SMALLTOOTH SAWFISH
(Pristis pectinata)

**5-Year Review:
Summary and Evaluation of**

United States Distinct Population Segment of Smalltooth Sawfish

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

2018

5-YEAR REVIEW

Species reviewed: Smalltooth Sawfish (*Pristis pectinata*)

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1.0 GENERAL INFORMATION

1.1 Reviewers:

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1.2 Introduction

The United States distinct population segment of smalltooth sawfish is listed as endangered under the Endangered Species Act of 1973 (ESA). Smalltooth sawfish are one of five species of sawfish. Like sharks and rays, sawfish are elasmobranchs whose skeletons are made of cartilage instead of bone. Sawfish are most closely related to rays as their gill slits are found on the ventral (bottom) side of their bodies. The sawfish gets its name from the long flattened, toothed rostrum (snout) that looks much like an actual saw. The rostrum is used for both feeding and defense. Sawfish use nearshore coastal habitats which greatly overlap with human activity. This overlap is likely a key to the decline of all sawfish species worldwide.

A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12) is accurate. The 5-year review is required by section 4(c)(2) of the Endangered Species Act of 1973, as amended (ESA). After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from threatened to endangered; or (3) have its status changed from endangered to threatened. This document reflects the current status of the ESA listed U.S. DPS of smalltooth and was prepared pursuant to the joint National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife 5-year Review Guidance and template (NMFS and USFWS 2010).

1.3 Methodology Used to Complete the Review:

The National Marine Fisheries Service (NMFS) initiated this 5-year review of the U.S. distinct population segment (DPS) of smalltooth sawfish in 2015 by contracting Haven Worth Consulting (now Havenworth Coastal Conservation) to develop a draft review. NMFS solicited information through a Federal Register Notice (81 FR 3781), while Haven Worth Consulting solicited information from social media platforms and direct correspondence with the Smalltooth Sawfish Recovery Implementation Team (Appendix 1). Three public comments were received (Amber Crooks, Conservancy of Southwest Florida; Dr. Abel Valdivia, Center for Biological Diversity; and Joseph Choromanski, Ripley Aquariums/Ripley Entertainment). To complete the review, all available scientific and commercial information on the species since the time of listing in 2003 was collected, evaluated, and incorporated. This included information from the recovery plan and critical habitat designation which were both finalized in 2009, and the first 5-year review completed in 2010. The present report describes the agency's findings whether a reclassification or delisting is warranted based on all of the information considered.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

The "Notice of Initiation of a 5 Year Review and Notice of Intent to Update a Recovery Plan; Request for Information" was published January 22, 2016 (81 FR 3781).

1.4.2 Listing history

<u>Original Listing</u>
FR notice: 68 FR 15674
Date listed: April 1, 2003
Entity listed: U.S. DPS of Smalltooth Sawfish (*Pristis pectinata)*
Classification: Endangered

1.4.3 Associated rulemakings:

<u>Critical habitat designation</u>
FR notice: 74 CFR 45353
Date designated: September 2, 2009

<u>Other sawfish species including the non-U.S. DPS of smalltooth sawfish</u>
FR notice: 79 FR 73977
Date listed: December 12, 2014
Entities listed:
non-U.S. DPS of Smalltooth Sawfish (*Pristis pectinata)*
Narrow Sawfish (*Anoxypristis cuspidata*)
Dwarf Sawfish (*Pristis clavata*)
Largetooth Sawfish (*Pristis pristis*)
Green Sawfish (*Pristis zijsron*)
Classification: Endangered

1.4.4 Review history:

Two status reviews of the U.S. DPS of smalltooth sawfish have been conducted: the original status review in 2000 and a 5-year review in 2010. The first provided evidence that the species was in danger of extinction and led to ESA listing. The second concluded that the species should be retained on the endangered species list without change to its classification.

NMFS. 2000. Status review of smalltooth sawfish, Pristis pectinata. National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

NMFS. 2010. Smalltooth Sawfish 5-Year Review: Summary and Evaluation. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Protected Resources Division, St. Petersburg, FL.

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

Following the listing and subsequent development of the smalltooth sawfish recovery plan, the U.S. DPS was assigned a recovery priority number of 7. This recovery priority was based on the magnitude of threats being "moderate", recovery potential being "low-moderate", and the potential for economic conflicts while implementing the recovery actions. However, we reassessed the recovery priority number during the biennial review for congress (NMFS 2017) which resulted in a new priority number of 5. The change in recovery priority number results from our understanding that recovery potential is high for this species rather than the "moderate to low" potential as previously thought.

1.4.6 Recovery Plan or Outline

NMFS. 2009. Recovery Plan for Smalltooth Sawfish (*Pristis pectinata).* Prepared by the Smalltooth Sawfish Recovery Team for the National Marine Fisheries Service, Silver Spring, MD.

2.0 REVIEW ANALYSIS

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

The ESA defines species as including any subspecies of fish or wildlife or plants, and any DPS of any species of vertebrate wildlife. The status review determined that smalltooth sawfish in U.S. waters comprise a DPS, and that the DPS is in danger of extinction throughout its range.

2.1.1 Is the species under review a vertebrate?

__✓__ Yes
______ No

2.1.2 Is the species under review listed as a DPS?

__✓__ **Yes**
______ **No**

2.1.3 Was the DPS listed prior to 1996?

______ Yes

__✓__ No

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

______ Yes

__✓__ No

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan[1] containing objective, measurable criteria?

__✓__Yes

______ No

The recovery plan was published in January of 2009 and the criteria it contains are objective, but not all are measurable and some are now outdated based on advances in our understanding of the species' biology. Therefore, NMFS, with the help of the Smalltooth Sawfish Recovery Implementation Team, is currently working to update the recovery plan and the criteria (see 81 FR 3781).

2.2.2 Adequacy of recovery criteria.

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

______ Yes

__✓__ No

NMFS and the Smalltooth Sawfish Recovery Implementation Team are working to update the recovery plan with the latest available scientific, commercial, and public information. This update will include changes to the recovery criteria accordingly. Very little was known about smalltooth sawfish at the time of listing, but research data obtained since then has changed our understanding of the biological requirements for recovery and the characteristics of a recovered population. Scientific advances have made it clear that some recovery criteria are not realistic or achievable, thus the need to update the plan.

Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

[1] Although the guidance generally directs the reviewer to consider criteria from final approved recovery plans, criteria in published draft recovery plans may be considered at the reviewer's discretion.

__✓__ **Yes**
______ **No**

The final listing rule found the species' endangered status resulted from four of the ESA's five causal listing factors (disease or predation was not found to be a factor causing the species' endangered status). Smalltooth sawfish were listed as endangered based on a combination of the following factors, described in section 4(a)(1) of the ESA:

- The present or threatened destruction, modification, or curtailment of habitat or range
- Overutilization for commercial, recreational, scientific, or educational purposes
- Inadequacy of existing regulatory mechanisms
- Other natural or manmade factors affecting its continued existence

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:

NMFS and the Smalltooth Sawfish Recovery Implementation Team are working to update the recovery plan with the latest available scientific, commercial, and public information and change the recovery criteria accordingly. Therefore, the objectives and criteria in the original recovery plan as described here are likely to change.

***Objective 1 – Minimize human interactions, and associated injury and mortality*.**

<u>Downlisting Criteria</u>
A. Effective ongoing programs are in place to educate the public about population status and the prohibitions against capturing, harming, or harassing smalltooth sawfish.

Criterion has been partially met through various outreach projects. Metal signs have been permanently posted at boat ramps throughout Florida and plastic placards have been affixed at roadway fishing access points in southwest Florida, both containing information on sawfish handling, release, and reporting (Figure 1). Expanding and continuing education of anglers regarding the status of the smalltooth sawfish is essential to help minimize any negative effects of incidental capture in the recreational fishery on the sawfish population. The criterion has not been fully met due to budget limitations and, as a result, much of the public is not well informed about the species and its protected status.

B. Safe handling and release guidelines have been developed, adopted, distributed, and are being effectively implemented in all state and Federal fisheries (commercial and recreational) that may interact with smalltooth sawfish within all recovery regions.

Criterion has been partially met through the development and distribution of the *Sawfish Safe Handling and Release Guidelines* that were developed and distributed to commercial fishers and are available in the species' recovery plan. A sawfish handling and release video and wheelhouse placards were also developed and distributed to Highly Migratory Species (HMS) permit holders and to Aquatic Release Conservation (ARC) for dissemination at training seminars. A variety of outreach products have also been developed to educate recreational anglers on safe release procedures. These items continue to be distributed to recreational anglers.

The criterion has not been fully met because distribution of safe handling and release information has not been sufficient to educate large portions of the public. As a result the fishing public is not fully informed about the species and how to safely release them unharmed after they are incidentally captured. Additionally, information on post-release mortality in various fisheries is still unknown. Ongoing actions related to this criterion focus on education and outreach efforts.

C. State and/or Federal fishing regulations specific to smalltooth sawfish are in place to ensure that injury and mortality from commercial and recreational fishing is maintained below or at levels that ensure the population increases at the rate, or stabilizes at the levels, described in the criteria identified in Objective 3.

Criterion has not been met. While federal and state regulations ban all harm to sawfish, people still violate these regulations – either intentionally or unintentionally – and enforcement and prosecution sufficient to deter subsequent violations has been rare.

Delisting Criteria
A. All downlisting criteria continue to be met.

B. State and/or Federal measures (not including those provided under the ESA) are in place to either prohibit harm or possession of smalltooth sawfish, or ensure that impacts are appropriately assessed, authorized, and minimized.

C. State and/or Federal measures (not including those provided under the ESA) are in place to maintain the population at levels at or above those required for delisting.

Delisting criteria will be addressed once downlisting criteria are met.

***Objective 2 – Protect and/or restore smalltooth sawfish habitats*.**

Downlisting Criteria
A. At least 95% of mangrove shoreline habitat existing at time of listing is maintained and effectively protected in recovery regions G, H, and I (Figure 2).

