 'strata' – a spawning population or group of spawning populations within a contiguous geographic area typically comprised of one or more watersheds. Diversity strata and management units allow the Services to evaluate species status and extinction risk and develop geographically specific recovery tasks that are appropriate to address unique threats to units smaller than the listed entity (Smith et al. 2018). This objective could be modified with more recent literature used in evaluating anadromous salmonid and sturgeon viability or extinction risk (Lindley et al. 2007). Minimum population size for habitat unit viability (i.e., low risk of extinction) could be established, along with minimum number of viable habitat unit populations required for viability of the listed entity. Along these lines, Morrow et al. (1999) and Flowers (2008) both recommended incorporating a minimum population size into revised recovery criteria in addition to a stable or increasing population size trend. Funding has been secured to support efforts to model extinction risk among the populations given various future scenarios (Population Status and Trends Study). These efforts may help to identify minimum population sizes necessary to support low risk of extinction. Evidence of straying and mixing of adult fish among the Escambia, Yellow, and Blackwater rivers (Rudd et al. 2014), and genetic results (Stabile et al. 1996) suggests that a viability analysis consider the fish present in all three systems (populations) part of a larger complex, or management unit.

Ahrens and Pine (2014) estimated historic carrying capacity of the seven spawning river systems using stock reduction analysis informed by historic landings data dating back to the early 1900s from the Apalachicola and Suwannee populations. The modeling approach related juvenile production to annual river discharge and stream channel length. The authors suggested that carrying capacity estimates could serve as realistic criteria (i.e., benchmarks) by which to assess sturgeon recovery, however, the ability to calibrate historic carrying capacity (i.e., 120 years ago) to what might be supported by contemporary ecosystem conditions remains undetermined, but would be necessary. In addition, the estimation of carrying capacity to systems that lack historic landings data, limits the validity of the estimates for the remaining five populations. It should be noted that carrying capacity abundance levels are not required under the ESA to achieve recovery of the Gulf Sturgeon.

Criteria

A. *The timeframe for delisting is based on known life history characteristics including longevity, late maturation, and spawning periodicity.*

   This statement explains why the original date of 2023 was selected as a potential timeframe for delisting in the 1995 Recovery Plan. The statement itself is valid, and supported by facts, but is not actually a criterion for recovery.

B. *A self-sustaining population is one in which the average rate of natural recruitment is at least equal to the average mortality rate over a 12-year period (which is the approximate age at maturity for a female Gulf Sturgeon).*

   Seven river systems continue to support reproducing populations of Gulf Sturgeon. Natural recruitment and mortality rates have not been estimated for any population over a continuous 12-year period in a manner that would satisfy this recovery criterion as originally written, but observed population growth and trajectory strongly suggests the

Suwannee River population has recovered and may have reached carrying capacity in the system (Ahrens and Pine 2014, Sulak et al. 2016). In 2009 NOAA funded an effort to assess adult Gulf Sturgeon mortality in each of the seven spawning populations. Estimates of mortality rate have been made (Rudd et al. 2014) and can now be incorporated into mark-recapture estimates to improve estimation and reduce uncertainty in the work underway in the Population Status and Trends study. In addition, the Services are engaged in a comprehensive study of recruitment and mortality of juvenile sturgeon in each reproducing population (Juvenile Sturgeon Dynamics Project). We anticipate that the synthesis of the results of both studies will permit a more comprehensive and quantitative evaluation of this criterion in the future.

C. *This objective will be considered achieved for a management unit when the population is demonstrated to be self-sustaining and efforts are underway to restore lost or degraded habitat.*

General estimates of population size have been calculated using mark-recapture data; estimates available for each population are displayed in Appendix A, Table 1. This information suggests a roughly stable or slightly increasing population trend in the four easternmost river systems (Yellow, Choctawhatchee, Apalachicola, and Suwannee rivers). On the other hand, recent events in the Apalachicola River system shed light on the impact of stochastic, mass mortality events. An investigation to determine the effects of Hurricane Michael (October 10, 2018) on the Apalachicola River population was recently completed. Several lines of evidence suggest that roughly one-third of the adult population perished during a hypoxic event that ensued following the storm. On the other hand, the storm did not cause a year class failure, and recruitment was higher in the two years following the storm than observed in the four years prior to the storm (Dula 2021). Continued monitoring will help determine whether this mass mortality event leads to continued population decline, or whether increased recruitment leads to a rebound in adult abundance over time.

Estimates of adult abundance in both the Pearl and Pascagoula rivers are outdated (last conducted in early 2000s) in the sense that mass mortality events are strongly suspected to have occurred in these systems more recently. Work is currently underway to examine and estimate recruitment of juvenile sturgeon. Over the next 5 years, mark-recapture efforts in both systems should allow for an updated estimate of abundance in both systems, thereby providing a perspective on the recovery of the two westernmost populations thought to have been significantly affected by major hurricanes (Andres et al. 2018) and contaminant releases (e.g., Bogalusa pot-liquor spill, Deepwater Horizon oil spill) during the last 15 years.

Efforts to identify the five focal habitats of Gulf Sturgeon have been underway since the inception of the recovery program: 1) spawning, 2) young-of-year riverine rearing, 3) summer holding, 4) juvenile winter estuarine, and 5) open marine winter habitat. Over the next 10 or more years resources available from the Deepwater Horizon oil spill injury settlement (i.e., 15 million dollars) will be directed toward the goal of restoring Gulf Sturgeon populations and their habitats to pre-injury condition.

3. ***Long-term Objective B*** *– is a long-term fishery management objective to establish, following delisting, a self-sustaining population that could withstand directed fishing pressure within management units. Note that the objective is not necessarily the opening of a management unit to fishing, but rather, the development of a population that can sustain a fishery. Opening a population to fishing will be at the discretion of state(s) within whose jurisdiction(s) the management unit occurs. As with Long-term Objective A, the objective may not be achievable for all management units, but will be sought for all units.*

Criteria:

A. *All criteria for delisting must be met.*

   This criteria is a fishery management objective and not a valid recovery criteria as it involves objectives following delisting (i.e., recovery) of individual management units. Gulf Sturgeon is listed as a species (50 CFR 17) and any single management unit may not be considered for delisting.

B. *This objective will be considered attained for a given management unit when a sustainable yield can be achieved while maintaining a stable population through natural recruitment.*

   As noted above, this is a fishery management objective and not a valid recovery criteria. Although this objective could be conceptually investigated to understand status of individual management units, the demographic parameters are currently lacking to evaluate sustainable yield (or if reproduction and recruitment of individuals into reproductive age classes would be consistently higher than mortality). Furthermore, sturgeon are highly susceptible to over-fishing due to slow maturation and periodic recruitment. Flowers (2008) describes how the historic overexploitation of Gulf Sturgeon led to a change in the age-structure of the populations that reduced annual reproductive output. Flowers et al. (2020) further discuss challenges in estimating what the current Apalachicola River population might support in terms of a future fishery. Thus, an important distinction exists between acknowledging a population's ability to support a fishery and the act of opening a fishery for harvest of Gulf Sturgeon, the latter having been formally recognized as the leading cause of species decline.

C. *Particular emphasis will be placed on the management unit that encompasses the Suwannee River, Florida, which historically supported the most recent stable fishery for the subspecies.*

   The Suwannee River population appears to be stable or increasing (Sulak et al. 2016) and modeling efforts are underway to assess potential population trends under additional hypothetical sources of mortality through the Population Status and Trends Study described previously. However, as previously noted, an individual management unit cannot be delisted and delisting of the entire species would be a precondition to the opening of a Gulf Sturgeon fishery in any management unit.

2.3. Updated Information and Current Species Status

2.3.1. Biology and Habitat

2.3.1.1. New information on the species' biology and life history

Brooks and Sulak (2005) described the distribution of Gulf Sturgeon food resources in the Suwannee River estuary. They found that benthic infauna biomass was greater in the summer than in the winter, and that the spatial distribution of likely prey items was patchy (high in certain areas and low in others).

Additional studies examining Gulf Sturgeon prey have been conducted based on Heard et al.'s (2002) assessment of the benthic macro invertebrate assemblages in Choctawhatchee Bay suggesting that ghost shrimp*, Lepidophthalmus louisianensis*, was an important food for Gulf Sturgeon greater than 1 m in length. McLelland and Heard (2004, 2005) later analyzed the benthic macro-invertebrate assemblages from two sites off the northern Gulf of Mexico coast of Florida and Alabama where Gulf Sturgeon were located by telemetry and believed to be foraging during winter. They reported in 2004 that annelids comprised the main group of organisms collected at both sites and with the exception of the high density of tube building polychaetes collected at the Alabama site, little difference in the benthic invertebrate populations was noted between the two sites. The density of benthic organisms did not substantially differ from 2004 to 2005. However, McLelland and Heard (2005) noted there were a few shifts in population structure: 1) an absence of the tube dwelling polychaete*, Hobsonia florida*, at the Alabama site that was predominate in 2004 and was replaced by the polychaete, *Mediomastusa ambiseta*; and 2) an increase in the number of mollusks with a decrease in arthropods at the Florida site. They speculated that the possible changes in the macro-invertebrate structure could reflect a response to increased nutrient loading from runoff or perhaps a physical shift due to the effects of Hurricane Ivan that made landfall in eastern Alabama in August 2004.

More recent studies have focused on benthic habitat in estuaries in the western Gulf of Mexico. Peterson et al. (2013) found differences between Gulf Sturgeon habitat between the Pascagoula River estuary and earlier studies focused on Florida estuaries, namely higher silt content and associated prey density in the Pascagoula River estuary compared to Florida estuaries. Wilber et al. (2019) also found regional variation in Gulf Sturgeon prey assemblages across the northern Gulf of Mexico and related patterns to physical habitat variables (e.g., sediment composition, dissolved oxygen (DO)). Whether these differences influence the vulnerability of populations to threats is unclear at this time.

Edwards et al. (2003) tracked the movements of Gulf Sturgeon in the Suwannee River estuary using ultrasonic tags and a fixed array of receivers. Tagged individuals displayed a pattern of directed slow, steady travel over several kilometers followed by periods of randomly directed travel. This pattern is consistent with a foraging strategy that is adapted to a patchy distribution of food resources by an animal that lacks advance knowledge of the location of the patches or an ability to detect the patches from afar. If applicable, this strategy may help to explain the regular detection of telemetry-tagged Gulf Sturgeon from natal river systems ranging from Louisiana to the Florida panhandle in the same marine foraging areas, such as the Mississippi barrier islands (Vick et al. (2018).

In a follow-up paper reporting results of satellite pop-up archival tags, Edwards et al. (2007) discussed mixing of Gulf Sturgeon from different populations and overlap of winter habitat utilization. Similarly, in a multi-year study Ross et al. (2009) found Gulf Sturgeon from both the Pascagoula and Pearl Rivers broadly overlap and use the shallow water along the Gulf barrier islands as foraging grounds in the winter. These marine habitats utilized by Gulf Sturgeon were all less than 7 m deep, generally well oxygenated, and with relatively clear water; bottom substrates were mostly coarse sand and shell fragments or fine sand (Ross et al. 2009). Also, Gulf Sturgeon tagged in four Florida panhandle river systems were monitored in the coastal waters off of Mississippi during the winter period (Vick et al. 2018). Evidence from the studies mentioned above illustrate that Gulf Sturgeon from different river systems were periodically located occupying the same area of marine habitat.

Harris et al. (2005) also tracked the movements of Gulf Sturgeon in the Suwannee River estuary using ultrasonic tags and sampled benthic infauna. Locations of tagged Gulf Sturgeon were associated with sandy substrates and high abundances of known prey items. Gulf Sturgeon individuals appeared to use different portions of the estuary in fall compared to spring.

Randall and Sulak (2007) estimated yearly recruitment of Gulf Sturgeon using 19 years of mark-recapture data for the Suwannee River population. Recruitment was positively correlated with high flows in September and December. They suggested that higher survival of age-0 sturgeon may be related to increased availability of lower-salinity estuarine feeding habitats in wet years.