Criterion A has been partially met through the designation of critical habitat in 2009 (74 FR 45353). Under this designation, red mangroves were identified as an essential feature of critical habitat that must be protected for the conservation of the species. The critical habitat designation aids in protecting red mangroves in recovery regions G and H. Federal agencies intending to permit, construct, or fund projects that have the potential to affect critical habitat are required to consult with NMFS under section 7 of the ESA.

B. Sufficient mangrove shoreline or alternate scientifically documented non-mangrove nursery habitat are available and accessible to support viable subpopulations of juvenile smalltooth sawfish in recovery regions J and K, and one additional recovery region (apart from G, H, I, J, and K). This level should be a minimum of 25% of the mangrove shoreline habitat that existed in 1940, in each of the above recovery regions. The level of non-mangrove nursery habitat must be determined once specific nursery habitat features are identified.

This criterion has not been met. Ongoing and future studies should provide valuable information that can be used to determine if sufficient nursery habitats are available and accessible for juveniles.

C. Freshwater flow regimes (including timing, distribution, quality, and quantity) into recovery regions G, H, I, J, K, and the one additional region used to meet the two previous criteria are appropriate to ensure natural behavior (e.g., feeding, resting, and predator avoidance) by maintaining salinities within preferred physiological limits of juvenile smalltooth sawfish.

While the criterion has not been met in regards to ensuring appropriate freshwater flow regimes, researchers have identified preferred salinity ranges for juvenile smalltooth sawfish in estuarine systems (Poulakis et al. 2011, Simpfendorfer et al. 2011, Poulakis et al. 2013). Ongoing and further studies should provide additional information to refine our knowledge so efforts can then be made to ensure freshwater flow regimes are appropriate for natural behavior.

D. Habitat areas of adult smalltooth sawfish abundance, including those used for aggregation, mating and pupping are identified, mapped, and effectively protected as appropriate.

This criterion has not been met. Ongoing and future studies should provide valuable information that can be used to identify the habitat requirements (e.g., breeding, pupping and salinity preferences) for the species.

<u>Delisting Criteria</u>
A. All habitat-based downlisting criteria continue to be met.

B. Sufficient mangrove shoreline or alternate scientifically documented non-mangrove nursery habitat is available and accessible to support viable subpopulations of juvenile smalltooth sawfish in recovery regions J and K, and one additional recovery region (apart from G, H, I, J, and K). This level should be a minimum of 25% of the mangrove shoreline that existed in 1940, in each of the above recovery regions. The level of non-mangrove nursery habitat must be determined once specific nursery habitat features are identified.

C. Freshwater flow regimes (including timing, distribution, quality and quantity)into recovery regions G, H, I, J, K and the four additional used to meet the previous delisting criteria appropriate to ensure natural behavior (e.g. feeding, breeding, and pupping) by maintaining salinities within preferred physiological limits of juvenile smalltooth sawfish.

Delisting criteria will be addressed once downlisting criteria are met.

Objective 3 – Ensure smalltooth sawfish abundance increases substantially and the species reoccupies areas from which it had been previously extirpated.

<u>Downlisting Criteria</u>

A. In recovery regions G, H, I, J, and K and at least one other recovery region the relative abundance of small juvenile smalltooth sawfish (<200 cm) either has increased at an average annual rate of at least 5% over a 27-year period with greater than 95% certainty or is at greater than 80% of carrying capacity.

B. Relative abundance of adult smalltooth sawfish in combined recovery regions J through L (east coast of Florida) has increased to a level at least 15-times higher than the level at the time of listing with greater than 95% certainty that abundance at this level has been sustained for a period of at least 14 years.

C. Relative abundance of adult smalltooth sawfish in combined recovery regions F through H (west coast of Florida) has increased to a level at least 15-times higher than the baseline level determined in Action 3.2.4 with greater than 95% certainty that abundance at this level has been sustained for a period of at least 14 years.

D. Verified records of adult smalltooth sawfish are observed in 12 out of 14 years, with consecutive records occurring in the last 3 years in recovery regions M or N, and in at least one of recovery regions A, B, C, or D.

As written the criteria listed under Objective 3 will require long-term recovery actions. Protocols were developed to monitor the relative abundance of smalltooth sawfish in southwest Florida (Wiley and Simpfendorfer 2007c) and relative abundance surveys are currently being carried out by partner agencies (Florida Fish and Wildlife Conservation Commission, NOAA Fisheries SEFSC Panama City Laboratory, and Florida State University). These surveys are necessary to ensure the recovery criteria are met and to monitor the status of smalltooth sawfish abundance. Continued long-term collection and addition of public sawfish encounter reports and ongoing research efforts should identify any changes in the distribution of the species.

NMFS and the Smalltooth Sawfish Recovery Implementation Team believe that, based on historical data, the current downlisting criteria are unachievable. Specifically, an annual rate of population increase of at least 5% over 27 years would lead to a final population that would exceed what we expected was present historically. While this was based on the best information available at the time of development, gains in life history data since have made clear the criterion is mathematically flawed. Therefore, NMFS and the Smalltooth Sawfish Recovery Implementation Team are working to update the recovery plan to establish more appropriate recovery criteria related to Objective 3.

<u>Delisting Criteria</u>

A. In recovery regions G, H, I, J, and K and at least 4 other recovery regions, one of which must be west of Florida, the relative abundance of small juvenile smalltooth sawfish (<200 cm) is stable or increasing over a period of 14 years following downlisting.

B. Relative abundance of adult smalltooth sawfish (>340 cm) in combined recovery regions J through L (east coast of Florida) is at least 20-times higher than the baseline level with greater than 95% certainty that abundance at this level has been sustained for a period of at least 14 years.

C. Relative abundance of adult smalltooth sawfish (>340 cm) in combined recovery regions F through H (west coast of Florida) is at least 20-times higher than the baseline level with greater than 95% certainty that abundance at this level has been sustained for a period of at least 14 years.

D. Verified records of adult smalltooth sawfish are observed in 12 out of 14 years, with consecutive records in the last 3 years, in recovery regions M or N, and in at least one of recovery regions A, B, C, or D.

E. In addition to the 6 downlisting recovery regions (G, H, I, J, and K and one additional region), the relative abundance of small juvenile smalltooth sawfish (<200 cm) in 3 other recovery regions, at least one of which must be west of Florida, is either increasing at an average annual rate of at least 5% over a 27-year period with greater than 95% certainty or at greater than 80% of carrying capacity.

Delisting criteria will be addressed once downlisting criteria are evaluated, revised, and met.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 Information on the species' biology and life history:

Age, growth, and reproduction

As with all elasmobranchs, fertilization in smalltooth sawfish is internal and development is yolk-sac viviparous. The embryos of smalltooth sawfish, while still bearing the large yolk sac, already resemble adults relative to the position of their fins and absence of the lower caudal lobe. During embryonic development the rostral blade is soft and flexible and the rostral teeth are enclosed in a sheath until birth. Shortly after birth, the rostral teeth become exposed as the sheath dissolves. Captures of neonates with embryonic rostral sheaths indicate size at birth of approximately 67.1–81.2 cm (Poulakis et al. 2011), though the smallest smalltooth sawfish captured during scientific field studies in Florida is 64 cm (25 in) stretched total length (L_{st})(Bethea et al. 2012). Bigelow and Schroeder (1953) reported gravid females carry 15–20 embryos, while Gelsleichter (2014) reported litter size to be 7-14. Poulakis et al. (2014) report a 1-year gestation period and a biennial reproductive cycle. Captures of neonates with embryonic rostral sheaths confirmed a protracted timing of parturition (November–July) which peaked between April and May (Poulakis et al. 2011, Poulakis et al. 2014) in Charlotte Harbor. In the Ten Thousand Islands and Everglades National Park, Bethea et al. (2015) reported parturition occurring in all survey months except September, with a peak from March through July.

Feldheim et al. (2017) used genetic analyses of juvenile fin clips (n=349) collected between 2004 and 2015 to reconstruct parental genotypes and provide insights into smalltooth sawfish reproduction. The study confirmed the biennial reproductive cycle suggested by Poulakis (2014), and also indicated high parturition site fidelity (propensity of mothers to return to the same parturition site), for specific nurseries within Charlotte Harbor Florida. From the reconstruction, 55 females gave birth to 142 broods over the 12 year period. Thirty-four females only gave birth in the Caloosahatchee River, 19 only gave birth in the Peace River, and 2 females used both. The reconstruction indicated 192 males accounted for the 142 broods, suggesting at least a portion of the females participate in polyandrous mating (mating with multiple males within a reproductive season). Only 4 percent of male genotypes were seen more than once within these nurseries (n=7), though some males mated in consecutive reproductive cycles or with multiple females within a season. These results suggest the two nurseries may need to be managed separately and future analysis of juvenile fin clips from smalltooth sawfish captured in Everglades National Park and the Ten Thousand Islands National Wildlife Refuge will likely yield additional nursery areas.

Growth studies of smalltooth sawfish suggest rapid early growth. Simpfendorfer et al. (2008) investigated the growth rates of juvenile smalltooth sawfish collected in Florida waters between 1999 and 2006. Using length-frequency (144 individuals ranging in size from 69.0–496.0 cm) and tag-recapture (28 recaptured individuals ranging from 77.5–215.0 cm) data they found rapid growth in smalltooth sawfish for the first 2 years after birth, with juveniles doubling in size during the first year. Stretched total length (L_{ST}) increased by 65.0–85.0 cm in the first year and by 48.0–68.0 cm in the second year. These early growth rates are substantially faster than those previously assumed for this species and may be among the highest reported for elasmobranchs (Simpfendorfer et al. 2008). Daily growth rates of immature smalltooth sawfish from gillnet survey recapture data were 0.01-0.48 cm L_{ST} day^{-1} (0.3-14.4 cm month^{-1}) (D. Bethea & J. Carlson unpublished data). Data for animals >220 cm were limited, so growth beyond 2 years of age is uncertain. The von Bertalanffy growth parameters estimated from L_{ST} frequency data were L_∞= 600 cm, K= 0.140 per year, and t_0= -0.863 years. Growth rates over the size range for which tag-recapture data were available were similar to that from L_{ST} frequency data.