Randall and Sulak (2012) were the first to present evidence suggesting fall spawning behavior by Gulf Sturgeon in the Suwannee River. More recently, D. Fox (Delaware State Univ., Dover) and S. Rider (Alabama Department of Conservation and Natural Resources) reported collecting eggs during the fall spawning period in the upper Choctawhatchee River system, thereby confirming the existence of fall spawning (D. Fox, pers. comm.). M. Price and M. Randall (USGS-Gainesville) are also planning to verify the unique genotypes of spring and fall spawning Gulf Sturgeon in the Suwannee River with genetic analysis of eggs collected during each spawning season. Initial evidence provided by telemetry identified spawning behavior and genetic analysis indicates that, temporally, there may be two genetically distinct spawning stocks in the Suwannee River (M. Price, pers. comm.). Collection of unusually short juvenile sturgeon (<310 mm fork length) in the late spring/summer period has also occurred in the Apalachicola, in both 2013 and 2019; these fish did not fall within the typical distribution of lengths (i.e., 340-530 mm fork length) observed for sturgeon spawned the previous spring, and more closely match the lengths of fish Randall and Sulak (2012) suggested belong to fish spawned during the previous fall season (i.e., less than one year elapsed time). Considering that both spring and fall spawning races have been identified among Atlantic Sturgeon (*A. oxyrinchus oxyrinchus*) populations (Balazik and Musick 2015), and the relatedness among the two subspecies, it seems logical that fall spawning behavior is exhibited by some, and perhaps all Gulf Sturgeon populations. Multiple spawning runs may make Gulf Sturgeon more resilient to threats such as catastrophic events. However, a given management unit may have multiple smaller populations with specific conservation or recovery requirements.

2.3.1.2. Abundance, population trends, demographic features, or demographic trends

Currently, seven rivers are known to support reproducing populations of Gulf Sturgeon; these same seven populations existed at the time the species was listed. Several populations were extirpated prior to listing; of these, the Mobile River basin likely had the largest reproducing population (Sulak et al. 2016). Using mark-recapture data, general estimates of population size over time have been calculated. Although variable, most populations appear relatively stable with a few exceptions (Appendix A, Table 1).

Research on Gulf Sturgeon population characteristics leading up to the 2009 5-Year Review was limited to the eastern five populations. The USFWS Panama City Fish and Wildlife Conservation Office and partners annually surveyed one or more of the four Florida Panhandle rivers (Escambia, Yellow, Choctawhatchee, and Apalachicola) since 2003 (fiscal year annual reports USFWS 2003-2008). USGS researchers completed the first assessment of the Yellow River population (Berg 2004, Berg et al. 2007). The most recent assessments of populations occurring in Florida Panhandle rivers are as follows: Yellow River (2010-2011), Blackwater River (2013), Apalachicola River (2014), and Escambia River (2015).

Results of surveys to assess abundance of Gulf Sturgeon within the seven river drainages with known reproducing populations are summarized in Appendix A, Table 1. Estimates provided refer to numbers of individuals greater than a specified size, which varies depending on sampling gear. Estimates may also vary depending on models selected for data analyses, and in some cases, estimates refer to numbers of individuals that use a particular portion of the river (e.g., a summer holding area or one migratory pathway among several). Thus, the interpretation of trends illustrated by these assessments is tenuous and must take into consideration various differences in methodology. Within the last 3-5 years, new investigations have been initiated in the western range of the species (Pearl and Pascagoula Rivers) but results of those population assessments are not yet available.

Working with data from the Suwannee River population, Pine et al. (2001) identified three parameters (i.e., egg-to-age-1 mortality, the percentage of females that spawn annually, and adult mortality) as those most sensitive in determining the trajectory of population. Pine et al. (2001) predicted that slight increases in estimated annual adult mortality (from 16% to 20%) would shift the population from an increasing trend into a decline. Flowers (2008) used an age-structured model to conclude that the Apalachicola population is probably slowly recovering, but still needs many years before returning to levels near its pre-exploitation abundance, although such abundance levels are not necessary to reach recovery. Sulak and Randall (2008) reported an analysis of mark-recapture data for the Suwannee River that suggests this population is regaining a semblance of its pre-exploitation age structure, with a shift from 10% mature individuals in 1996 to 40% in 2007.

Flowers (2008) describes the rapid decline in Gulf Sturgeon landings in the early 1900s as likely reflective of the removal of larger, older, more fecund individuals, leading to a rapid change in the age-structure of the population and thereby reducing annual reproductive output and population recovery. Using several formulations (varying key input parameters, such as annual natural mortality) of an age-structured mark-recapture model (ASMR), Pine and Martell (2009) analyzed all available Gulf Sturgeon sampling data collected since the late 1970s for the Apalachicola and Suwannee Rivers. For the Apalachicola River data, the models generally estimated population sizes (age 1+ Gulf Sturgeon) of fewer than 500 individuals in the early 1980s, which increased to about 2,000 fish in 2005. These estimates are substantially higher than for other non-age-structured models. This is partly because estimates from Pine and Martell (2009) include younger age-classes than those included in Zehfuss et al. (1999). The most recent population assessment conducted in the Apalachicola occurred in 2014, with the fishing of both small and larger mesh gill nets to capture all sizes of fish at Age-1 or older. Population abundance estimated from this assessment was 1,288 fish >300 mm fork length. Side scan sonar was used to identify all holding area habitats occupied by Gulf Sturgeon, and fishing effort was expended in all occupied habitats. More than half of the estimated population was handled/observed within the 2014 fishing season (i.e., May-July), leading to unusually precise estimates of the abundance of fish present (Appendix A, Table 1). Despite key differences in input data and model assumptions, a general trend of gradually increasing abundance was apparent in the Apalachicola River through 2014 (Appendix A, Table 1).

Pine et al. (2001) estimated a positive population growth of about 5% annually for adults within the Suwannee River Gulf Sturgeon population using modeling approaches that examined data from 1986 to 1995. If the Suwannee River population represents the most noteworthy example of a rebounding population, and the rate of growth under this “best case scenario” has been observed at only 5% per year, these realities have important implications for establishing expectations in the context of future sturgeon abundance targets. For example, at a sustained growth rate of 5% per year it would take a population approximately 14 years to double in size, regardless of initial population size, if all other variables remain constant. Thus, a small population of about 100 adults would not reach a target abundance of 500 adults (NMFS 2018) for more than three decades (i.e., 34 years), tenuously assuming the population sustained growth at the maximum rate each year and that no stochastic mortality events occurred during that time period. Another consideration in recovery timeframes is carrying capacity. Populations at carrying capacity (e.g., potentially the Suwannee River population) may have little to no annual population growth.

Gulf Sturgeon population estimates based on mark-recapture data are frequently imprecise, with more than half of the confidence intervals reported (Appendix A, Table 1) exceeding 65% of the abundance estimate. This is likely due to the low capture/recapture probabilities associated with sampling this species, which was estimated to be <10% using closed-system models by Zehfuss et al. (1999). It is not necessary in this review to compare and contrast the methods of these various assessments; however, there is a need to develop a standardized data reporting system, and to direct the research and development necessary to provide 1) a clearer picture of range-wide status, and 2) to determine whether it is feasible to reveal trends in recruitment and population abundance that may occur on the relatively short times scales associated with the evaluation of restoration actions and the 5-year review cycle.

2.3.1.3. Genetics, genetic variation, or trends in genetic variation

Sulak et al. (2016) synthesized information related to genetic variation among fish sampled from each of the occupied rivers and confirmed straying behavior beyond adjacent populations is likely to be uncommon in Gulf Sturgeon. Gulf Sturgeon exhibit a high degree of genetic discreteness at the population level, and also exhibit group-level discreteness when the following population groupings are compared: West (Pascagoula/Pearl), Central (Escambia/Yellow/Choctawhatchee), and East (Apalachicola/Suwannee) (Stabile et el. 1996, Waldman et al. 2002). Rudd et al. (2014) provided an analysis of straying rates (i.e., referred to as “transition probabilities”) among river systems that generally indicated some straying among geographically adjacent systems (e.g., individuals move between the Escambia River and the adjacent Yellow River system), and limited to no straying among systems more geographically distant from one another (e.g., Suwannee River and Yellow River). Local straying does not necessarily translate into increased genetic exchange, as maternal homing and reproduction within an individual’s system of origin is likely necessary to maintain the high levels of genetic discreteness observed (Stabile et al. 1996).

2.3.1.4. Taxonomic classification or changes in nomenclature

No changes.

2.3.1.5. Spatial distribution, trends in spatial distribution, or historical range

The most comprehensive study of marine movements and spatial distribution of adult Gulf Sturgeon conducted to date occurred during the 2010-2012 NRDA BP Oil Spill Injury Assessment. Over the two-year period 251 Gulf Sturgeon were outfitted with acoustic transmitters and their movements monitored via approximately 150 acoustic receivers deployed in nearshore waters across the northern Gulf of Mexico. Findings from the monitoring did not appear in detail in the Final Programmatic Damage Assessment and Restoration Plan (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016), but a committee of research partners are currently working towards the development of one or more publications that will present and interpret the data collected. Qualitative analyses of the data conducted during the NRDA injury assessment illustrated areas of higher-use that were frequented by adult fish from the seven populations.

Coincident with the increase in population abundance of Suwannee River Gulf Sturgeon, sightings of living and deceased sturgeon suggest an expansion of the freshwater and marine range used or occupied seasonally. Sturgeon have been reported in the Santa Fe River (tributary to the Suwanee River) in recent years (Sulak et al. 2016), and mortalities of sturgeon in upper Tampa Bay indicate this system is also being utilized (FWCC Fish Kill Hotline; USFWS/NMFS mortalities database).

Summer holding habitats are thought to represent important bioenergetic refugia during a period of trophic dormancy (Sulak et al. 2016). The relocation to holding area habitats in adjacent rivers following the spring spawning period is noteworthy and may indicate that summer holding area habitat is limited or in short supply in some systems. Sulak et al. (2016) noted that the relevance of summer holding habitat quality and quantity to theoretical carrying capacity of adults and subadults is one that had not been considered by Ahrens and Pine (2014). Telemetry monitoring in Florida in recent years has revealed seasonal (i.e., summer) residency of adult Gulf Sturgeon in the Perdido River near the Wilson B. Robertson Boat and Canoe Launch by fish originally tagged in the Escambia Bay complex of rivers (i.e., Escambia, Blackwater, Yellow; USFWS unpublished data). Population assessments conducted in the lower Blackwater River have indicated increasing numbers of resident fish in that system over the last 5 years, particularly within Coopers Basin (USFWS, unpublished data). Moreover, monitoring and fish sampling in the Ochlockonee River (FL) have also revealed regular use of portions of the lower river as summer holding habitat (USFWS, unpublished data).

2.3.1.6. Captive Propagation / Reintroduction/Translocation

Large-scale hatchery supplementation of Gulf Sturgeon has not been attempted and adults are currently not removed from the wild for use as hatchery broodstock. Any future proposals for Gulf Sturgeon hatchery program should include an evaluation of the potential population consequences – loss of wild broodstock, low survival or fecundity of hatchery fish, genetic dilution, etc. Sulak et al. (2014) evaluated survival of an experimental release of juvenile Gulf Sturgeon in the Suwannee River over 19 years. Survival of hatchery fish was significantly lower than wild sturgeon such that few of the 1,192-hatchery sturgeon were estimated to have survived to maturity; less than three individuals were predicted to have survived to 2011, 19 years after their release (Sulak et al. 2014). An experimental translocation of ten adult male sturgeon above Jim

Woodruff Lock and Dam was conducted to determine whether adult fish would continue upstream migration into the tributary systems in the Apalachicola Basin. Results were largely inconclusive as fish either returned back downstream below the dam or perished after becoming trapped in the reservoir (Marbury et al. 2021).

2.3.2. ESA Definitions/Listing Determinations

The ESA provides the following definitions:

"endangered species" is defined as "any species which is in danger of extinction throughout all or a significant portion of its range."

"threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

The process for determining whether a species (as defined above) should be listed is based upon the best available scientific and commercial information. The status is determined from an assessment of factors specified in section 4 (a)(1) of the ESA that may be contributing to decline, including:
(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; or
(E) Other natural or manmade factors affecting the continued existence of the species.

2.3.3. Five-Factor Analysis

Under each factor, we note the impacts and threats that were analyzed in the 1991 listing rule, followed by a discussion of current threats and changes to previously identified threats.

2.3.3.1. Present or threatened destruction, modification or curtailment of its habitat or range:

The 1991 listing rule cited the following impacts and threats:

- Dams on the Pearl, Alabama, and Apalachicola rivers, and on the North Bay arm of St. Andrews Bay;
- Channel improvement and maintenance activities – dredging and de-snagging;
- Water quality degradation; and
- Contaminants.