Smalltooth sawfish have been opportunistically sampled in south Florida and aged by counting opaque bands in sectioned vertebrae. Scharer et al. (2012) estimated ages that ranged from 0.4 years for a 60 cm (23.6 in) total length (TL) male to 14.0 years for a 435 cm (171 in) TL female. Von Bertalanffy growth parameters estimated from size at age data were 4.48 m for L_∞, 0.219 y^{-1} for K, and -0.81 y for t_0. Maximum age based on this study was estimated at 30 years, because the largest sawfish was approximately 60% of maximum size which was aged at 14 years old (Carlson and Simpfendorfer 2015).

Due to a limited number of necropsied adult sawfish, there is still a high degree of uncertainty in age and size of sexual maturity, especially for females. Simpfendorfer et al. (2008) reported sexual maturation of males occurs between 253 and 381 cm STL and females mature around 360 cm (Simpfendorfer 2002). Simpfendorfer (2000) estimated age at maturity of 10-24 years; however, back-transforming known lengths of maturity to age from the growth model of Scharer et al. (2012), Carlson and Simpfendorfer (2015) predicted age at maturity of 7-11 years. The smallest observed mature male was 363 cm (Grubbs unpublished data).

Recent preliminary *in situ* information on size at maturity and reproductive seasonality has been obtained through blood assays and plasma concentrations of gonadal steroids as part of a non-lethal approach for determining aspects of reproduction (Poulakis et al. 2014). Male smalltooth sawfish sampled in March, April, May, July, and August had notably elevated levels of testosterone during March and April—consistent with levels observed during spermatogenesis and/or mating in other male rays (Poulakis et al. 2014). Circulating levels of F prostaglandins, another indicator of male vertebrate reproduction (particularly mating), have also been measured in mature male sawfish collected from March, April, May, and July (n = 13). The relative levels of follicle-stimulating hormone (FSH), an indicator of early spermatogenesis, were examined in male sawfish via Western blot. Relative levels of FSH increased specifically during July-August. Lastly, a mature male accidently captured by a commercial fisherman in November 2012 was found to be undergoing peak spermatogenesis and a mature animal examined by FWC in January 2012 was found to possess regressing testes. The combination of these data suggest that male sawfish may be undergoing early spermatogenesis in the late summer (July–August), followed by peak sperm production in the fall (October-November). Evidence for testis regression in winter (January), but elevated testosterone and F prostaglandin levels in the spring (March–April) suggest that males may store sperm and mate throughout the spring. To date, five males have been necropsied by FWC and UNF and all contained female as well as male reproductive organs suggesting that a rudimentary form of hermaphroditism is common in males of this species (Poulakis et al. 2014).

A comparison of estradiol levels in female sawfish captured in January, March, May, and July suggests that levels of this hormone increase during summer; however, levels were low and not indicative of active vitellogenesis (Poulakis et al 2014). Levels of estradiol were found to be lower in immature animals in comparison to clearly mature individuals. Levels of estradiol in a 377 cm STL individual suggested that it was the smallest mature animal examined. F prostaglandins (indicators of mating and early follicular development in some sharks) were also measured in females and shown to be highest during May and July. Relative FSH levels (an indicator of early follicular development in female vertebrates) were also examined in females and they were also found to be prominent only in July samples. Last, dissections of mature females obtained during the months of January and April have shown that this is a period of vitellogenesis in non-pregnant animals. The combination of these data suggests that female sawfish are undergoing early vitellogenesis in the summer (July). Early stages of vitellogenesis are not generally associated with elevated estradiol levels, potentially explaining the increased but not dramatically high concentrations of this hormone observed during this period. Sawfish are undergoing mid-late vitellogenesis in January to April in non-pregnant animals, confirming the biennial nature of reproduction and suggesting that ovulation and fertilization occur in April-May (Poulakis et al. 2014).

Information on mating has primarily been obtained through field observations. Grubbs (2015) reported that mating is occurring in spring (March-April). Papastamatiou et al. (2015) hypothesize that mating occurs in Florida Bay based on aggregations of mature animals coinciding with the proposed mating period, initial sexual segregation of adults followed by some evidence of females moving through areas where males show seasonal residency, and a high percentage of animals showing evidence of rostrum inflicted injuries. Females and males displayed scars which appeared to have been caused by the rostrum of other sawfish and some males caught at East Cape Canal had fresh and/or healed scars (Papastamatiou et al. 2015).

Facultative parthenogenesis is the ability of sexually reproducing species to sometimes produce offspring asexually. Fields et al. (2015) documented the first examples of viable parthenogens in smalltooth sawfish based on abnormally high levels of genetic homozygosity across surveyed loci—measured through internal relatedness of each individual. The sawfish parthenogens were of normal size for their age, thus demonstrating that individuals produced in this way can survive in the wild. Their reproductive competence is unknown because they were immature at the time of capture, but there is evidence that parthenogens are capable of sexual reproduction in both birds and reptiles.

Feeding and diet

The elongated rostra of sawfishes initially evolved not to aid in mud grubbing, but to aid in prey immobilization (Wueringer et al. 2009). The morphology of rostral teeth additionally shows a high adaptation for immobilization of fast prey in the water column (Wueringer et al. 2009). Receptors such as the ampullae of Lorenzini of the electroreception system and the neuromasts of the lateral line system found along the saw aid in prey detection, similar to what has been described for the cephalofoil in sphyrnid hammerhead sharks (Wueringer et al. 2009).

Historically, there has been little information on the diet of sawfish. Available information gathered from direct observations, anglers, and necropsies indicate this species feeds on clupeids, carangids, mugilids, dasyatids, pinfish (*Lagodon rhomboides*), and pink shrimp (*Farfantepenaeus duorarum*) (Poulakis et al. 2013, Poulakis et al. 2014). Due to the lack of stomach content data, researchers are now inferring diet from stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$). The isotopic signatures for each sawfish are determined from small fin clips and compared to the isotopic signatures of potential prey items in the estuary. Using this approach, Poulakis et al. (2014) found that smalltooth sawfish primarily feed on teleosts (bony fish) at all life stages.

Other biology

There is little information on parasites infecting sawfish. Based on external parasites of gills and internal parasites of the heart, stomach, intestine, and spiral valve collected opportunely from recovered carcasses, Poulakis et al. (2014) have noted relatively high parasite diversity and a low intensity of infections and none of these infections appeared to be associated with significant disease or mortalities.

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

There is currently no estimate of smalltooth sawfish abundance throughout its range and there are few long-term abundance data sets that include smalltooth sawfish. However, it is clear from the limited data and anecdotal reports that the abundance of smalltooth sawfish in U.S. waters has decreased over the past century. One data set from shrimp trawlers off Louisiana from the late 1940s through the 1970s suggests a rapid decline in the species from the period 1950–1964. However, this data set has not been validated nor subjected to statistical analysis to correct for factors unrelated to abundance.

More recent analyses of smalltooth sawfish data indicate the population decline may be diminishing as the core population stabilizes. An analysis of dock-side angler interview data from Everglades National Park using a log-normal generalized linear model to correct for factors unrelated to abundance (e.g., change in fishing practices) indicated a slight increasing trend in abundance for smalltooth sawfish in the park between 1989 and 2004 (Carlson et al. 2007). Completing a similar analysis with updated data, Carlson and Osborne (2012) found the standardized relative abundance trend was stable to slightly increasing (~5% per year) although variation was high. Evidence from other data sources also indicates the current population of smalltooth sawfish is at least stable throughout its core with the potential for the core area of abundance (southwest Florida from Charlotte Harbor to Florida Bay) to be expanding. These results suggest current management recommendations outlined in the recovery plan have been successful in stopping the historic decline of smalltooth sawfish and may be improving the status of the species (Carlson and Osborne 2012).

Using a demographic approach and life history data for smalltooth sawfish and similar species from the literature, Simpfendorfer (2000) estimated intrinsic rates of natural population increase as 0.08 to 0.13 per year and population doubling times from 5.4 years to 8.5 years. These low intrinsic rates of population increase are associated with the life history strategy known as k-selection. K-selected animals are usually successful at maintaining relatively small, persistent population sizes in relatively constant environments. Consequently, they are not able to respond rapidly to additional and new sources of mortality resulting from changes in their environment. Musick (1999) and Musick et al. (2000) noted that intrinsic rates of increase less than ten percent were low, and species with such rates of increase are particularly vulnerable to excessive mortality and rapid population declines, after which recovery may take decades. As such, smalltooth sawfish populations will recover slowly from depletion, confounding recovery efforts. Simpfendorfer (2000) concluded that recovery is likely to take decades or longer depending on how effectively sawfish can be protected. However, if ages at maturity for both sexes prove to be lower than those previously used in demographic assessments, then population growth rates are likely to be greater and recovery times shorter (Simpfendorfer et al. 2008).

Using updated life history information, Carlson and Simpfendorfer (2015) constructed an age-structured Leslie matrix model for the U.S. population of smalltooth sawfish to determine the species' ability to recover under scenarios of variable life history inputs and the effects of bycatch mortality and catastrophes. As expected, population growth was highest (λ=1.237 yr^{-1}) when age-at-maturity was 7 yr and decreased to 1.150 yr^{-1} when age-at-maturity was 11 yr. Despite a high level of variability throughout the model runs, in the absence of fishing mortality or catastrophic climate effects, the population grew at a relatively rapid rate approaching carrying capacity in 40 years when the initial population was set at 2250 females or 50 years with an initial population of 600 females. However, population projections under various levels of fishing mortality resulted in extinction when mortality was highest, initial population size was small, and age-at-maturity was 11 yr. Scenarios testing the potential effects of extreme cold exposure showed little difference to those scenarios testing the effects of fishing mortality. Carlson and Simpfendorfer (2015) concluded that smalltooth sawfish in U.S. waters appear to have the ability to recover within the foreseeable future based on a model relying upon optimistic estimates of population size, lower age-at-maturity and the lower level of fisheries-related mortality. They also note that effective management and recovery of this species can only be achieved by keeping fishing-related mortality low.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation:
Understanding the geographical structuring of populations is relevant for management because it may identify evolutionarily independent units that are important for conservation. Faria et al. (2013) investigated patterns of geographical structuring of the five most widespread sawfish species based on mitochondrial DNA sequences and rostral tooth counts. Two haplotypes were observed for 62 West Atlantic specimens of smalltooth sawfish. The only haplotype observed for two East Atlantic specimens was also common to the West Atlantic specimens suggesting no geographical structuring of the haplotypes. However, differences in rostral tooth counts between the two geographic regions indicate population structuring and thus the two regions may represent separate units for conservation purposes.