2.3.3.1.1. *Habitat – dams*

Dams serving as barriers to movement: All of the dams noted in the listing rule continue to block passage of Gulf Sturgeon to historical spawning habitats and thus either reduce the amount of available spawning habitat or impede access to it. Dams can also affect natural flow regimes, sediment composition, and salinity in downstream and estuarine reaches. Several dam construction proposals were noted on rivers that support Gulf Sturgeon in previous status review (USFWS and NMFS 2009) but no major dams have been approved for construction to date.

Studies conducted to determine the feasibility of Gulf Sturgeon passage through the lock system at Jim Woodruff Lock and Dam on the Apalachicola River revealed limited success for passage by operating the lock for such purposes (USFWS and NMFS 2009). A study conducted in spring 2015 by University of Georgia and USFWS involved capture, tagging, and transport of ten adult male sturgeon above the dam and release into Lake Seminole to determine whether wild adults would continue migrating upstream in search of spawning habitat. Six of the ten males moved back down below the dam within one week of release, surviving passage over or through the structure. Two fish demonstrated upstream movement into the riverine portions of the lower Flint River, then subsequently returned downstream to the reservoir near Jim Woodruff Lock and Dam. The four males that remained trapped above the dam (two of which had previously exhibited movement into the lower Flint River) were believed to have perished in the reservoir. Overall, the results were inconclusive in terms of determining feasibility of providing access to upstream habitat by passing adult sturgeon above the dam (Marbury 2016).

Dam operations impacting habitat and survival: The effects on Gulf Sturgeon from the U.S. Army Corps of Engineers (USACE) operation of Federal dams and reservoirs in the Apalachicola River basin were assessed in recent biological opinions (USFWS 2006, 2007a, 2008a, 2012, 2016). The 2008 opinion concluded that some lethal take of Gulf Sturgeon eggs and larvae could occur under certain circumstances of rapidly declining river stages during the spawning season. Based on further analysis of flow records and operational practices, USACE determined that it appears feasible to operate the system in a manner that would avoid take of eggs and larvae in most, if not all, circumstances (USACE 2009). Flowers et al. (2009) examined the possibility of reduced recruitment associated with low flows in the Apalachicola River system and suggested that decreased spawning habitat availability could delay population recovery or reduce population viability. The most recent opinion (USFWS 2016) concluded that the new Water Control Manual may negatively affect Gulf Sturgeon by expanding the potential for hydropeaking (cycles of high and low flows) during the spring spawning season and less inundation of floodplain habitats in late summer, fall, and winter. The opinion of the USFWS is that these effects will not jeopardize the continued existence of the Gulf

Sturgeon, nor destroy or adversely modify designated critical habitat for the species.

Overall, no dam removal or significant fish passage improvement has occurred in Gulf Sturgeon habitat since the previous status review. Dams and associated water management operations continue to threaten Gulf Sturgeon and their designated critical habitat.

2.3.3.1.2. *Habitat – dredging*

Riverine, estuarine, and coastal navigation channels are often dredged to support commercial shipping and recreational boating. Maintenance dredging occurs regularly in numerous navigation channels that traverse the bays, passes, and river mouths of all seven river drainages that are used by Gulf Sturgeon. Dredging of sediments used in marsh restoration and beach renourishment also occurs at considerable levels in Gulf Sturgeon habitat. Dredging activities can pose significant impacts to aquatic ecosystems by: 1) direct removal/burial of prey organisms; 2) turbidity/siltation effects; 3) contaminant re-suspension; 4) noise/disturbance; 5) alterations to hydrodynamic regime and physical habitat; and 6) loss of riparian habitat. Because Gulf Sturgeon are benthic omnivores, the modification of the benthos affects the quality, quantity, and availability of prey. Dredging operations may also disrupt spawning migrations, and cause siltation over spawning substrate. The direct lethal effects to Gulf Sturgeon resulting from interaction with dredges is discussed later in section 2.3.3.11.

In summary, dredging and disposal of sediments occurs frequently within designated Gulf Sturgeon habitat and throughout the range of the Gulf Sturgeon. Although efforts are underway to better understand Gulf Sturgeon movements around estuarine and nearshore dredging and borrow areas, this activity continues to threaten the species and affect its designated critical habitat.

2.3.3.1.3. *Habitat – point and non-point discharges*

Evaluations of water and sediment quality in Gulf Sturgeon habitat on the northern Gulf of Mexico coast, have consistently shown elevated pollutant loading. This has been observed in both tidal coastal rivers of the type that the sturgeon use in the spring and summer (Hemming et al. 2006, 2007b). Widespread contamination has also been documented throughout the overwintering feeding habitat of the Gulf Sturgeon (Brim 1998, Brim et al. 2000, NWFWMD 1997, 1998, Hemming and Brim 2002, Hemming et al. 2003a, 2003b, 2004, 2007a). Although the specific effects of these widely varied pollutants on sturgeon in their various life stages is not clearly understood, there is ample evidence summarized below to show potential deleterious effects to Gulf Sturgeon and their habitat.

Sulak et al. (2004) suggest that successful egg fertilization for Gulf Sturgeon may require a relatively narrow range of pH and calcium ion concentration. These parameters vary substantially along the length of the Suwannee River.

Egg and larval development are also vulnerable to various forms of pollution and other water quality parameters (e.g., temperature, DO). The sensitivity of Gulf Sturgeon eggs, embryos, larval, and juvenile sturgeon to elevated water temperatures (i.e., mortality when temperatures exceed 25° C) was reported by Chapman and Carr (1995) and Kynard and Parker (2004); this information was synthesized and discussed in detail in the 2016 Biological Opinion pertaining to the ACF Water Control Manual Update (USFWS 2016). Top-release dams such as Jim Woodruff Lock and Dam impound water and can alter thermal regimes of receiving waters, potentially increasing the rate at which river temperature reaches and exceeds 25° C during the spring spawning period.

Potential threats to Gulf Sturgeon critical habitat were documented in the upper Choctawhatchee and lower Pea Rivers (Popp and Parauka 2004, Newberry et al. 2009). Potential habitat threats were identified based on degraded habitat characteristics, such as erosion, riparian condition, presence of unpaved roads, and presence of agriculture.

Pollution from industrial, agricultural, and municipal activities is believed responsible for a suite of physical, behavioral, and physiological impacts to sturgeon worldwide (Karpinsky 1992, Barannikova 1995, Barannikova et al. 1995, Khodorevskaya et al. 1997, Bickham et al. 1998, Khodorevskaya and Krasikov 1999, Billard and Lecointre 2001, Kajiwara et al. 2003, Agusa et al. 2004). Although little is known about contaminant effects on Gulf Sturgeon, a review estimating potential reactions has been performed (Berg 2006). It was found that loss of habitat associated with pollution and contamination has been documented for sturgeon species (Verina and Peseridi 1979, Shagaeva et al. 1993, Barannikova et al. 1995). Specific impacts of pollution and contamination on sturgeon have been identified to include muscle atrophy; abnormality of gonad, sperm and egg development; abnormal morphogenesis of organs; tumors; and disruption of hormone production (Graham 1981, Altuf'yev et al. 1992, Dovel et al. 1992, Georgi 1993; Romanov and Sheveleva 1993, Heath 1995, Khodorevskaya et al. 1997, Kruse and Scarnecchia 2002). The extreme of this situation can be observed in the Caspian Sea, likely the most polluted sturgeon habitat in the world. Researchers there have suggested that nearly 90% of sturgeon suffer from organ pathologies and decreased physiological condition associated with sub-lethal levels of pollution (Akimova and Ruban 1996, Luk'yanenko et al. 1999, Kajiwara et al. 2003). In addition, nearly 20% of the female sturgeon experience some impact to egg development. Although there has been a reduction in pollution export into the Caspian Sea, the severity of past pollution and nature of the pollutants ensure their presence in the sediments, water column, and tissues of organisms will continue.

More recently, pharmaceuticals and other endocrinologically active chemicals have been found in fresh and marine waters at biologically relevant concentrations (reviewed in Fent et al. 2006). These compounds enter the aquatic environment via wastewater treatment plants, agricultural facilities, and farm runoff (Folmar et al. 1996, Culp et al. 2000, Wildhaber et al. 2000, Wallin et al. 2002). These compounds are the source of both natural and synthetic substances including, but not limited to, polychlorinated biphenyls, phthalates, pesticides, heavy metals, alkylphenols, polycyclic aromatic hydrocarbons, 17β-estradiol, 17α-ethinylestradiol, and bisphenol A (Pait and Nelson 2002, Aguayo et al. 2004, Nakada et al. 2004, Iwanowicz et al. 2009, Björkblom et al. 2009).

The impact of these exposures on Gulf Sturgeon is unknown, but endocrine disruption presumably from pollutants has been described in multiple sturgeon species (e.g., Matsche et al. 2013). One major class of endocrine disrupting chemicals, estrogenic compounds, have been shown to affect the male to female sex ratio in fish in streams and rivers via decreased gonad development, physical feminization, and sex reversal (Folmar et al. 1996). All of these changes could result in reduced reproductive capacity of affected individuals. Settlement of these contaminants to the benthos may affect benthic foragers to a greater extent than pelagic foragers due to foraging strategies (Geldreich and Clarke 1966).

Several characteristics of the Gulf Sturgeon (i.e., long lifespan, extended residence in riverine and estuarine habitats, benthic predator) predispose the species to long-term and repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants. Chemicals and metals such as chlordane, DDE, DDT, dieldrin, PCBs, cadmium, mercury, and selenium settle to the river bottom and are later incorporated into the food web as they are consumed by benthic feeders, such as sturgeon or macroinvertebrates. Some of these compounds may affect physiological processes and impede the ability of a fish to withstand stress.

While laboratory results are not available for Gulf Sturgeon, we believe studies of stress response in closely related species (Shortnose and Atlantic Sturgeon) may elucidate responses by Gulf Sturgeon. Signs of stress observed in Shortnose Sturgeon exposed to low DO included reduced swimming and feeding activity coupled with increased ventilation frequency (Campbell and Goodman 2004). These factors could ultimately result in behavioral disruption, reduced growth, or mortality. Niklitschek (2001) observed that egestion levels for Atlantic and Shortnose Sturgeon juveniles increased significantly under hypoxia, indicating that consumed food was incompletely digested. Behavioral studies indicate that Atlantic and Shortnose Sturgeon are quite sensitive to ambient conditions of oxygen and temperature: in experiments designed to assess water quality preferences, juvenile sturgeons consistently selected normoxic (i.e., expected oxygen levels at saturation given a specific temperature) over hypoxic conditions (Niklitschek 2001). Beyond escape or avoidance, sturgeons respond to hypoxia through increased ventilation, increased surfacing (to ventilate relatively oxygen-rich surficial water), and decreased swimming and routine metabolism (Crocker and Cech 1997, Secor and Gunderson 1998, Niklitschek 2001).

The majority of published data regarding contaminants and sturgeon health are limited to reports of tissue concentration levels. While these data are useful and allow for comparison between individuals, species, and regions, they do not allow researchers to understand the impacts of the concentrations. There is expectation that Gulf Sturgeon are being negatively impacted by organic and inorganic pollutants given high concentration levels (Berg 2006). Gulf Sturgeon collected from a number of rivers between 1985 and 1991 were analyzed for pesticides and heavy metals (Bateman and Brim 1994); concentrations of arsenic, mercury, DDT metabolites, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons were sufficiently high. More recently, 20 juvenile Gulf Sturgeon from the Suwannee River, FL, exhibited an increase in metals concentrations with an increase in individual length (Alam et al. 2000).

Federal and state water quality standards are protective of most taxa in many habitats. However, impacts of reduced water quality continue to be realized at species-specific, and habitat-specific scales and magnification through the trophic levels continues to be assessed. The result is that current water quality standards are not always protective of federally listed species (Augsburger et al. 2003, Augsburger et al. 2007). To compound the issue, many previously identified water quality problems as realized through violation of state water quality standards are addressed through the necessarily slow and deliberate process of regulated point, and non-point source, pollutant load reductions (Total Maximum Daily Loads, TMDLs) for chemicals that have specific quality criteria. Because there are thousands of chemicals interacting in our natural environment, many of them of human design, many do not have federal or state water quality standards associated with them. Further, effects of most of these chemicals on the Gulf Sturgeon or other protected species are poorly understood. For these reasons point and non-point discharges to the Gulf Sturgeon's habitat continue to be a threat.

As described in section 1, USFWS is responsible for all ESA section 7 consultations regarding Gulf Sturgeon and critical habitat in riverine habitat units, NMFS is responsible for all consultations regarding the species and its critical habitat in marine units, and the Services divide responsibility in estuarine units. NMFS evaluated the effects of Environmental Protection Agency's registration of pesticides containing chlorpyrifos, diazinon, and malathion on Gulf Sturgeon in estuarine and marine areas and concluded that these pesticides would not jeopardize Gulf sturgeon or adversely modify their critical habitat (NMFS 2017). USFWS recently evaluated the effects of Environmental Protection Agency's registration of pesticides containing malathion on Gulf Sturgeon (including freshwater areas) and also concluded that these pesticides would not jeopardize Gulf Sturgeon or adversely modify their critical habitat (USFWS 2022).

Since the previous status review in 2009, pollutant loading has likely increased in Gulf Sturgeon habitat as a result of several well documented, point-source releases. Substantial areas of Gulf Sturgeon critical habitat in the northern and western Gulf of Mexico were impacted by the historic Deepwater Horizon oil spill in 2010, and significant numbers of adult fish were potentially exposed to these contaminants (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Another point-source release was the Bogalusa paper mill wastewater spill in 2011 that caused a fish kill (which included at least 28 Gulf Sturgeon mortalities) over several miles of the Pearl River (LDWF 2011, Reuters 2011). Moreover, some small and moderate-sized accidental oil spills are anticipated during oil and gas production activities in the northern Gulf of Mexico over the next 50 years (NMFS 2020); Gulf Sturgeon and their habitat are likely to be further impacted (e.g., poor water quality, contaminated prey) by these future spills.

2.3.3.1.4. *Habitat – climate change*

Climate change has potential implications for the status of the Gulf Sturgeon through alteration of its habitat. The U.S. Global Change Research Program (USGCRP 2018) projected increases in air and ocean temperatures, sea levels, and extreme weather events over this century. Warmer water, sea level rise and ocean acidification could lead to accelerated changes in habitats utilized by Gulf Sturgeon. Changes in water temperature may negatively alter the growth, survival, and timing of life history events (e.g., spawning, migration) of fishes and affect distribution and abundance (USGCRP 2018). As mentioned previously (section 2.3.3.4) and summarized by USFWS (2016), Gulf Sturgeon early life stages (i.e., eggs, embryos, larvae) have a narrow range of temperature tolerances and are susceptible to poor development and mortality in elevated water temperatures. Both droughts and floods could become more frequent and more severe, which would affect river flow, water temperature, water quality, channel morphology, estuarine salinity regimes, and many other habitat features that will result in deterioration of habitat that is important to the conservation of Gulf Sturgeon. Reduced precipitation may also increase agricultural water demand in Florida, and further reduce freshwater flow and Gulf Sturgeon spawning and rearing habitat quality (Price 2019). Conversely, increases in severe weather events could increase storm water runoff and spills, which may result in associated fish kills from hypoxia and contaminants (Price 2019). Higher water temperatures combined with increased nutrients from storm runoff may also lead to or exacerbate harmful algal blooms and related fish kills (USGCRP 2018).

A rise in water temperature may create conditions suitable for invasive and exotic species that may prey upon or compete with sturgeon for resources. Climate change may also alter the distribution of native sturgeon competitors and predators, increasing resource competition and sturgeon predation rates. The rate that climate change and corollary impacts are occurring may outpace the ability of the Gulf Sturgeon to adapt given its limited geographic distribution and low dispersal rate.

2.3.3.2. Overutilization for commercial, recreational, scientific, or educational purposes:

Incidental take by commercial shrimpers was believed to be a significant threat to Gulf Sturgeon in the 1991 listing rule (NOAA and USFWS 1991). The discussion of incidental take in fisheries activities occurs below in section 2.3.3.4 (Inadequacy of existing regulatory mechanisms).

All directed fisheries of Gulf Sturgeon have been closed since 1972 in Alabama, 1974 in Mississippi, 1984 in Florida, and 1990 in Louisiana (USFWS and GSMFC 1995). Overutilization due to directed harvest is no longer a threat. Although confirmed reports are rare, Gulf Sturgeon mortality as bycatch in fisheries is potentially significant. Berg (2004) noted finding a dead juvenile Gulf Sturgeon on a trot line in the Blackwater River; a dead adult sturgeon was recovered in Choctawhatchee Bay in September 2017 that had part of a trot line and hook stuck in its mouth (USFWS- unpublished data). We discuss bycatch mortalities in greater detail in section 2.3.3.4. Scientific efforts to study and monitor Gulf Sturgeon typically rely on gill netting to capture fish, and such methods do infrequently result in mortality (see also section 2.3.3.2 on mortality occurring during a fish relocation study). A variety of best practices employed by those involved in Gulf Sturgeon research help to minimize mortality attributable to scientific activities. Nevertheless, one of the primary benefits of developing a non-invasive means of monitoring sturgeon populations via remote sensing (i.e., SSS surveys) is the fact that fish handling and disturbance will effectively be eliminated.

2.3.3.3. Disease or predation:

Disease was not known to be a factor in the 1991 listing rule (NOAA and USFWS 1991). No additional information regarding the threat of disease or predation is available; therefore, it is still not known to be a factor.

2.3.3.4. Inadequacy of existing regulatory mechanisms:

Similar to what was noted in the 1991 listing rule, direct take of Gulf Sturgeon is still prohibited in all four states within the current range of the species. Amendment Three of the Florida Constitution, known as the net ban, was approved by voter referendum in November 1994 and implemented in July 1995. The amendment prohibited the use of entangling nets (i.e., gill and trammel nets) in Florida waters. Florida’s net ban has likely benefited or accelerated Gulf Sturgeon recovery. Gulf Sturgeon commonly occupy estuarine and coastal habitats where entangling gear was used. Capture of small Gulf Sturgeon in mullet gill nets was documented by state fisheries biologists in the Suwannee

River fishery in the early 1970s. Large mesh gill nets and runaround gill nets were the gear of choice in historic Gulf Sturgeon commercial fisheries. Prohibition of this gear in Florida eliminates a potential source of mortality of Gulf Sturgeon.

Outside of Florida, fisheries directed at other species that employ various trawling and entanglement gear in areas regularly occupied by sturgeon pose a risk of incidental bycatch. One such fishery is directed at gars (family Lepisosteidae) in southeast Louisiana, where Gulf Sturgeon mortality in entanglement gear has been observed (D. Walther, USFWS, pers. comm.). Louisiana Wildlife and Fisheries Commission staff proposed a ban on commercial netting in freshwater areas of southeast Louisiana (the Parishes which include East Baton Rouge, East Feliciana, West Feliciana, Livingston, St. Helena, St. Tammany, Tangipahoa, and Washington) in September 2006. The ban was intended to reduce the incidental bycatch of Gulf Sturgeon but was never adopted. Consequently, incidental bycatch is still a threat to Gulf Sturgeon in Louisiana's waters.

Incidental bycatch in shrimp trawling and gill/trammel net fisheries (excluding Florida) still remains a threat to Gulf Sturgeon population recovery. Relocation trawling associated with dredging activities typically involves operation of shrimp trawls to capture and relocate protected species away from dredging operations. Reports of Gulf Sturgeon capture in relocation trawls highlight the ongoing susceptibility of sturgeon to trawling gear; since the previous status review, 32 Gulf Sturgeon were reported in relocation trawling off the coast of Alabama in 2012-2013 and 2 Gulf Sturgeon were reported off the coast of Mississippi in 2018. Additional information regarding Gulf Sturgeon bycatch is reported in Sulak et al. (2016), but quantitative estimates are still lacking due to poor observer coverage and likely low levels of self-reporting.

Although a number of steps have been taken to reduce the potential for Gulf Sturgeon to be incidentally caught by anglers or commercial operations, existing regulatory mechanisms do not prevent take of adult Gulf Sturgeon due to fishing bycatch. Because the loss of a few reproducing adults directly affects population size and growth, bycatch continues to be a threat.

2.3.3.5. Other natural or manmade factors affecting its continued existence:

The 1991 listing rule cited the following impacts and continuing threats:

- Life history characteristics make the species slow to recolonize areas from which extirpated.
- Threat of hybridization due to accidental or unlawful release of non-native sturgeon species.

2.3.3.5.1. *Life history characteristics and population growth*

As described in section 2.3.1.2, all new data continues to support the previous conclusion that Gulf Sturgeon are slow to recolonize areas where they formerly occurred such as the Mobile River system. In addition, slow population growth has been observed in many populations (Sulak et al. 2016). Recent telemetry investigations on the Suwannee River suggest higher spawning periodicity (i.e., more frequent spawning) in female Gulf Sturgeon which may infer higher potential population growth (Price 2019). Although we are learning more about population structure, there continues to be a number of uncertainties requiring additional research, including estimation of recruitment rates or population growth rates over time, and risk of population extinction under varying future scenarios.

2.3.3.5.2. *Dredging*

Our discussion above (section 2.3.3.3) provides an overview of habitat impacts related to dredging activities; in this section we discuss the direct lethal and sub-lethal effects to Gulf Sturgeon. Hydraulic (e.g., hopper) dredges can lethally harm sturgeon directly by entraining sturgeon in dredge drag arms and impeller pumps. Sturgeon mortalities have also been documented in mechanical dredges. Reine et al. (2014) summarized observed takes (e.g., injury, mortality) of 42 sturgeon from dredging activities conducted by the Corps between 1995 and 2013 (3 Gulf; 11 shortnose; and 34 Atlantic). Of the three types of dredges included (hopper, clamshell, and pipeline) in the report, the majority of sturgeon (all species) were taken with a hopper dredge (Reine et al. 2014).

Potential impacts from hydraulic dredge operations are avoided in some instances by scheduling dredging when sturgeon are not likely to be in the project area or imposing time-area work restrictions when sturgeon are most vulnerable to mortalities from dredging activity (i.e., migration, staging, and feeding). Relocation trawling is also utilized to capture and move sea turtles and sturgeon. In relocation trawling, a boat equipped with nets precedes the dredge to capture sturgeon and sea turtles and then releases the animals out of the dredge pathway, thus avoiding lethal take. Relocation trawling has been successful and routinely moves sturgeon in the Gulf of Mexico (described in 2.3.3.8).

2.3.3.5.3. *Hurricanes*

Gulf Sturgeon mortalities as a result of hurricane-induced hypoxic conditions have been reported in most occupied systems–Pearl, Pascagoula, Escambia, Choctawhatchee, and Apalachicola. Fish kills from hurricanes are primarily caused by low DO, or hypoxia, in floodwaters caused by the entrainment and decomposition of organic matter transported into rivers from the floodplain, saturated soils, and wastewater and septic inputs (Mallin and Corbett 2006). Harm to benthic invertebrate communities by hurricanes has been documented as well (Poirrier et al. 2008) and may lead to indirect effects on Gulf Sturgeon populations through temporary loss of prey. The severity of impacts to Gulf Sturgeon may be related to the strength of the hurricane and geographic aspects of its landfall.

The number of Gulf Sturgeon in the Escambia River system may have declined in 2004 due to the impact of hurricane Ivan. The most recent population assessment conducted by USFWS occurred 10-years post-storm in 2015 and resulted in an estimate of 373 fish >900 mm fork length (Sulak et al 2016). Hurricanes Ivan (2004) and Katrina (2005) are suspected to have impacted both the Pearl and Pascagoula populations (Andres et al. 2018), but the current size of the Gulf Sturgeon populations within the Pearl and Pascagoula rivers have not been recently estimated. An investigation of the impacts of Hurricane Michael (October 10, 2018) on the Apalachicola River population was recently completed. A fish kill was documented in the weeks post-storm; 10 subadult and adult sturgeon were documented in an advanced state of decay 16 days after the storm had passed, and many more were observed (A. Strickland, FWCC, salvage reports). Furthermore, approximately 46% (19 of 41) of the sonic-tagged fish present in the system when the storm made landfall remain unaccounted for, and are presumed to have perished in the hypoxic waters of the lower river (Dula 2021) Given that tagged fish were mixed in the population and not thought to behave any differently than the population at-large, this observation suggests that the adult population may have suffered a significant loss of individuals.