Given the magnitude of decline observed in the U.S. DPS of smalltooth sawfish and the well-established link between genetic diversity and population viability, there was some concern about the genetic health of smalltooth sawfish in Florida (Chapman et al. 2008). It is also important to better understand the level of connectivity between different sawfish breeding grounds in Florida to effectively scale management actions. A suite of eleven microsatellite DNA markers (10–46 alleles per locus, average heterozygosity 0.84) have been developed from the smalltooth sawfish genome and have proven useful for addressing these issues. Tissue samples have been collected from more than 100 individual sawfish and have been genotyped at these markers. These analyses have shown that (1) robust genetic variation persists in the Florida smalltooth sawfish population and there is no signature of a genetic bottleneck arising from the recent large decline in their numbers; (2) different Southwest Florida breeding grounds are genetically connected, indicating that they should be managed as a single interbreeding unit; and (3) pairs or groups of juvenile sawfish captured together in shallow habitats are often siblings (Chapman et al. 2008). When combined with tagging and tracking data, this postnatal association of littermates indicates that juvenile sawfish stay close to the place they were born for long periods and such habitats could be considered nursery areas.

Chapman et al. (2011) used 8 polymorphic microsatellite markers to show that this remnant population still exhibits high genetic diversity in terms of average allelic richness (18.23), average alleles per locus (18.75, standard deviation [SD] 6.6) and observed heterozygosity (0.43–0.98). Inbreeding is rare (mean individual internal relatedness = -0.02, SD 0.14; F_{IS} = -0.011, 95% confidence interval [CI] = -0.039 to 0.011), even though the estimated effective population size (N_e) is modest (250–350, 95% CI = 142–955). Simulations suggest that the remnant smalltooth sawfish population will probably retain >90% of its current genetic diversity over the next century even at the lower estimate of N_e. There is no evidence of a genetic bottleneck accompanying last century's demographic bottleneck and genetic diversity is similar to other, less depleted elasmobranch populations (Chapman et al. 2011).

Bayesian clustering analysis confirmed a single population of smalltooth sawfish in southwest Florida (Poulakis et al. 2014). The pairwise F_{ST} (genetic divergence among subpopulations) between samples collected in the Caloosahatchee River and Everglades/Florida Keys was significantly different ($p < 0.05$) but the statistical difference was small (0.002), indicating that there is at most weak differentiation between these sites and allele frequencies between sites are very similar. A larger sample of individuals for multiple two-year bins was collected from the Caloosahatchee River region during the study to estimate the effective number of breeding adults (N_b) for these years. Estimates were of 28 to 78 individual breeders per biennial period, with upper confidence intervals of <200 individuals. The global inbreeding coefficient (F_{IS}) was not significantly different from zero in the total sawfish population, indicating a lack of inbreeding. The internal relatedness of individuals was typically very close to zero, further indicating that mating between relatives is very rare. Despite the rarity of inbreeding, seven individuals (all females) were found that had extremely high internal relatedness. Two individuals with internal relatedness (IR) = 1.0 were homozygous at every single locus sampled, while the remaining individuals were homozygous at all but 1 or 2 loci. Four of the latter are most likely broodmates given that they were the same age and genotype (share more than 50% of their alleles, including several rare ones). The probability of an individual being homozygous at every locus in this population assuming sexual reproduction and Hardy-Weinberg Equilibrium (HWE) is 1×10^{-9}. Even assuming that these individuals are the products of familial mating it is highly unlikely they would always receive the same alleles from their parents, suggesting these individuals are parthenogens (Poulakis et al. 2014).

Although it is illegal to land or trade smalltooth sawfish within the U.S. or across its borders, it is difficult to enforce these regulations for some sawfish body parts because they resemble legally-traded shark body parts (e.g. dried fins). Feldheim et al. (2010)

developed: (1) a rapid polymerase chain reaction (PCR)-based test to identify smalltooth sawfish body parts in trade in the U.S. and western Atlantic, (2) a DNA-barcode based on 520 base pairs (bp) of cytochrome b that resolves smalltooth sawfish and other extant sawfish species, and (3) a suite of 11 polymorphic smalltooth sawfish microsatellite markers that can be used in a variety of conservation genetics applications for this and other sawfish species. Feldheim et al. (2010) anticipate that this suite of genetic tools will contribute to the conservation of this critically endangered species and its relatives by reinforcing landings and trade restrictions and enabling future conservation genetics research.

The PCR-based genetic assay can distinguish body parts (e.g., fins, meat, or cartilage) of smalltooth sawfish from those of all other elasmobranchs (Feldheim et al. 2010). The assay furthergenerates a diagnostic DNA fingerprint for smalltooth sawfish which can be visually distinguished from similar fingerprints that are simultaneously generated for at least 30 commercially-important shark species. The NADH-2 gene may similarly serve as a marker for the identification of rostra and fins involved in illegal trade (Faria et al. 2013). Suites of microsatellite markers have been identified to genotype every individual sampled and to aid in mating studies (Kevin Feldheim, The Field Museum, email communication to Dana Bethea, NMFS, August 11, 2015).

2.3.1.4 Taxonomic classification or changes in nomenclature:
Conservation efforts for sawfish have been hampered by the taxonomy of the sawfish family and the poor state of knowledge about the family's geographical population structure (Faria et al. 2013). However, recent research efforts have shed light in this area.

Rostral tooth counts of smalltooth sawfish specimens from museum collections, research surveys, and fisheries activities were examined for information on sexual dimorphism and bilateral asymmetry, and to aid in the resolution of the taxonomic uncertainty that surrounds the Family Pristidae (Wiley et al. 2008). Tooth counts were taken from 105 smalltooth sawfish captured in Florida and Georgia from 1834 to 2007. The number of rostral teeth ranged from 22 to 29 per side and 45 to 56 bilaterally. Ranges of tooth counts were more constrained, and mean values lower, than historically reported for this species in the literature due to mixed species samples used in some earlier studies. Smalltooth sawfish rostral tooth counts exhibited sexual dimorphism, with males on average having more rostral teeth than females. Bilateral asymmetry in rostral tooth counts was displayed in 73 percent of individuals, with no consistent side on which the greatest count occurred. No significant difference between left and right side rostral tooth counts was found.

Based on historical taxonomy, external morphology, and mitochondrial DNA sequences (NADH-2), Faria et al. (2013) report that, globally, the sawfish family comprises five species in two genera: *Pristis pristis* (circumtropical), *Pristis clavata* (east Indo-West Pacific), *Pristis pectinata* (Atlantic), *Pristis zijsron* (Indo-West Pacific), and *Anoxypristis cuspidata* (Indo-West Pacific, except for East Africa and the Red Sea). Furthermore, based on both or either of NADH-2 and the number of rostral teeth per side, populations of *P. pristis, P. pectinata*, *P. zijsron*, and *A. cuspidata* exhibit significant geographic structuring across their respective ranges, suggesting that regional-level conservation will be required.

2.3.1.5 Spatial distribution, trends in spatial distribution, or historic range: Faria et al. (2013) reported *P. pectinata* is distributed throughout the tropical Atlantic; however, discrete populations (e.g., West and East Atlantic populations) likely represent separate units for conservation purposes. Claims of smalltooth sawfish have been reported from the eastern Atlantic in Europe and West Africa, the Mediterranean, South Africa, and the Indo-West Pacific, including the Red Sea, India, Burma, and the Philippines (Bigelow and Schroeder 1953; Van der Elst 1981; Compagno and Cook 1995). However, the current distribution of smalltooth sawfish in the eastern Atlantic is uncertain due to species misidentification, lack of reporting, and the general contraction of its range. Pacific coast records of smalltooth sawfish off Central America (Bigelow and Schroeder 1953; Compagno and Cook 1995) are likely misidentifications of other sawfish species (Faria et al. 2013).

In the western Atlantic, the smalltooth sawfish has been reported historically from Brazil through the Caribbean and Central America, the Gulf of Mexico, and the Atlantic coast of the United States (Carlson et al. 2013). However, the smalltooth sawfish has been wholly or nearly extirpated from large areas of its historic range and is now found in <20% of this range (Dulvy et al. 2014) (Figure 3). While smalltooth sawfish historically occurred in Mexican waters, there is no information to suggest that there is currently a resident population remaining there. Smalltooth sawfish are now known to occur in the southeastern United States, Bahamas, Cuba, Honduras, and Belize (Carlson et al. 2013). Yet, the Bahamas is the only country, besides the U.S., where smalltooth sawfish can be reliably encountered in the western Atlantic Ocean (Guttridge et al. 2015). Tagging research indicates there is currently no apparent mixing between U.S. and Bahamas smalltooth sawfish or of any other long distance migrations (Carlson et al. 2013).

Historic capture records within the United States range from Texas to New York. Water temperatures lower than 16–18°C and the lack of appropriate coastal habitat serve as the major environmental constraints limiting the northern movements of smalltooth sawfish in the western North Atlantic (Poulakis et al. 2011). As a result, most records of this species from areas north of Florida occur during spring and summer periods (May to August) when inshore waters reach appropriately high temperatures. Most specimens captured along the Atlantic coast north of Florida have also been large (>10 ft or 3 meters [m]) adults and likely represent seasonal migrants, wanderers, or colonizers from a historic Florida core population to the south rather than being members of a continuous, even-density population (Bigelow and Schroeder 1953). There is only one winter record from the Atlantic coast north of Florida.