The term "hurricane" does not appear in the 1995 Gulf Sturgeon Recovery/Management Plan, and only a short paragraph was devoted to the topic in the 2009 5-year Review, suggesting that hurricanes were not perceived as a significant threat to Gulf Sturgeon in the past. Knutson et al. (2019) reported that tropical cyclone intensity and rainfall rates are likely to increase in the 21st century. Given the sensitivity of Gulf Sturgeon population trajectories to elevated mortality rates (Pine and Martell 2009, Rudd et al. 2014, Flowers et al. 2020), and mounting evidence that major hurricanes can produce significant mortality of river resident sturgeon, the relevance of these natural disasters to the recovery of the species is likely higher than previously considered. The ability of stochastic hurricane-related mortality to restructure populations, and to "reset the clock" in terms of recovery of population abundance is something that should be studied and modeled more closely- not only in terms of the relationship of this threat to population extinction risk, but also as a plausible explanation for observed population status and trends across the entire range. If recurring hurricane mortality is a factor that effectively prevents Gulf Sturgeon from reaching higher population abundances in the foreseeable future it must be accounted for in reviews of species status and recovery.

2.3.3.5.4. *Collisions with boats*

Collisions between jumping Gulf Sturgeon and fast-moving boats on the Suwannee River and elsewhere continue to be a source of sturgeon mortality and pose a serious public safety issue. Since the previous status review in 2009, FFWC recorded 19 Gulf Sturgeon collisions including one human fatality (FFWC 2019). FFWC maintains a public awareness campaign about the risk to the boating public with the message “Go slow on the Suwannee.” Placards have been posted and distributed along the Suwannee River in areas where Gulf Sturgeon are frequently spotted jumping and in areas of high boat traffic. In 2016, the Sturgeon Strikes Task Force interagency committee was formed in response to mounting concerns for the safety of boaters and those recreating in areas frequented by jumping sturgeon; representatives of the Services were part of the committee. Additional signs were deployed in 2019 at boat ramps near many of the high-use sturgeon areas on the Suwannee and other coastal plain rivers. Public outreach and education continues to alert boaters to slow down in areas where Gulf Sturgeon are known to jump. However, the number of boating trips has been and is likely to continue increasing and continues to be a threat to Gulf Sturgeon. Boat collisions along with the potential mortality of adult Gulf Sturgeon poses a unique threat to the recovery of the species given the potential for negative public perception of the species as threat to public safety and property.

Sulak et al. (2013; presentation at the Annual Gulf Sturgeon Workshop) addressed the question of why sturgeon jump by demonstrating that jumping, and the coincident gulping of air, helps to adjust buoyancy compensation in the air bladder. This demonstration was accomplished by outfitting sturgeon with an accelerometer that recorded fish depth over time, revealing that prior to jumping, the fish exhibit a loss of buoyancy which translates into variable depth orientation in the water column. After jumping, fish were able to successfully descend to depth and maintain this position (K. Sulak, unpublished data). Sulak et al. (2016) provided a summary of the physiological mechanisms associated with the need to breach and gulp air. In addition to buoyancy compensation, jumping is also hypothesized to provide a means of communication to maintain group cohesion (Sulak et al. 2016). In summary, jumping is a physiological requirement for Gulf Sturgeon and is a behavior that occurs in both freshwater and marine environments where collisions with boats and ships will likely continue to occur into the future.

Edwards et al. (2007) note that sturgeon jump in marine waters as well. The regular jumping and breaching behavior of sturgeon also puts them at risk of strikes by large vessels at the water surface. To date, there have been five documented Gulf Sturgeon mortalities that exhibited tell-tale signs of collision with large vessels. This may be a result of low rates of Gulf Sturgeon ship strikes, or low rates of reporting where ship strikes are occurring. The threat of ship strikes may increase in areas of the northern Gulf of Mexico where barge and tug boat traffic associated with coastal protection, restoration, and infrastructure activities is expected to increase.

2.3.3.5.5. *Red tide*

Red tide is the common name for a harmful algal bloom (HAB) of marine algae (*Karenia brevis*) that can make the ocean appear red or brown. *K. brevis* is known to cause red tide throughout the Gulf of Mexico, with occasional red tides in the mid- and south-Atlantic United States. *K. brevis* naturally produces a brevetoxin that is absorbed directly across the gill membranes of fish or through ingestion of algal cells and can be lethal at high concentrations (Landsberg 2002 and references therein).

A red tide outbreak along the Florida Panhandle that encompassed areas from Apalachicola to Perdido Key in late Fall 2015 through the winter of 2016 coincided with the reports of eight dead sturgeon that washed up on area beaches (FWC Tools for Tracking Red Tides; https://myfwc.com/research/redtide/tools/; accessed July 2021). Another red tide outbreak on the Florida Gulf Coast began in late 2017 and persisted until early 2019. Three dead Gulf Sturgeon were reported where the red tide was more intense in the Tampa Bay area in 2018 and early 2019. The true relationship between the number of dead sturgeon reported in areas affected by red tide, and the actual number of sturgeon killed in the area, is unclear. Based on the best available information, toxins associated with red tide have likely killed Gulf Sturgeon at both the juvenile and adult life stages. Because the loss of a small number of reproducing adults can have a significant overall effect on the status and trend of the population (Flowers et al. 2020), red tide is recognized as a persistent and relevant threat to the recovery of Gulf Sturgeon.

2.3.3.5.6. *Aquaculture / Hybridization*

The Florida Department of Agriculture and Consumer Services Division of Aquaculture was permitted to lease marine bivalve aquaculture areas in Gulf Sturgeon designated critical habitat in August 2018 (USACE 2018). This permit includes special conditions to minimize impacts to Gulf Sturgeon critical habitat including deposit of cultch materials only on existing shell substrata and prohibition of off-bottom methodologies that directly cover the bottom. Only a small amount of the Florida coastline has been designated suitable for shellfish propagation and harvest, and the presence of healthy oyster reefs may improve Gulf Sturgeon prey abundance in adjacent areas. Still, there are potential negative effects to Gulf Sturgeon critical habitat associated with shellfish aquaculture such as increased turbidity, noise, and vessel traffic, and some disruption in movement through avoidance of off-bottom gear and aquaculture operations.

The previous status review describes the Florida Aquaculture Division requirements for sturgeon aquaculture facilities in the State. This program includes best management practices (BMPs) intended to minimize impacts of sturgeon aquaculture on wild Gulf Sturgeon (e.g., standards for animal containment and effluent water quality). Although there have been no reports of accidental captive sturgeon release in the state of Florida, the risk of escapement and hybridization is still present. Occasional escape of fish from aquaculture or research facilities into local waterways is likely, even with appropriate safeguards. Wind and rain associated with hurricanes and unusual weather events can cause overflow of tanks or holding ponds, impacts to irrigation systems, and result in unintended escape of fish. The geographic location of many farms nearby streams and rivers would allow easy entry of farmed fish into sturgeon habitat. As many farms use spring-fed wells as their source for irrigation, sturgeon raised in farms have likely acclimated to local water temperatures and would presumably survive in local rivers. While effects of intra-specific competition between native and non-natives sturgeons are unknown, diet and habitat overlap and introduction of disease are possible threats.

Other states within the geographic range of the Gulf Sturgeon have not implemented similar licensing, monitoring, or BMPs. There are two records of White Sturgeon, *A. transmontanus,* taken from the Coosa River system (Alabama/Georgia) which are considered to be escapes from a north Georgia private aquaculture facility where the species is reared for commercial purposes (M. Pierson, Alabama Power Company, pers. comm.; D. Catchings, Alabama Department of Conservation and Natural Resources, pers. comm.). Although this facility is located upstream of a series of hydropower dams, sturgeon can survive downstream movement through a dam. These incidents illustrate that the threat of introduction of captive fish into the wild, and potential hybridization, competition, and disease introduction can occur and are valid threats.

2.4. Synthesis

Mortality rate is a critical driver in every Gulf Sturgeon population. Pine et al. (2001) reported that Gulf Sturgeon population dynamics models are especially sensitive to small increases in mortality. Flowers (2008) describes how the historic overexploitation of Gulf Sturgeon led to a change in the age-structure of the populations that reduced annual reproductive output. Rudd et al. (2014) estimated river specific and regional survival rates for adult Gulf Sturgeon and found that survival rates were lower in the western Gulf, particularly the Pascagoula River. Restoration of population age-structure, and a rebound to historical abundance (if even possible) will likely take multiple decades (Flowers et al. 2020) given Gulf Sturgeon life history characteristics such as long life, slow growth, and late age at maturity.

Threats to the species that can increase mortalities and result in population declines as described above include direct and indirect mortality from fishery bycatch, dredging operations, point and non-point sources, and ship strikes. Furthermore, efforts to better understand the importance of recurring natural sources of mortality such as tropical cyclones and red tide events in terms of structuring populations, influencing population growth rates, and explaining contemporary abundance, will serve to set expectations regarding the future status of Gulf Sturgeon in a changing and unpredictable environment.

Abundance data (Appendix A, Table 1) indicate a roughly stable or slightly increasing population trend over the last decade in the eastern river systems (Florida), with a much stronger increasing trend in the Suwannee River. Populations in the western portion of the range (Mississippi and Louisiana) are believed to exhibit lower abundance than those in the eastern portion of the range. Sulak et al. (2016) discuss the results of these efforts and several factors hypothesized to explain low contemporary abundance, including hurricane impacts in that region of the species range. The current status of the two western Gulf of Mexico populations is uncertain as comprehensive surveys have not occurred since the previous review.

Based on the information in the preceding sections, the Services believe the Gulf Sturgeon continues to meet the definition of a threatened species given the continuation or worsening of threatening factors and: 1) the highly variable abundance estimates limited to riverine populations in the east of the sub-species' range, coupled with the unknown status of smaller western populations; 2) results of population modeling that indicate slight increases in annual mortality would quickly shift trends from increasing to decreasing; 3) the unknown age-structure of all but two populations; 4) their long-lived, slow growing and late maturing life history characteristics; 5) unknown population bottlenecks (i.e., limiting factors, for example- poor recruitment to the adult population due to elevated overwinter mortality of juvenile sturgeon); and 6) remaining gaps in the identification of focal habitats (e.g., spawning areas, summer holding areas) in occupied systems that prevent targeted efforts to monitor, protect, or restore these habitats.

The geographic range of the species as defined at the time of listing has not decreased to our knowledge. Seven riverine systems continue to have evidence of reproducing populations. Information shows a roughly stable or slightly increasing population trend in the eastern (Florida) systems. However, population size and structure of some populations, particularly in the western part of the range, is unknown, as population assessments have not been conducted in over 15 years. Although the Apalachicola River population suffered a reduction in adult abundance following Hurricane Michael, monitoring is underway to determine whether abundance rebounds in the coming years. Recent survey work directed at juvenile fish has demonstrated consistent reproduction and recruitment of juveniles in both the Pearl and Pascagoula river systems (USFWS, USM, unpublished data).

Direct and indirect impacts to the Gulf Sturgeon and its habitat continue to affect its continued existence through: 1) present or threatened destruction, modification or curtailment of its habitat or range; 2) inadequacy of existing regulatory mechanisms; and 3) other natural or manmade factors. These factors include negative impacts to populations and their habitats by dams, dredging, point and nonpoint discharges, climate change, bycatch, hurricanes, red tide, and boat collisions. The juvenile and early-life-history stages of Gulf Sturgeon remain the least understood, and perhaps the most vulnerable to some of these threats. Gulf Sturgeon remain in the river for their first year of life and are therefore exposed to most of the threats faced by the species and its habitat. Furthermore, the species' life history characteristics (i.e., long-lived, late-maturing, intermittent spawning) make the recovery of population structure and abundance a very slow process. Given the lack of consistent population demographic estimates, the uncertainty regarding status of the two westernmost populations (Pearl and Pascagoula), and the presence of persistent and unquantified threats, the Gulf Sturgeon continues to meet the definition of a threatened species under the Act.

3. RESULTS

3.1. Recommended Classification:

_____ Downlist to Threatened
_____ Uplist to Endangered
_____ Delist
_X__ No change needed

3.2. New Recovery Priority Number

Based on the information synthesized in this review, FWS is assigning a new recovery priority number (RPN) of 9C to the Gulf Sturgeon. The number 9C pertains to a subspecies that has a moderate degree of threat and high recovery potential that may be in conflict with construction, development projects, or other economic activity. In addition to adding a C to the RPN, the main change in the RPN from 12 to 9 comes from a new assessment of potential of recovery being changed from a low recovery potential to a high recovery potential. Based on the fact that all 7 populations that existed at the time of listing have persisted over the last 30 years despite several catastrophic mortality events occurring as a result of hurricanes or pollution events, and that the available data suggests most are either stable or increasing, recovery in terms of attaining self-sustaining populations that represent the species across a majority of its historic range seems likely in the future.