The Status Review Team (NMFS 2000) collected and compiled literature accounts, museum collection specimens, and other records of the species to document the changes in distribution and abundance. On the basis of the Status Review (NMFS

2000) and recent encounter database research (Seitz and Poulakis 2002, Poulakis and Seitz 2004, Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2010, Waters et al. 2014, G. Burgess unpublished data), the historic and current distributions of the U.S. DPS of the smalltooth sawfish in four regions of the eastern United States are described below.

New York to Virginia

The northernmost U.S. record of the smalltooth sawfish is based upon a 15 ft (4.5 m) specimen from New York taken in July 1782 (Schopf 1788). This is the only record of smalltooth sawfish from New York waters. There is always concern with early reports of any species from New York because those reports often were based on market specimens that were shipped to New York from other nearby areas. Documented reports of the species from the bordering State of New Jersey, however, and the historical presence of many large, inshore, tropical species in the New York region prior to human-induced environmental degradation suggest the New York record may be valid. Records of smalltooth sawfish from the mid-Atlantic are only from the late 1800s and early 1900s. There are three records from New Jersey. Shields (1879) reported a 16 ft (4.8 m), 700 lb (311 kg) specimen in Grassy Sound near Cape May, one was taken at Cape May in 1883, and Fowler (1906) noted the occurrence of two sawfish in the ocean off Cape May in or about August 1900. References to smalltooth sawfish in Maryland and Virginia are similarly dated. Uhler and Lugger (1876) reported that it occasionally enters Chesapeake Bay, and Fowler (1914) and Truitt and Fowler (1929) reported on a 10 ft (3.0 m) Ocean City specimen. Hildebrand and Schroeder (1928) later noted that it was rarely taken in lower Chesapeake Bay, sometimes one or two fish a year and sometimes none. There have been no reports of smalltooth sawfish in New Jersey, Maryland, or Virginia since 1927.

North Carolina to Georgia

There are multiple reports of sawfish in North Carolina waters from the late 1800s and early 1900s, some being reiterations of earlier reports: Yarrow (1877: Core Sound, Bogue Sound, New River), Jenkins (1885: Beaufort), Wilson (1900: Beaufort), Smith (1907: Core Sound, Bogue Sound, New River, Beaufort, Cape Lookout), Gudger (1912: Cape Lookout), Coles (1915: Cape Lookout), Radcliffe (1916: Cape Lookout), and Gudger (1933: Cape Lookout). Yarrow (1877) indicated the sawfish was abundant in brackish waters emptying into Bogue and Cove [= Core] Sounds and that they were frequently taken in the New River. Wilson (1900) also noted that it is frequently taken in North Carolina. Smith (1907) later reported that this fish is not rare in the sounds and brackish waters of North Carolina and that in the Beaufort region and at Cape Lookout the species is observed almost every year, and some seasons is common. Since 1915 there have been only three published records of captures in North Carolina: one in 1937 (Fowler 1945), one in 1963 (Schwartz 1984), and a recent report from 1999 (Schwartz 2003). Additional unpublished encounters occurred in 1938, 1951, and 1958.

Records from South Carolina and Georgia are sparse. Jordan and Gilbert (1882) and True (1883) were the first publications to report sawfish in South Carolina waters, but there are records of the species in state waters from as early as 1817. The species was taken with some regularity, based on multiple State Museum and newspaper records, until about 1938, with the last reported capture in 1958. The two earliest reports were of a 4.11 m adult at St. Simon's Island in 1889 and Fowler's (1945) report of a 3 ft (0.91 m) juvenile at Ossabaw Island in March 1908. There are only two recent records of sawfish documented in Georgia. In 2002 a bottom longline fishery observer documented the capture of an estimated 13 ft (4.0 m) adult from depths of 152–242 ft (45.6–72.6 m) (G. Burgess, unpublished data). In 2015 a research trawl off Cumberland Island captured a smalltooth sawfish which had previously been tagged in 2010 off the Florida Keys, then an estimated 400 cm (13.1 ft) (J. Carlson, unpublished data).

Texas to Alabama

Records of smalltooth sawfish in the northern Gulf of Mexico exhibit a similar seasonal pattern of occurrence in that more than two-thirds of the records are from April through August. While less common, winter records from the northern Gulf of Mexico (including juveniles) do suggest that at least a portion of the population may have been resident year-round in the region. Smalltooth sawfish were described as abundant by Jordan and Evermann (1896) and common by Breder (1952) in the Gulf of Mexico. These authors may have been a bit generous in attributing these levels of abundance, as the records of smalltooth sawfish in this area are substantially fewer than in waters off peninsular Florida. Nevertheless, smalltooth sawfish apparently were more common in the Texas and northern Gulf region than in the Atlantic Ocean north of Florida.

The smalltooth sawfish was first recorded within this region by Rafinesque (1820) in the lower Mississippi River upstream as far as the Red River in Arkansas (his report of the species in the Ohio River is thought to be erroneous). Numerous records of smalltooth sawfish exist from the Gulf of Mexico: Goode and Bean (1882), Jordan and Gilbert (1883), Jordan (1886), Evermann and Kendall (1894: Galveston), Jordan and Evermann (1900: Pensacola), Gowanloch (1932: LA), Gunter (1935: LA), Baughman (1943: TX), and Boschung (1957, 1992: AL). Baughman (1943) reported that smalltooth sawfish were frequently taken and plentiful in Texas waters. Bigelow and Schroeder (1953) later regarded smalltooth sawfish as abundant in Texas. As recently as the late 1950s sawfish were characterized as being not uncommon in Alabama waters (Boschung 1957), and recreational fishers reportedly took many sawfish prior to the 1960s in Texas (Caldwell 1990). However, the number of encounters with smalltooth sawfish in the northern and western Gulf of Mexico dwindled in the 1970-2015 period and recent studies to document encounters have yielded only a handful of records. There are only three records from Alabama, one in Mississippi, seven from Louisiana, and 15 from Texas (G. Burgess, unpublished data). Two of the Alabama encounters, the Mississippi record, five of the Louisiana observations, and five of the Texas reports occurred after 2003.

Florida

Peninsular Florida has been the U.S. region with the largest numbers of capture records of smalltooth sawfish (Seitz and Poulakis 2002, Poulakis and Seitz 2004, Wiley and

Simpfendorfer 2010, Waters et al. 2014) and apparently is the main area that historically hosted the species year round. The region's subtropical to tropical climate and availability of desirable habitat, including large expanses of lagoons, bays, mangroves, and nearshore reefs are suitable for the species. Although no longer common, smalltooth sawfish were once characteristic and prominent elements of the inshore Florida ichthyofauna.

The earliest record of smalltooth sawfish from Florida is an 1834 museum specimen from Key West. Published reports of the species in Florida were common over the next 100 years: Goode (1879a: FL; 1879b: east coast FL; 1884: Indian River, St. Johns River, Everglades, St. Andrews Bay), Jordan and Swain (1884: Cedar Keys), Henshall (1891: Big Gasparilla, FL west coast), Bean (1892: San Carlos Bay), Lönnberg (1894: Punta Gorda), Henshall (1895: Tampa), McCormick in Smith (1896: Biscayne Bay), Evermann and Bean (1898: Eau Gallie, Eden, Stuart in Indian River), Smith (1896: Biscayne Bay), Jordan and Evermann (1900: Pensacola), Evermann and Kendall (1900: east FL), Evermann and Marsh (1900: Indian River), Fowler (1906: FL Keys; 1915: Ft. Pierce), Radcliffe (1916: FL), Nichols (1917: Sandy Key), and Fowler (1945: Plantation Key). Museum records from this time period are also reasonably common.

Historically, the Indian River Lagoon on the east coast of Florida was an area of smalltooth sawfish abundance. Goode (1884) reported that in the Indian River and its tributaries sawfish was very common and Evermann and Bean (1898) noted the sawfish was an abundant species, with a single commercial fisher having captured 300 smalltooth sawfish in a single fishing season. Published and museum records of sawfish are plentiful from the lagoons south of Cape Canaveral throughout this time period. Records also exist from more northerly (off Daytona Beach and Jacksonville) and southerly (Biscayne Bay) peninsular east coast localities during the late 1800s. Goode (1884) reported that "in the St. John's River individuals of all sizes…are taken as high up as Jacksonville." Post-1907 records from this region, however, have been far more limited and occurrences north of the Florida Keys on the east coast are currently noteworthy events. During a 1973–1976 Florida Bay fish survey Schmidt (1979) reported three juvenile and adult specimens captured along the northern Florida Bay shoreline. Snelson and Williams (1981) did not capture any sawfish in an extensive multi-year study of the Indian River Lagoon system. They speculated that the species' absence was caused by heavy mortality associated with incidental captures by commercial fishermen because the decline seemed to pre-date most of the man-made habitat alterations of the area. Current records from the east coast of Florida remain relatively scarce compared to the west coast, Florida Bay, and the Florida Keys. Most of the encounter records for the east coast are of larger-sized sawfish occurring along the beaches and at offshore reefs, though more recently a few juvenile-sized individuals have been reported inside the Indian River Lagoon system (Simpfendorfer and Wiley 2005a; Wiley and Simpfendorfer 2007a, Wiley and Simpfendorfer 2010, G. Poulakis unpublished data).

Smalltooth sawfish are rarely observed within Biscayne National Park (Lewis 2008), on Florida's southeast coast. The park's wildlife observation database does not contain any documented observations of the species, although there have been unconfirmed, anecdotal reports from around the Arsenicker Keys, the Safety Valve area (just south of Key Biscayne) and southeast of Soldier Key. Public encounters reported to the International Sawfish Encounter Database support the rarity of this species in Biscayne Bay as less than two dozen encounters have been reported within Biscayne Bay since 2003 (G. Burgess unpublished data). The lack of documented occurrences of smalltooth sawfish within Biscayne National Park is likely due to a combination of naturally low numbers of the species in the area and infrequent efforts to examine the species' distribution within the park (Lewis 2008).