4. ONGOING and FUTURE CONSERVATION ACTIVITIES

4.1. Recovery Actions

As described previously, three projects are currently underway that are funded under the NRDA program that focus on various aspects of habitat identification, habitat use, and population dynamics. The projects are anticipated to inform and prioritize future on-the-ground restoration actions taken to protect or restore Gulf Sturgeon habitat. One of the long-standing recovery actions discussed in the Recovery Plan includes the removal of sills in the Pearl and Pascagoula River systems that intermittently impede access to upstream habitats. We anticipate that NRDA funding may be directed toward either the removal of these sills or the provision of passage at these sites, pending the results of these ongoing NRDA projects.

4.2. Research and Development

Standardization of survey and monitoring protocols are being implemented through multiple initiatives to assess the status of Gulf Sturgeon populations across the range. A range-wide study of juvenile sturgeon recruitment, mortality and habitat use is in progress through the Juvenile Sturgeon Dynamics Project, as is the development and implementation of a modern tagging database and data management protocols through the Population Status and Trends Study. During the latter project, specific metrics will be calculated and evaluated for inter-basin comparison of population trends. Areas of data insufficiency will be identified, providing managers the information needed to direct limited resources toward filling those gaps. Given that the recovery status of a species has much to do with the future risk of extinction, these important studies will assess the population status, trajectory, and viability of each of the seven populations, taking into consideration stochastic threats such as hurricane-related mortality, red tide, and point-source pollution discharges. In tandem, these studies will identify factors that limit each of the seven populations from achieving higher population growth rates, lower mortality rates, or higher abundances. Future restoration and recovery efforts will be informed by this improved understanding of population status and the relative impacts of the myriad threats to recovery.

Efforts are underway to develop and implement a reliable remote sensing method based on SSS for monitoring large Gulf Sturgeon. This method can be a potential substitute for more widely used labor-intensive, mark-recapture approaches to abundance estimation, or in some cases, generate abundance indexes in areas where little to no sampling has occurred. Moreover, focal habitats have not been fully identified or mapped for each population. The ability to rank the influence of limiting factors, and identify focal habitats remains a crucial aspect of prioritizing restoration approaches and geographic locations for project implementation. Hence, development of a geodatabase is also recommended that incorporates spatial datasets identifying the distribution of the five focal habitats. Improved understanding of Gulf Sturgeon spatio-temporal distribution in the context of life history needs will provide the Services a more effective baseline for evaluation of anthropogenic activities through the ESA section 7 consultation process.

Early life stage (i.e., egg to larval phase) survival has emerged as a relatively sensitive variable in the age-structured population models developed for the Gulf Sturgeon (Pine et al. 2001). Long-term research is already underway to estimate recruitment and annual survival of juvenile sturgeon to test hypotheses associated with hydrologic influences on population dynamics. An overarching objective of all Gulf Sturgeon NRDA projects is to evaluate the potential benefits of enhancing or improving access to spawning habitat in the western Gulf of Mexico. The Juvenile Sturgeon Dynamics Project also includes plans to further investigate genetic discreteness and significance of spring and fall spawning. Age-1 (or younger) fish should accurately represent the genetic makeup of the adult fish spawning in each river and enable us to eliminate the confounding effects of adult straying among adjacent systems (Kreiser 2012). This analysis will improve our understanding of potential recolonization and recovery times, and also genetic distinctness of the seven populations.

Communication with individual states responsible for issuing Gulf Sturgeon research permits was recommended in the 2009 5-year review and remains a valid recommendation. The states have permitting authority (56 FR 49658; September 30, 1991) and no annual reporting to the Services is required. Summary information regarding permits granted, along with a description of the action would greatly assist the Services in tracking research and recovery. Other ongoing or emerging areas of Gulf Sturgeon research include impacts to critical habitat from large-scale dredging, marsh restoration, and off-bottom aquaculture. Several large-scale dredging and marsh restoration projects have been proposed in Gulf Sturgeon critical habitat (e.g., Gulf Spill Restoration – Restorations Areas 2020) and the impact of depth modification over broad swaths of estuarine habit are poorly understood and difficult to predict (Van Dolah et al. 1984, Kelaher et al. 2003); however, these projects can result in long-term alterations in benthic habitat composition and associated alterations in benthic community structure that may reduce foraging opportunities for Gulf Sturgeon (Quigley and Hall 1999). Off-bottom shellfish aquaculture is also increasing in estuarine and nearshore areas of the Gulf of Mexico and the effects of these activities on Gulf Sturgeon foraging habitat and behavior are unclear. Focused research on Gulf Sturgeon movement, prey species, and water quality in these areas would greatly improve the Services' ability to evaluate these project types.

Ongoing and Future Research

Until recently, juvenile sturgeon received little attention during research and monitoring efforts. As a result, little is known about patterns of recruitment, mortality, and habitat use by this life stage. A better understanding of the ability of each population to produce juvenile fish, and of the variation in production across the species range is important to prioritize recovery actions that would benefit young life stages.

Investigation into juvenile sturgeon recruitment and mortality was first undertaken in the Apalachicola River and a demonstration of these accomplishments was represented in the thesis work of Marbury (2016) and Hancock (2019). During this time period, a coincident study aimed at validating the use of second marginal fin rays for aging juvenile Gulf Sturgeon was completed by K. Moran with assistance from UGA and USFWS and was presented in Moran (2018).

The relationship between juvenile recruitment, or year class strength, and years with high river flows has been described in multiple sturgeon species, including Gulf Sturgeon (Randall and Sulak 2007). Research on Apalachicola River juveniles has occurred annually since 2013 with funding from both USFWS and the Army Corps of Engineers (USACE) and will continue through at least 2022 under the Juvenile Sturgeon Dynamics Project. The goal of the sustained effort is to provide a long-term record of recruitment that will be evaluated against a set of competing hypotheses relating hydrologic conditions to year class strength in a statistical modeling framework. Studies have demonstrated that the population produces juvenile sturgeon each year, and that age-1 cohort size varies by a factor of 4 but is generally small (30-60 individuals per year). This effort is expected to improve our overall understanding of the relationship between flows and sturgeon production in this regulated river system and highlight potential limiting factors that may be addressed through future management actions.

Efforts to capture, tag, and monitor juvenile Gulf Sturgeon are also now underway in the Yellow and Escambia rivers by the Florida Fish and Wildlife Conservation Commission, in the Pascagoula River by The University of Southern Mississippi, and in the Pearl River by the USFWS-Baton Rouge Field Office. Following the Apalachicola model, these studies are generating comparable data, and are expected to advance our understanding of juvenile sturgeon across their range. Furthermore, funding has been acquired to support such juvenile dynamics research in all seven occupied systems over 3 years (i.e., 2020-2022) under the Juvenile Sturgeon Dynamics Project. In addition to providing insights on recruitment, overwinter mortality, and estuarine habitat use, the acquisition of tissue and fin ray samples during this work will provide an opportunity to conduct a comparative age and growth study, and to conduct a juvenile genetics study that will allow us to take a new look at genetic distinctness among populations, breeding population sizes, and relatedness of progeny within populations. This new information will improve our overall knowledge of population and demographic trends heading into the next Gulf Sturgeon status review.

As described earlier, the monitoring of Gulf Sturgeon populations has been traditionally undertaken through directed mark-recapture population surveys, resulting in point-in-time estimates of net-vulnerable population numbers (summarized in Appendix A, Table 1). These efforts typically required months of sustained effort in the field and are costly and time intensive. The ability to statistically detect changes in population abundance using this approach is consequently driven by two primary factors: 1) the precision of the estimates, and 2) the time that has elapsed between surveys and the concomitant change in population abundance between time periods. Abundance estimates are, however, typically imprecise, and Gulf Sturgeon populations exhibit slow rates of change as previously discussed. Both of these factors limit the ability to detect changes over the short (i.e., 5-year) time scales that managers are required to reassess species status, thus highlighting the need for a more rapid and efficient means of population monitoring.

The use of SSS as a remote sensing tool for enumeration of large-bodied sturgeons has become a contemporary focus of sturgeon research. Sonar survey and subsequent classification and enumeration of sturgeon targets has been demonstrated to provide a means of detecting, assessing distribution, and estimating abundance of sturgeon, although several aspects of the methodology remain under development and investigation. Flowers and Hightower (2015) used a multi-pass approach and "N-mixture" modeling to estimate the abundance of Atlantic Sturgeon in several coastal systems, although estimates were typically imprecise and could not be validated against independently derived population estimates. Hughes et al. (2018) used the N-mixture modeling approach to estimate the abundance of White Sturgeon, and Vine et al. (2019) estimated the spawning migration abundance of Atlantic Sturgeon. Andrews et al. (2020) developed an approach for automating the enumeration of Shortnose Sturgeon (*A. brevirostrum*) present in sonar imagery, and extrapolating counts to areas not scanned to estimate system-wide abundance of the species in the St. Johns River system. Kayzak et al. (2020) developed an approach that integrated SSS counts with telemetry data to estimate the run size of Atlantic Sturgeon in the Hudson River.

Efforts to develop and validate a technique for monitoring the relative abundance of Gulf Sturgeon using low-cost SSS have been underway since 2012, led by A. Kaeser at the

USFWS Panama City Fish and Wildlife Conservation Office. A transition to SSS-based population monitoring comes with a large cost and time savings but does not provide some of the data that can only be obtained by handling and marking fish. Nonetheless, reduced fish handling is a major benefit of this technological approach should the techniques be fully vetted and implemented over the long term for purposes of tracking recovery.

The Gulf Sturgeon Status and Trends Study involves the overhaul and redesign of a Gulf-wide tagging and telemetry database and is vital to our assessments of the status, trends, and outstanding data needs for all seven Gulf Sturgeon populations. An effort to redesign the database began in 2016 and has since progressed through several phases including data acquisition, normalization, and reconciliation. A review of the completeness and accuracy of records incorporated for each system has been completed. A data entry system is under development that will, in the future, integrate field data collection with real-time data entry through the use of Bluetooth-enabled PIT tag readers and an electronic logbook, reducing entry errors and time spent handling data. The completion of the database project was the first step toward enabling an assessment of current status, trends, and data needs for each population; these assessments will conclude in 2024.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of GULF STURGEON (*Acipenser oxyrinchus desotoi*)

Current Classification: Threatened

Recommendation resulting from the 5-Year Review:

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

Review Conducted By:
Adam J. Kaeser, Ph.D., U.S. Fish and Wildlife Service (850) 769-0552
Joe Heublein, National Marine Fisheries Service (727) 209-5962

FIELD OFFICE APPROVAL:

Field Supervisor, Florida Ecological Services Field Office, U.S. Fish and Wildlife Service

Approve: LOURDES MENA Digitally signed by LOURDES MENA Date: 2022.05.06 16:49:22 -04'00' Adobe Acrobat version: 2022.001.20117 Date: 5/6/22

REGIONAL OFFICE APPROVAL:

Assistant Regional Director – Ecological Services, U.S. Fish and Wildlife Service, South Atlantic-Gulf and Mississippi Basin Regions.

Approve: CATHERINE PHILLIPS Digitally signed by CATHERINE PHILLIPS Date: 2022.06.01 09:44:14 -04'00' Date: 6/1/22

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
GULF STURGEON (*Acipenser oxyrinchus desotoi*)

Current Classification: Threatened

Recommendation resulting from the 5-Year Review

☐ Downlist to Threatened
☐ Uplist to Endangered
☐ Delist
☒ No change is needed

Review Conducted By:
Joe Heublein, National Marine Fisheries Service (727) 209-5962
Adam J. Kaeser, Ph.D., U.S. Fish and Wildlife Service (850) 769-0552

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

Approve: STRELCHECK.ANDREW.JAMES.1365863152 Digitally signed by STRELCHECK.ANDREW.JAMES.1365863152 Date: 2022.04.26 13:18:32 -04'00' Date: 4/26/22

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

☒ Concur ☐ Do Not Concur

Signature RAUCH.SAMUEL.D.III.1365850948 Digitally signed by RAUCH.SAMUEL.D.III.1365850948 Date: 2022.05.05 14:48:35 -04'00' Date________

Appendix A.

Table 1. Gulf Sturgeon abundance estimates, with confidence intervals (CI), for the seven known reproducing populations, plus fish residing in the Blackwater River.

Note: Estimates refer to numbers of individuals greater than a certain size, which varies between studies (source column) depending on sampling gear, and in some cases, to numbers of individuals that use a particular portion of the river (e.g., a summer holding area or one migratory pathway among several). Estimates are sorted by river, then by researcher and year, because estimates are not necessarily comparable between researchers due to key differences in methods and assumptions. Multiple estimates for a single year and river result from the application of multiple models or represent updated results incorporating additional data. Refer to original publication for details. Total length or age estimates provided by the original authors and corresponding to the abundance estimate were converted to fork length using the following sources: Andres et al. (2018); Brundage and Meadows (1982); Flowers et al. (2009); and Huff (1975).

River	Year of data collection	Abundance Estimate	Lower 95% CI	Upper 95% CI	Fork length	Source
Pearl	1993	67	28	not reported	>320 mm	Morrow et al. 1996
	1994	88	59	171	>320 mm	Morrow et al. 1996
	1995	124	85	236	>320 mm	Morrow et al. 1996
	1996	292	202	528	>500 mm	Morrow et al. 1998
	2001	430	323	605	>623 mm	Rogillio et al. 2001
Pascagoula	1999	162	34	290	>1,029 mm	Ross et al. 2001
	1999	193	117	363	>1,029 mm	Ross et al. 2001
	1999	200	120	381	>615 mm	Ross et al. 2001
	2000	181	38	323	>599 mm	Ross et al. 2001
	2000	206	120	403	>599 mm	Ross et al. 2001
	2000	216	124	429	>615 mm	Ross et al. 2001
Escambia	2003	558	83	1,033	unspecified	USFWS 2004
	2004	573	402	745	>418 mm	USFWS 2004
	2006	451	338	656	>529 mm	USFWS 2007b
	2006	511	265	987	$\geq$900 mm	USFWS, unpublished data[a]
	2015	372	241	576	$\geq$900 mm	Sulak et al. 2016[a]
Blackwater	2013	329	165	661	$\geq$900 mm	Sulak et al. 2016[a]
Yellow	2001	566	378	943	>800 mm	Berg et al. 2007
	2002 spring	500	319	816	>800 mm	Berg et al. 2007
	2002 fall	754	408	1,428	>800 mm	Berg et al. 2007
	2003 spring	841	487	1,507	>800 mm	Berg et al. 2007
	2003 fall	911	550	1,550	>800 mm	Berg et al. 2007
	2010-	1,036	724	1,348	unspecified	Sulak et al. 2016

River	Year of data collection	Abundance Estimate	Lower 95% CI	Upper 95% CI	Fork length	Source
	2011					
	2011	867	363	2,347	≥900 mm	USFWS, unpublished data[a]
	2012	398	111	1,859	≥900 mm	USFWS, unpublished data[a]
Choctaw-hatchee	1999	3,000	not reported	not reported	>529 mm	USFWS 2000
	2000	2,500	not reported	not reported	>529 mm	USFWS 2001
	2001	2,800	not reported	not reported	>529 mm	USFWS 2002
	2007	2,800	not reported	not reported	>890 mm	USFWS 2008b
	2007	2,576	1,427	4,744	≥900 mm	USFWS, unpublished data[a]
	2008	3,314	not reported	not reported	>890 mm	USFWS 2009
	2008	2,677	1,248	6,071	≥900 mm	USFWS, unpublished data[a]
Apalachicola	1983	282	181	645	>500 mm	Wooley and Crateau 1985
	1984	103	62	299	>755 mm	Barkuloo 1988
	1985	96	74	138	>500 mm	Barkuloo 1988
	1986	60	37	157	>500 mm	Barkuloo 1988
	1987	111	64	437	>500 mm	Barkuloo 1988
	1988	131	84	305	>500 mm	Barkuloo 1988
	1977	236	198	297	>500 mm	Pine and Martell 2009[b]
	1978	276	235	348	>500 mm	Pine and Martell 2009[b]
	1979	298	256	370	>500 mm	Pine and Martell 2009[b]
	1980	390	344	467	>500 mm	Pine and Martell 2009[b]
	1981	451	405	528	>500 mm	Pine and Martell 2009[b]
	1982	441	399	509	>500 mm	Pine and Martell 2009[b]
	1983	414	374	475	>500 mm	Pine and Martell 2009[b]
	1984	364	327	419	>500 mm	Pine and Martell 2009[b]
	1985	320	287	368	>500 mm	Pine and Martell 2009[b]
	1986	275	242	318	>500 mm	Pine and Martell 2009[b]
	1987	278	244	318	>500 mm	Pine and Martell 2009[b]
	1988	276	241	318	>500 mm	Pine and Martell 2009[b]
	1989	276	241	321	>500 mm	Pine and Martell 2009[b]
	1990	316	273	367	>500 mm	Pine and Martell 2009[b]
	1991	312	266	370	>500 mm	Pine and Martell 2009[b]
	1992	328	280	383	>500 mm	Pine and Martell 2009[b]
	1993	354	308	416	>500 mm	Pine and Martell 2009[b]
	1994	379	320	445	>500 mm	Pine and Martell 2009[b]
	1995	507	434	596	>500 mm	Pine and Martell 2009[b]
	1996	544	475	647	>500 mm	Pine and Martell 2009[b]
	1997	562	487	662	>500 mm	Pine and Martell 2009[b]
	1998	627	554	731	>500 mm	Pine and Martell 2009[b]
	1999	696	602	814	>500 mm	Pine and Martell 2009[b]
	2000	576	483	702	>500 mm	Pine and Martell 2009[b]
	2001	552	454	685	>500 mm	Pine and Martell 2009[b]
	2002	542	429	671	>500 mm	Pine and Martell 2009[b]
	2003	735	581	932	>500 mm	Pine and Martell 2009[b]
	2004	798	624	1,000	>500 mm	Pine and Martell 2009[b]
	2005	714	518	939	>500 mm	Pine and Martell 2009[b]
	2006	729	487	1,010	>500 mm	Pine and Martell 2009[b]
	2007	773	470	1,246	>500 mm	Pine and Martell 2009[b]

River	Year of data collection	Abundance Estimate	Lower 95% CI	Upper 95% CI	Fork length	Source
	1990	108	75	196	unspecified	USFWS 1990
	1998	270	135	1,719	>551 mm	USFWS 1998
	1999	321	191	1,010	>551 mm	USFWS 1999
	2004	350	221	648	>573 mm	USFWS 2004
	1983	149	115	208	>500 mm	Zehfuss et al. 1999
	1983	111	76	146	>500 mm	Zehfuss et al. 1999
	1984	87	59	150	>500 mm	Zehfuss et al. 1999
	1984	119	87	150	>500 mm	Zehfuss et al. 1999
	1985	101	87	127	>500 mm	Zehfuss et al. 1999
	1985	117	92	142	>500 mm	Zehfuss et al. 1999
	1986	65	47	105	>500 mm	Zehfuss et al. 1999
	1986	108	92	142	>500 mm	Zehfuss et al. 1999
	1987	116	70	225	>500 mm	Zehfuss et al. 1999
	1987	103	78	128	>500 mm	Zehfuss et al. 1999
	1988	109	81	164	>500 mm	Zehfuss et al. 1999
	1988	88	69	107	>500 mm	Zehfuss et al. 1999
	1989	62	37	131	>500 mm	Zehfuss et al. 1999
	1989	91	61	120	>500 mm	Zehfuss et al. 1999
	1990	112	88	155	>500 mm	Zehfuss et al. 1999
	1990	218	114	321	>500 mm	Zehfuss et al. 1999
	1991	95	35	406	>500 mm	Zehfuss et al. 1999
	1991	144	83	205	>500 mm	Zehfuss et al. 1999
	2010	1,051	300	5,018	>900 mm	USFWS, unpublished data[a]
	2014	785	631	1,037	>900 mm	Sulak et al. 2016[a]
	2014	503	450	569	300-900 mm	Sulak et al. 2016[c]
	2014	1,288			>300 mm	Sulak et al. 2016[d]
Suwannee	1992	2,285	1,887	2,683	>756 mm	Carr et al. 1996
	1987	2,473	2,002	2,944	>759 mm	Chapman et al. 1997
	1988	2,144	1,865	2,423	>759 mm	Chapman et al. 1997
	1989	3,055	2,650	3,460	>759 mm	Chapman et al. 1997
	1990	3,049	2,677	3,421	>759 mm	Chapman et al. 1997
	1991	2,097	1,779	2,415	>759 mm	Chapman et al. 1997
	1992	2,832	2,283	3,381	>759 mm	Chapman et al. 1997
	1993	5,312	3,588	7,036	>759 mm	Chapman et al. 1997
	1994	2,898	2,250	3,546	>759 mm	Chapman et al. 1997
	1995	3,370	1,807	4,933	>759 mm	Chapman et al. 1997
	1996	4,295	1,703	6,887	>759 mm	Chapman et al. 1997
	1991	7,650	not reported	not reported	>520 mm	Sulak and Clugston 1999
	1998	7,650	not reported	not reported	>520 mm	Sulak and Clugston 1999
	1982	1,368	1,102	1,675	>500 mm	Pine and Martell 2009[b]
	1983	2,107	1,753	2,473	>500 mm	Pine and Martell 2009[b]
	1984	2,644	2,234	3,052	>500 mm	Pine and Martell 2009[b]
	1985	2,910	2,500	3,302	>500 mm	Pine and Martell 2009[b]
	1986	3,109	2,738	3,450	>500 mm	Pine and Martell 2009[b]
	1987	3,322	2,929	3,746	>500 mm	Pine and Martell 2009[b]
	1988	3,421	3,080	3,802	>500 mm	Pine and Martell 2009[b]
	1989	3,632	3,261	4,009	>500 mm	Pine and Martell 2009[b]
	1990	3,908	3,562	4,365	>500 mm	Pine and Martell 2009[b]

River	Year of data collection	Abundance Estimate	Lower 95% CI	Upper 95% CI	Fork length	Source
	1991	3,607	3,260	4,022	>500 mm	Pine and Martell 2009[b]
	1992	3,305	2,999	3,663	>500 mm	Pine and Martell 2009[b]
	1993	3,468	3,133	3,899	>500 mm	Pine and Martell 2009[b]
	1994	3,989	3,555	4,493	>500 mm	Pine and Martell 2009[b]
	1995	4,435	3,930	5,129	>500 mm	Pine and Martell 2009[b]
	1996	4,528	4,002	5,230	>500 mm	Pine and Martell 2009[b]
	1997	4,821	4,185	5,664	>500 mm	Pine and Martell 2009[b]
	1998	4,897	4,221	5,827	>500 mm	Pine and Martell 2009[b]
	1999	4,461	3,778	5,587	>500 mm	Pine and Martell 2009[b]
	2000	4,203	3,427	5,296	>500 mm	Pine and Martell 2009[b]
	2001	4,335	3,576	5,450	>500 mm	Pine and Martell 2009[b]
	2002	4,524	3,542	5,634	>500 mm	Pine and Martell 2009[b]
	2003	4,606	3,555	6,337	>500 mm	Pine and Martell 2009[b]
	2004	4,250	3,207	6,072	>500 mm	Pine and Martell 2009[b]
	2005	3,815	2,864	5,396	>500 mm	Pine and Martell 2009[b]
	2006	4,142	3,116	6,389	>500 mm	Pine and Martell 2009[b]
	2007	4,005	2,693	6,274	>500 mm	Pine and Martell 2009[b]
	1987	2,059	1,490	2,890	unspecified	Randall and Sulak 2008
	1988	1,895	1,544	2,349	unspecified	Randall and Sulak 2008
	1989	2,118	1,777	2,543	unspecified	Randall and Sulak 2008
	1990	2,473	2,166	2,839	unspecified	Randall and Sulak 2008
	1991	2,923	2,516	3,409	unspecified	Randall and Sulak 2008
	1992	3,379	2,855	4,011	unspecified	Randall and Sulak 2008
	1993	4,273	3,442	5,321	unspecified	Randall and Sulak 2008
	1994	3,508	2,821	4,376	unspecified	Randall and Sulak 2008
	1995	3,579	3,122	4,119	unspecified	Randall and Sulak 2008
	1996	5,525	3,524	8,684	unspecified	Randall and Sulak 2008
	1997	4,061	3,310	4,998	unspecified	Randall and Sulak 2008
	1998	7,606	5,983	9,702	unspecified	Randall and Sulak 2008
	1999	4,944	4,075	6,017	unspecified	Randall and Sulak 2008
	2000	4,217	3,149	5,660	unspecified	Randall and Sulak 2008
	2001	5,021	3,771	6,706	unspecified	Randall and Sulak 2008
	2002	5,220	3,805	7,185	unspecified	Randall and Sulak 2008
	2005	1,817	1,303	2,544	unspecified	Randall and Sulak 2008
	2006	9,728	6,487	14,664	?871 mm	Randall and Sulak 2008
	2006	14,496	7,745	27,428	?345 mm	Sulak et al. 2016[d]
	2007	8,877	6,351	12,446	>871 mm	Sulak et al. 2016[a]
	2012-2013	9,743	3,437	29,653	>871 mm	Sulak et al. 2016[a]

[a] *Fish ≥900 mm fork length.*

[b] *The primary author cited characterizes these as "preliminary estimates" in reviewing this document.*

[c] *Fish <900 mm fork length.*

[d] *Fish ≥Age-1.*

Table 2. Gulf Sturgeon counts derived from side scan sonar surveys, for sturgeon ≥900 mm fork length residing in rivers of Florida. All surveys conducted within a fixed reference reach (i.e., the index reach) of each river (USFWS, unpublished data).