The U.S. region that has always harbored the largest numbers of smalltooth sawfish lies in south and southwest Florida from Charlotte Harbor through the Dry Tortugas. Goode (1884) stated that in the Everglades these fish are said to be exceedingly abundant. There has been a continuous and frequent record of sawfish occurrences in the Everglades since the first report in 1834, and the vicinity (including Charlotte Harbor) now serves as the last U.S. stronghold for the species (Seitz and Poulakis 2002; Poulakis and Seitz 2004; Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2007a; Wiley and Simpfendorfer 2010). Waters et al. (2014) indicated the majority of encounters (92.4%) were juveniles reported off south and south-west Florida, corroborating the results of previous studies and supporting previously identified nursery areas (Seitz and Poulakis 2002; Poulakis and Seitz 2004; NMFS 2009b; Wiley and Simpfendorfer 2010; Norton et al. 2012). Wiley and Simpfendorfer (2010) identified four areas with the highest encounter densities (>0.151 encounters km^{-2}): the lower Caloosahatchee River, Ten Thousand Islands/northern Everglades National Park coast from Palm Bay to Sunday Bay, central Everglades National Park coast from Lostman's River to northern Ponce de Leon Bay, and northern Florida Bay coast from East Cape to Garfield Bight. These areas are at the mouths of major rivers or other sources of freshwater flow (i.e., Everglades freshwater flow). In a similar effort, Waters et al (2014) identified spatial "hotspots" based on increased numbers of encounters of large juveniles (201–340 cm) and adults (>340 cm) in southern Charlotte Harbor, the Ten Thousand Islands, Florida Bay, the Atlantic side of the Florida Keys, and off St. Lucie in south-east Florida.

Smalltooth sawfish also occasionally occur on the west coast of Florida north of Charlotte Harbor, but historically appear to never have been as common in this region as in the east coast lagoons and south Florida. One of the earliest published records from the west coast was reported in 1883 from the Cedar Keys off the northwestern Florida peninsula. Other 1800s' captures were documented in Tampa Bay and in the southwest coast off Charlotte Harbor and San Carlos Bay. Henshall (1895) relates reports of hundreds occurring on the Gulf coast of peninsular Florida, though records of capture since that time period have been limited.

Recent records of smalltooth sawfish indicate there is a resident reproducing population of smalltooth sawfish in south Florida (Seitz and Poulakis 2002; Poulakis and Seitz 2004; Simpfendorfer and Wiley 2005a; Wiley and Simpfendorfer 2010, Waters et al. 2014) and although all size classes were reported, the majority were sawfish ≤200 cm estimated total length (Wiley and Simpfendorfer 2010). Smalltooth sawfish were found to be year-round residents of Florida and showed relatively consistent spatial and temporal trends by life stage throughout the year (Waters et al. 2014). Seasonally, numbers of encounters of all life stages combined peaked from March through July (Wiley and Simpfendorfer 2010, Waters et al. 2014), primarily driven by annual recruitment of juveniles during this period (Waters et al. 2014, Poulakis et al. 2014).

Studies examining patterns of distribution by size in Florida have produced variable results. Wiley and Simpfendorfer (2010) found an inverse relationship between sawfish size and extent of northern distribution, with ≤200 cm animals having a wider latitudinal distribution and occurring farthest north, and >200 cm animals reported mostly in southern Florida. In contrast, Waters et al. (2014) ran models which showed shorter individuals were expected in western Florida with an increase in expected lengths observed in northeast Florida. There was an increasing average individual length from western Florida to northeastern Florida for all seasons, except during the summer when a peak of larger individuals was reported in northwest Florida (Waters et al. 2014). It has been suggested that adult sawfish perform seasonal northward migrations in Florida waters (e.g. Bigelow and Schroeder 1953, Waters et al. 2014) and up the U.S. east coast (NMFS 2009a), but early satellite tracking data were not able to identify such behavior (Carlson et al. 2014). Papastamatiou et al. (2015) obtained some evidence to support the migration theory as northward summer movements were observed from three individuals, but there were no corresponding southerly movements. However, no data were collected during late fall and winter when southerly movements would be predicted. The recapture of an adult in the summer of 2015 off Cumberland Island—an adult originally tagged in winter 2010 in the Florida Keys (D. Bethea, unpublished data)—and a satellite tag from a sawfish tagged in Florida Bay popping off in the Gulf of Mexico off Charlotte Harbor (D. Grubbs, unpublished data) provide some evidence of northward movement.

2.3.1.6 Habitat or ecosystem conditions:

At the time of listing the status review document (NMFS 2000) summarized smalltooth sawfish's habitat use in the following way: sawfish inhabit the shallow coastal waters of most warm seas throughout the world; are found very close to shore in muddy and sandy bottoms; seldom descend to depths greater than 32 ft (10 m); and are often found in sheltered bays, on shallow banks, and in estuaries or river mouths.

In the years since the status review, additional research has revealed a more complex pattern of habitat use than previously known, with different life history stages having different patterns of habitat use. Ongoing research will undoubtedly inform recovery efforts in the future. A variety of methods have been applied to studying habitat use patterns of smalltooth sawfish including field surveys, public encounter databases (Seitz and Poulakis 2002; Poulakis and Seitz 2004; Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2007b, Wiley and Simpfendorfer 2010, Waters et al. 2014), active and passive acoustic monitoring (Simpfendorfer 2003, Wiley and Simpfendorfer 2007b, Wiley and Simpfendorfer 2007d, Simpfendorfer et al. 2010, Poulakis et al. 2011, Simpfendorfer et al. 2011, Hollensead 2012, Poulakis et al. 2013, Hollensead et al. 2015, Papastamatiou et al. 2015), and satellite archival tagging (Simpfendorfer and Wiley 2005b, Carlson et al. 2013). The majority of this research has been targeted at juvenile sawfish, but some information on adult habitat use has also been obtained.

General habitat use observations

Sawfish inhabit shallow coastal waters, estuaries, and rivers of the tropics and subtropics, down to a maximum depth rarely exceeding 100 m and are associated with mangrove and seagrass habitats (Dulvy et al. 2014). Juvenile smalltooth sawfish have a pattern of habitat use that is relatively consistent among individuals of similar sizes and display ontogenetic changes (Simpfendorfer et al. 2010, 2011; Poulakis et al. 2013). Ontogenetic shifts in habitat use will require that recovery efforts for different size or maturity classes be focused in different areas (Wiley and Simpfendorfer 2010). Sawfish ≤200 cm have the most specific habitat associations in nearshore areas and can be targeted relatively easily with recovery efforts. However, larger size classes have more varied habitat use and recovery efforts will need to be more broadly based or targeted at specific areas that may provide the greatest benefits to the population (e.g., aggregating, mating, feeding) (Wiley and Simpfendorfer 2010).

Encounter data have provided some general insight into the habitat use patterns of smalltooth sawfish. Encounter reports indicate sawfish are generally associated with mangroves, seagrasses, and shoreline habitats (Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2010). Poulakis and Seitz (2004) reported that where the substrate type of encounters was known 61 percent were over mud, 11 percent sand, 10 percent seagrass, 7 percent limestone, 4 percent rock, 4 percent coral reef, and 2 percent sponge. Encounter data have also demonstrated that smaller smalltooth sawfish occur in shallower water than larger sawfish (Poulakis and Seitz 2004, Wiley and Simpfendorfer 2010). Poulakis and Seitz (2004) reported that almost all of the sawfish <10 ft (3 m) in length were found in water less than 32 ft (10 m) deep and 46 percent of encounters with sawfish >10 ft (3 m) in Florida Bay and the Florida Keys were reported to occur at depths between 200 to 400 ft (70 to 122 m). Similarly, Simpfendorfer and Wiley (2005a) reported a substantial number of larger sawfish in depths greater than 32 ft (10 m). Wiley and Simpfendorfer (2010) found the vast majority (88.5%) of encounters occurred in water ≤5 m deep and there was a significant relationship between depth and estimated length, with smaller animals tending to occur in shallower water.

Encounter data have also identified river mouths as areas where many people observe sawfish (Seitz and Poulakis 2002, Simpfendorfer and Wiley 2005a). Whether this observation represents a preference for river mouths because of physical characteristics (e.g., salinity), biological characteristics (e.g., mangroves or prey), or both is unclear. Wiley and Simpfendorfer (2010) identified four areas with the highest encounter densities (>0.151 encounters km^{-2}) and all are at the mouths of rivers or other sources of freshwater flow: the lower Caloosahatchee River, Ten Thousand Islands/northern Everglades National Park coast from Palm Bay to Sunday Bay, central Everglades National Park coast from Lostman's River to northern Ponce de Leon Bay, and northern Florida Bay coast from East Cape to Garfield Bight.

Juvenile habitat use

Habitat use of juvenile smalltooth sawfish continues to be studied using a variety of techniques. Results indicate juvenile sawfish are closely associated with shallow estuarine environments, comprised of red mangrove shorelines and a specific range of environmental parameters. It is believed that the shallow, red mangrove-lined environments provide for predator avoidance and serve as a source for abundant prey (Norton et al 2012). Areas containing these habitat characteristics can have higher abundances of juvenile smalltooth sawfish. Poulakis et al. (2011) found juvenile sawfish were continuously captured and identified during acoustic monitoring in five areas of the Charlotte Harbor estuarine system and defined these areas as "hotspots". Four of these areas were located in the Caloosahatchee River and one was found in the Peace River. As juveniles grow, they undergo habitat shifts, moving from shallow water, protected shorelines to more open water environments.

Acoustic tracking results for young-of-the-year (YOY, ≤150 cm STL) smalltooth sawfish indicate that shallow depths and red mangrove root systems are likely important for reducing predation (Simpfendorfer 2003). YOY smalltooth sawfish spend the vast majority of their time on shallow mud or sand banks that are less than 50 cm deep (Simpfendorfer et al. 2010). Tide was found to be the main factor influencing movement since water depth on these banks varies with the tide and the movement of small sawfish appears to be directed towards remaining in shallow water (Simpfendorfer et al. 2010). Neonate individuals (<100 cm) have limited movements in relation to salinity (Simpfendorfer et al. 2011). Remaining in these very shallow areas allows the YOY sawfish to be inaccessible to predators (mostly sharks) and increases survival. Their dorso-ventrally compressed body shape helps them in inhabiting these shallow areas. Simpfendorfer (2003) observed very small sawfish moving into prop root habitats when shallow habitats were less available (especially at high tide). One small animal tracked over three days moved into a small mangrove creek on high tides when the mud bank on which it spent low tide periods was inundated at depths greater than 1 ft (30 cm). While in this creek it moved into areas with high prop root density.

Previous smalltooth sawfish studies have reported a correlation between habitat use and proximity to mangroves (Simpfendorfer 2003, Simpfendorfer et al 2010, Wiley and Simpfendorfer 2010) and Hollensead (2012) reported a higher probability of seeing a juvenile smalltooth sawfish when mangrove prop root density was high. The use of red mangrove prop root habitat is likely to aid YOY sawfish in avoiding predators, as the complexity of the prop root habitat likely restricts the access of predators (Simpfendorfer 2003). Poulakis et al. (2015) reported juvenile sawfish were found near red mangrove habitat ten times more often than at seawalls, and twenty-seven times more often than at the oyster-covered groins in the Peace River. Sawfish that used non-mainstem habitat spent more time in canals with mangroves than canals without mangroves (Poulakis et al. 2014). Comparisons of tracked animal locations and random locations by Hollensead et al (2015) in the Ten Thousand Islands suggested there was selection for those habitats in close proximity to mangrove shoreline and in all cases the mean distance of actively tracked animals from the mangrove-fringed shoreline was less than 100 m. YOY and juveniles up to 2.2 m used mangrove habitats more than 10% of the time they were monitored in the Charlotte Harbor estuarine system, a system less natural than the area monitored by Hollensead et al. (2015). Natural shorelines and areas with high mangrove prop root density may be particularly important to preserve as potential juvenile smalltooth sawfish nursery habitat (Hollensead 2012, Poulakis et al. 2013, 2014).

Juvenile sawfish have been collected in a variety of physiochemical water parameters ranging in temperature from 14.6 to 32.6°C, salinity from 0.1 to 33.6 psu, and freshwater inflow from 0.0 to 627.4 m^3s^{-1} (Simpfendorfer et al. 2011). Yet, Poulakis et al. (2011) indicated most juvenile sawfish collected within the rivers of Charlotte Harbor between 2005 and 2009 had an affinity for water less than 1 m deep with a temperature greater than 30°C, dissolved oxygen greater than 6 mg/L, and salinity between 18 and 30 psu. In the Caloosahatchee River, juvenile sawfish avoided water cooler than 18°C, dissolved oxygen less than 6 mg/L, and salinity greater than 30 psu (Poulakis et al. 2011).

Poulakis et al. (2014) compared sawfish electivity in the flow-managed Caloosahatchee River to the natural flow and habitat of the Peace River using data between 2010 and 2013. Electivity results were largely similar to the results from the period of sampling between 2005 and 2009 (Simfendorfer et al. 2011). YOY sawfish (<1.5 m) had an affinity for water less than 1 m deep and larger juveniles (>1.5m) had an affinity for water greater than 1 m deep in both rivers. All juvenile sawfish in the Caloosahatchee River had an affinity for dissolved oxygen greater than 6 mg/l, temperatures greater than 27°C, and salinity 27-33 psu (a second peak in affinity for salinities between 6 and 9 psu was also evident during high flow events). Sawfish in the Peace River had an affinity for dissolved oxygen greater than 4 mg/L, temperatures greater than 24°C and salinity 12-27. The differences in affinities for physicochemical conditions between the two rivers can likely be attributed to the managed flow of the Caloosahatchee River. Poulakis et al. (2013) reported the distribution of all smalltooth sawfish combined in the Caloosahatchee River was significantly related to 90-day lagged response to salinity, with sawfish moving slowly upriver as salinity increased. Conversely, smalltooth sawfish moved downstream rapidly after high flow events (Poulakis et al. 2014).

Using data from 2012-2013, Poulakis et al. (2014) found differences in the response of juvenile smalltooth sawfish to changes in salinity in the Caloosahatchee and Peace Rivers. In the Caloosahatchee River the distribution of juvenile smalltooth sawfish was related to a 60-day lagged response to salinity. In contrast, juvenile sawfish movement in the Peace River was continuous and only lagged changes in salinity by a few days (Poulakis et al. 2014). The difference in movement and response of sawfish between the Caloosahatchee and Peace Rivers may be attributed to the layout of the rivers and the amount of available habitat. Sawfish in the Peace River may choose to stay in "hotspots" that provide greater protection over following physiochemical preferences. Simpfendorfer et al. (2011) reported several sawfish moved up the Caloosahatchee

River, beyond detection range, during drier conditions and that the different size classes of juvenile smalltooth sawfish move at different salinities. Poulakis et al. (2013) reported similar results showing salinity patterns within the Caloosahatchee River had a greater effect on the distribution (mean river position) of YOY smalltooth sawfish (90-day lagged salinity response) than on that of older individuals (120-day lagged salinity response). Salinity electivity analysis demonstrated an affinity for salinities between 18 and 30 psu, suggesting movements are likely made in part, to remain within this range (Simpfendorfer et al. 2011, Poulakis et al. 2011). This suggests flow, in conjunction with physical factors such as depth, plays some role in individual location within the river, possibly through its influence on salinity (Simpfendorfer et al. 2011). Thus, freshwater flow from Lake Okeechobee (and its effect on salinity) affects the location of individuals within the estuary, although it remains unclear whether or not these movements are threatening recovery (Simpfendorfer et al. 2011).

Smalltooth sawfish use both main stem river and non-main stem habitats (adjacent canals or tidal creeks), though there are differences in use rates between the two. In the Caloosahatchee River, smalltooth sawfish used the main stem river with more regularity than the non-main stem habitats (Poulakis et al. 2013). However, the study found smalltooth sawfish used non-mainstem habitats (red mangrove-lined creeks and seawall-lined canals) extensively with 83% of tracked sawfish using the non-main stem habitat at some point during the study. The study also indicated that of the types of non-main stem habitats, sawfish used red mangrove-lined creeks more than seawall-lined canals.

Smalltooth sawfish in the Peace River also used non-main stem habitat, though less than sawfish in the Caloosahatchee River. Poulakis et al. (2015) found diel movements in relation to the shoreline in the Peace River where juvenile sawfish were found closer to shore during the day and moving to open water at night. All larger scale movements tended to occur at night and smaller movements during the day were due to tidal fluctuations (Poulakis et al. 2015).

Tide was found to be the main factor influencing movement on short time scales (Simpfendorfer et al. 2010). Juveniles >130 cm had high levels of site fidelity for specific nursery areas for periods up to almost 3 months, but the smaller juveniles had relatively short site fidelity to specific locations (Simpfendorfer et al. 2010). In the Caloosahatchee River mean daily activity space was 1.42 km of river distance and the distance between 30-minute centers of activity was typically <0.1 km, suggesting limited movement over short time scales (Simpfendorfer et al. 2011).

Acoustic monitoring studies have shown that juveniles have fidelity for specific nursery areas for periods up to almost 3 months (Wiley and Simpfendorfer 2007b). Simpfendorfer et al. (2010) found YOY smalltooth sawfish <100 cm stretched total length (STL) had the smallest home ranges, low linearity of movement and a preference for very shallow mud banks. Acoustic tracking studies have shown that at this size sawfish will remain associated with the same mud bank over periods of several days. These banks are often very small and daily home range sizes can be of the magnitude of

100–1,000 m^2 (Simpfendorfer 2003). Hollensead et al. (2015) reported similar results that indicated activity spaces ranged from 70-170 m^2 using 95% Minimum Convex Polygons (MCP), 10-160 m^2 based on 50% kernel density estimates (KDE), and 80-680 m^2 based on 95% (KDE). Rates of movement (ROMs) ranged from 2.4-6.1 meters/min and activity space and ROMs reflected the morphology of the bay in which the animal was tracked such that fish in small bays had small activity spaces and ROMs (Hollensead et al. 2015). Hollensead et al. (2015) report that while the daily movements of small juveniles and young-of-the-year are confined, there is a steady and increasing expansion of overall activity space with size and this fine-scale expansion in daily activity space provides a mechanism for ontogenetic shifts in habitat area that have been described in previous studies (Simpfendorfer et al. 2010, Poulakis et al. 2013). There were no detectable differences in activity space or ROM between ebb and flood tide or high or low tide, though diel trends showed increased ROM and decreased activity space at night, likely suggesting foraging behavior (Hollensead et al. 2015). ROMs reported by Hollensead (2015) were similar to those observed by Simpfendorfer et al. (2010) in both Mud Bay (2.87 m/min) and Faka Union (3.25 m/min).

Age-1 juveniles have many of the same habitat use characteristics seen in YOY small sawfish, though their associations with specific shallow water habitats become less obvious as they grow. Their association with very shallow water (< 1 ft deep) is weaker, and they will move into deeper areas at times. One juvenile sawfish acoustically tracked in the Caloosahatchee River spent the majority of its time in the shallow waters near the riverbank, but for a period of a few hours it moved into water 4–6 ft deep (Simpfendorfer 2003). During this time, it was constantly swimming, a stark contrast to active periods in shallow water that lasted only a few minutes before resting on the bottom for long periods. Simpfendorfer et al. (2010) reported that as sawfish attain larger size (>180 cm total length) they move from shallow mangrove habitats in sheltered areas (creeks, rivers, enclosed bays) to similar habitats on the marine fringe and hypothesize that this is a precursor for further movement offshore.