River	Year of data survey	Sonar Count
Escambia	2015	260
	2016	366
	2018	227
	2019	482
	2020	409
	2021	271
Blackwater	2013	291-350
	2014	361
	2015	435
	2016	467
	2018	539
	2019	603
	2020	688
	2021	626
Yellow	2015	393
	2016	362
	2018	373
	2019	419
	2020	269
	2021	231
Choctawhatchee	2015	1,788
	2016	1,599
	2018	1,680
	2019	2,098
	2020	1,940
	2021	1,387
Apalachicola	2012	717
	2014	762
	2015	755
	2016	523
	2018	613
	2019	241
	2021	390

Appendix B.

Summary of peer review for the 5-year review of Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

A. Peer Review Method:
See “B” below.

B. Peer Review Charge:

In April 2020 USFWS sent out a letter and the “Policy for Peer Review in Endangered Species Act Activities (59 FR 34270)” through email to six professional biologists with expertise on the Gulf Sturgeon and its habitats. The letter requested a critical review of the scientific information and data presented and asked them to identify missing literature or other relevant information. The letter was sent to the individuals listed below. We received comments from all of the reviewers contacted; these comments are summarized in section “C” below. A detailed spreadsheet that identifies each comment, the section and page referred to, and the edit or response provided to the comment can be obtained by request from the USFWS, Panama City Field Office.

Peer Reviewers:
Dr. Michael Andres and Dr. Mark Peterson, University of Southern Mississippi
Dr. Adam Fox, University of Georgia
Dr. William Pine, University of Florida
Michael Randall and Melissa Price, United States Geological Survey, Gainesville, FL

C. Summary of Peer Review Comments:

Drs. Michael Andres and Mark Peterson (retired), University of Southern Mississippi, Gulf Coast Research Laboratory, Ocean Springs, MS

Dr. Andres and Dr. Peterson suggested several additional citations to be included in the review that pertain to knowledge on western (Pearl and Pascagoula) populations and their habitats and identified several errors in reference dates and citations not included in the references section. The reviewers suggested clarifying content associated with mortality from hurricanes in the Western Gulf and holding area studies. Various minor editorial corrections were identified.

Dr. Adam Fox, University of Georgia, Athens, GA

Dr. Fox noted in his review that the University of Georgia lab had been working to assess juvenile survival in the Apalachicola River, and also that separate offshore research on different species resulted in the detection of sturgeon ~20 km from shore. Fox asked if that information was relevant for inclusion in the 5-year review.

Dr. Bill Pine, University of Florida, Gainesville, FL

1. Dr. Pine suggested that all materials referenced in the review should be archived for future access.
2. Reviewer suggested providing a variety of details associated with the population estimates reported in Sulak et al. 2016 to better explain or justify how population trends were determined.
3. Reviewer suggested an assessment of external factors that may influence other count-based metrics under development (i.e., side scan sonar counts as indices of abundance).
4. Reviewer identified the mortality rate work of Rudd et al. 2014 as informing current efforts underway in NRDA project 3- Population Status and Trends.
5. Reviewer took issue with the critique offered by Sulak et al. 2016 of the carrying capacity estimates reported in Ahrens and Pine 2014.
6. Reviewer identified the work of Flowers et al. 2020 as discussing the demographic characteristics of Gulf Sturgeon populations and their effect on time to recovery, and also their discussion of the recovery criteria aimed at sustainable yield in a fishery context.
7. The reviewer recommended an independent review of this section to determine whether sampling efforts planned during the Juvenile Dynamics Project (NRDA funded) and ongoing side scan survey work can inform the third initiative (i.e., the Population Status and Trends Study).
8. Reviewer suggested that an alternative, more appropriate reference to the Bogalusa paper mill spill be substituted for Rudd et al. (2014).
9. Reviewer suggested referencing the mortality of 4 male fish during a fish passage/relocation research study in this section.
10. Reviewer suggested that the findings of Rudd et al. 2014 with respect to higher mortality in the western GOM populations been included in the discussion.
11. Reviewer pointed out that a reference to the low historic abundance of western populations should be added.
12. Reviewer suggested deleting Appendix A because the data presented could be misleading.
13. Reviewer suggested deleting the Figure that presents the abundance estimates by river and year.

Michael Randall and Melissa Price, Wetland and Aquatic Resource Center, US Geological Survey, Gainesville, FL

1. Reviewers suggested revising statement on Suwannee population trend.
2. Reviewers commented on implications of multiple spawning runs and recommended some discussion of the implications of fall spawning.
3. Reviewers recommended discussion of extirpated population in Mobile basin.
4. Reviewers suggested adding carrying capacity to discussion of conceptual population growth.
5. Reviewers commented that the discussion of recapture rate involves long-term vs short-term analysis.
6. Reviewers suggested adding citation on relationship between flow and recruitment in Suwannee.

7. Reviewers suggested populations may be in danger of extinction from stochastic events.
8. Reviewers noted documented endocrine disruption in wild North American sturgeon.
9. Reviewers provided specific citation on climate change impacts to Gulf Sturgeon in Florida.
10. Reviewers provided comment on potential increases in native predators associated with climate change.
11. Reviewers provided comment and citation on potential higher spawning periodicity in Gulf Sturgeon.
12. Reviewers questioned the use of the term "best" in the Aquaculture section.
13. Reviewers provided example of marsh restoration project.

D. Response to Peer Review:

Drs. Michael Andres and Mark Peterson (retired), University of Southern Mississippi, Gulf Coast Research Laboratory, Ocean Springs, MS

In response to the review provided by Drs. Andres and Peterson, many references and additional background information were incorporated into the document, edits were made to correct erroneous citations, and edits were made to provide additional clarity as suggested.

Dr. Adam Fox, University of Georgia, Athens, GA

The suggestions associated with the study of juvenile survival were deemed addressed by the language included in the review focusing on overwinter mortality. The findings of Gulf Sturgeon farther offshore than discussed in the review can be incorporated into a future review when the work is published. The finding does not materially affect the conclusions of the review.

Dr. Bill Pine, University of Florida, Gainesville, FL

1. A folder with all of the referenced materials is being developed as requested.
2. Upon closer inspection of Sulak et al. 2016, it was determined that the authors did not explicitly state a population trajectory for most of the Gulf Sturgeon populations, although each section head in the paper was entitled- "X River population- abundance, mortality, and population trend." At best, population trends may be loosely inferred from the reported population assessments over time for some populations, with varying degrees of confidence in those inferences. Sulak et al. 2016 report many of the suggested details the reviewer was requesting to be added, including: year, net mesh size, size range of fish estimated, model type used, and reference, thus, these details can be gleaned from Sulak et al. 2016 and by studying the original references provided in Appendix A. We concur with the reviewer that the inference of population trend is tenuous, and complicated in each case, and in light of the fact that Sulak et al. do not explicity report population trajectory we have removed mention of trend from the section. It is perhaps worth noting that 1) the 2009 5-Year review did not report population trend, and 2) that

one of the NRDA funded studies underway (i.e., Population Status and Trends Project) is aimed at assessing whether population trends can be estimated using the historic catch data that has been compiled from all of the individual studies referenced in Appendix A. We anticipate a more robust and informed discussion of population trend to appear in either a forthcoming Species Status Assessment or future 5-Year Review.

3. An assessment of factors influencing side scan sonar-based counts as indices of abundance is currently underway in 5 of the 8 systems occupied by Gulf Sturgeon (this set includes Blackwater River, a summer holding area).
4. This point was included in Recovery Criteria section "Long-term Objective A, Criteria B" which addresses rate of recruitment relative to mortality rate over a 12-year period.
5. Sentence referencing Sulak's critique has been removed.
6. Flowers et al. 2020 is now referenced in both sections.
7. The Juvenile Dynamics Project has specific objectives related to the study of juvenile Gulf Sturgeon which are captured using gear that selects for smaller fish, whereas the Population Status and Trends Project aims to compile existing historic catch data (primarily catch of sub-adult and adult fish; not juveniles), and analyze those data to assess the status and trends of each of the 7 populations, determining through the process whether such assessments can be made adequately for each occupied system. The sonar-based monitoring efforts (2012-present) generate count data that are not part of the historic catch record being analyzed under the Population Status and Trends Project. Thus, the first 2 initiatives were not designed to inform the 3rd initiative, and an independent panel review of the matter seems unwarranted. Furthermore, a review of the merits of conducting research on juvenile Gulf Sturgeon, or research to further develop a non-invasive, remote sensing tool for monitoring trends in GS populations over time (both initiatives explicitly called for in the last 2009 5-year Review; see pages 27-28) is beyond the scope of the current peer review of this document. It is also worth clarifying here that a well-defined, standardized monitoring program for Gulf Sturgeon has never existed across the range of the species; a good bit of the work presented in Appendix A is the result of short-term projects (e.g., MS thesis research) that occurred opportunistically as funds were available. Moreover, the NRDA projects are not by design long term monitoring projects, but rather fixed duration restoration studies involving fish sampling; it is unclear whether sampling efforts will be maintained by partners beyond the sunset of current NRDA project funding.
8. Reference to Rudd et al. 2014 removed and replaced with LDWF 2011, and Reuters 2011.
9. Reference to earlier section containing that information included, in addition to a few lines about mortality occurring as a result of scientific activities.
10. Reference to Rudd et al. 2014 added to section.
11. Upon closer inspection, the statement in question was one that was carried over from the 2009 5-year review verbatim, and no reference was provided. However, information summarized in Sulak et al. 2016 suggests revision is necessary. Paragraph revised for accuracy.
12. Appendix A summarizes best available information relating to population abundance assessments and is nearly identical to Appendix A of the 2009 5-year Review with the inclusion of additional data (updates). Formatting also is identical to the 2009 Review. The paragraph above the table beginning with "Note" clearly presents the caveats

associated with the data found in the table, and states "the estimates are not necessarily comparable between researchers due to key differences in methods and assumptions". These caveats were also articulated in the 2009 5-Year Review, a document that Dr. Pine reviewed without requesting the deletion of Appendix A. Appendix A will be retained in document.

13. Figure was deleted from final version of 5-yr review.

Michael Randall and Melissa Price, Wetland and Aquatic Resource Center, US Geological Survey, Gainesville, FL

1. Statement in Recovery Criteria section revised to include the term “stable” when discussing Suwanee population trend.
2. Sentences added to highlight the potential for multiple spawning runs on the Suwannee River and implications of additional spawning runs in the “New information on the species’ biology and life history” section of the review.
3. A discussion of the extirpated population in Mobile River Basin added to the “Abundance, population trends, demographic features, or demographic trends” section.
4. Discussion of carrying capacity added to the section as suggested by reviewers.
5. To address the reviewer’s comment, the discussion of long-term recapture rate was deleted for clarification.
6. Citation on relationship between flow and recruitment in the Suwannee River added to the discussion in the “Abundance, population trends, demographic features, or demographic trends” as suggested by reviewers.
7. The reviewer’s comment suggesting populations may be in danger of extinction from stochastic events was noted, although we have not observed extinction of any of the 7 extant populations since the time of listing (i.e., 30 years), despite several stochastic events occurring that posed threats to the species. Work is currently underway to develop a PVA model that will estimate extinction risk under various scenarios including stochastic events such as hurricanes, contaminant spills, and red tide.
8. Discussion of documented endocrine disruption in North American sturgeon was added to the “Habitat-point and non-point discharges” section.
9. Discussion and citation added pertinent to climate change impacts to Gulf Sturgeon in Florida.
10. A brief discussion added that pertains to native predators and competitors as suggested by reviewers.
11. Sentence and citation added to address concept of potential higher spawning periodicity in Gulf Sturgeon.
12. The sentence using the word “best” was rephrased and the term removed to address reviewers’ comment.
13. Examples of marsh restoration added at the suggestion of reviewers.