Several sawfish approximately 59 in (150 cm) in length (age-1) fitted with acoustic tags have been relocated in the same general areas over periods of several months, suggesting a high level of site fidelity (Simpfendorfer 2003). The daily home ranges of these animals are considerably larger (1-5 km^2) than for the YOY sawfish and there is less overlap in home ranges between days. Acoustic monitoring systems studying the longer-term site fidelity of sawfish has confirmed these observations, and also identified that changes in environmental conditions (especially salinity) may be important in driving changes in local distribution and, therefore, habitat use patterns (Poulakis et al. 2011, Simpfendorfer et al. 2011).

Given that YOY and small juveniles exhibit daily expansion of habitat use, a continuous distribution of red mangrove shoreline habitat may be crucial for animals to grow and eventually recruit to the adult population. In areas with high concentrations of YOY during peak pupping seasons, rapid expansion into other areas could limit intraspecies competition for resources (Hollensead 2012).

There are few data on the habitat use patterns of large juvenile sawfish (200-340 cm STL). To date researchers have struggled to capture sawfish in the size class and thus there are few details on habitat use and preference. However, there are some limited data available from the deployment of pop-up archival transmitting (PAT) tags. These tags record depth, temperature, and light data, which is stored on the tag until it detaches from the animal, floats to the surface, and sends data summaries back via the ARGOS satellite system. More detailed data can be obtained if the tag is recovered. A PAT tag deployed on a 79 in (200 cm) sawfish in the Marquesas Keys collected 120 days of data. The light data indicated that the animal had remained in the general vicinity of the outer Keys (more detailed location data are not available) for this entire period. Depth data from the tag indicated that this animal remained in depths less than 17 ft (5 m) for the majority of this period, making only two excursions to water down to 50 ft (15 m) in depth. A PAT tag deployed on an 87 in (222 cm) female smalltooth sawfish at Rabbit Key in Everglades National Park in 2013 collected 40 days of data, indicating the animal spent 93% of its time in depths less than 6.5 ft (2 m) with one excursion to 115 ft (35 m) and 90% of its time at temperatures 26-32 °C (John Carlson unpublished tracking data). Papastamatiou et al. (2015) reported that over short time periods, movements appeared primarily tidal driven with some evidence that animals moved into shallow water during the ebbing or flooding tides and no individuals showed any evidence of diel or crepuscular patterns of movement.

Adult habitat use

Encounter data have been useful in identifying water depths used by adult smalltooth sawfish. Encounter data suggest that adult sawfish occur from shallow coastal waters to deeper shelf waters (Seitz and Poulakis 2002; Poulakis and Seitz 2004; Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2007b, Wiley and Simpfendorfer 2010, Waters et al. 2014). International Sawfish Encounter Database records indicate that about three-quarters of adult encounters occur in depths less than 30 ft (9.1 m). However, encounters by depth strata may be variable by location and/or time of year. Poulakis and Seitz (2004) observed that nearly half of the encounters with adult-sized sawfish in Florida Bay and the Florida Keys occurred in depths from 200 to 400 ft (70 to 122 m). Simpfendorfer and Wiley (2005a) and Wiley and Simpfendorfer (2010) also reported encounters in the deeper water off the Florida Keys, noting that these were mostly reported during winter. There are 58 U.S. records of adult smalltooth sawfish from depths of 100-149 ft (30.4-45.4 m), 18 from 150-199 ft (45.7-60.6 m), 14 from 200-249 ft (60.9-75.9 m), and seven from 250-550 ft (76.2-167.6). Maximum depth of encounters was 500-600 ft (152.4-182.8 m) off Ft. Lauderdale, Florida. Little other information is available on the habitat use patterns of the adults from encounter data.

Carlson et al. (2013) tagged 12 adult/large juvenile smalltooth sawfish to document distance travelled, water depth, and water temperature. They reported all tagged smalltooth sawfish generally remained in coastal waters within the region where they were initially tagged, travelling an average of 80.2 km from deployment to pop-up location. The shortest distance moved was 4.6 km and the greatest 279.1 km, averaging 1.4 km/day. Seasonal movement rates for females were significantly different with the greatest movements in autumn and winter (females move slower in spring and summer). Tagged sawfish spent the majority of their time at shallow depths (96% of their time at depths <10 m; the deepest dive was to 88m), and warm water temperatures (22–28°C). In a similar study, Papastamatiou et al. (2015) reported that adult sawfish rarely go into waters warmer than 30°C although they were occasionally in water of 32–34°C. This is in contrast to juvenile sawfish that were reported to have an affinity for waters warmer than 30°C as described by Poulakis et al. (2011).

Limited data are available on the site fidelity of adult sawfish. Seitz and Poulakis (2002) reported that one adult-sized animal with a broken rostrum was captured in the same location over a period of a month near Big Carlos Pass suggesting that they may have some level of site fidelity for relatively short periods.

Seasonal sexual segregation of adult smalltooth sawfish has been reported with males found by mangrove-lined canals in the spring and females predominantly found in outer parts of the bay (Papastamatiou et al. 2015). Males migrated from canals starting in late May, potentially as temperatures increased above 30°C. Some males and females migrated north (but still in south Florida) during the summer, while others may have remained within deeper portions of Florida Bay. Male sawfish displayed site fidelity to Florida Bay as some individuals were recaptured 1–2 years after originally being tagged and showed high periods of residency to East Cape Canal with some individuals being detected almost daily over periods of 1–3 months. Papastamatiou et al. (2015) found evidence of tidally related movements, swimming over warm shallow seagrass beds during the ebbing or flooding tide and deeper cooler channels at slack tide. Given sawfish show a degree of site fidelity punctuated by limited migratory movements emphasizes the need for conservation and management of existing coastal habitats throughout the species' range (Carlson et al. 2013).

2.3.1.7 Other:

Sawfishes are threatened primarily due to a combination of their low intrinsic rates of population increase as compared to teleosts, high catchability in fisheries, and high economic value in markets for shark fin soup and curios (Dulvy et al. 2014). Sawfishes are among the world's largest marine fishes, and they are caught by a wide range of fishing gears owing to their tooth-studded rostra being easily entangled, their fins are some of the most valuable for shark fin soup, and their rostra have long been traded as curios. Due to their close association with shallow coastal waters, estuaries, and rivers they are susceptible to anthropogenic influences (e.g., capture, habitat degradation, etc.). The global conservation strategy specifies actions to protect sawfish and their habitats; such actions are urgently warranted to avoid global extinction and to restore robust populations for the benefit of coastal ecosystem function and biodiversity (Harrison and Dulvy 2014).

Facilitating recruitment into the adult population by protecting smalltooth sawfish nursery habitat was identified in the recovery plan as a key conservation objective. NMFS (2009) used the Heupel et al. (2007) framework for defining nursery areas for sharks and related species such as sawfish along with juvenile smalltooth sawfish encounter data to identify nursery habitat for juvenile smalltooth sawfish in south Florida. Heupel et al. (2007) proposed that shark nursery areas can be defined based on three primary criteria: 1) juveniles are more common in the area than other areas, i.e., density in the area is greater than the mean density over all areas; 2) juveniles have a tendency to remain or return for extended periods (weeks or months), i.e., site fidelity is greater than the mean site fidelity for all areas; and 3) the area or habitat is repeatedly used across years whereas other areas are not. NMFS analyzed juvenile smalltooth sawfish encounter data and mapped the location of the areas that met the Heupel et al. (2007) criteria for defining a nursery area. Two nursery areas met these criteria and were included in a critical habitat designation (NMFS 2009b, Norton et al. 2012). The northern nursery area is located within the Charlotte Harbor Estuary and the southern nursery area is located in the Ten Thousand Islands area south into Everglades National Park. The Charlotte Harbor Estuary Unit comprises approximately 221,459 acres (346 mi^2) of coastal habitat and the Ten Thousand Islands/Everglades Unit (TTI/E), comprises approximately 619,013 acres (967 mi^2) of coastal habitat. The habitat features determined to be essential to the conservation of the species within the nursery areas are red mangroves (*Rhizophora mangle*) and shallow euryhaline habitats with water depths less than 3 ft (0.9 m) in depth at mean lower low water. These essential features are necessary to facilitate recruitment of juveniles into the adult population, because they provide for predator avoidance and habitat for prey in the areas currently being used as juvenile nursery areas (NMFS 2009b, Norton et al. 2012).

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

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

Smalltooth sawfish habitat has been degraded or modified throughout the southeastern U.S. from agriculture, urban development, commercial activities, channel dredging, boating activities, and the diversion of freshwater runoff. These same habitats are being affected by changes in climate. While the degradation and modification of habitat is not likely the primary reason for the decline of smalltooth sawfish abundance and their contracted distribution, it has likely been a contributing factor and almost certainly hampers the species' recovery.

The principal habitats for juvenile smalltooth sawfish in the southeast U.S. are the shallow coastal areas and estuaries, with some specimens moving up river into freshwater (Bigelow and Schroeder 1953). The continued urbanization of the southeastern coastal States has resulted in substantial loss or modification of these coastal habitats. Activities such as agricultural and urban development, commercial activities, dredge and fill operations, boating, erosion, and diversions of freshwater runoff contribute to these losses (South Atlantic Fisheries Management Council [SAFMC] 1998). Loss and degradation of habitat have contributed to the decline of many marine species and are believed, but not confirmed, to have affected the distribution and abundance of smalltooth sawfish. Today, smalltooth sawfish remain in the United States typically in protected or sparsely populated areas off the southern and southwestern coasts of Florida; the only known exception is the nursery area in the Caloosahatchee River in an area of waterfront residences and seawalls (Simpfendorfer and Wiley 2005a, Poulakis et al. 2013). However, a recent study suggests juvenile smalltooth sawfish within this nursery have higher metabolic stress compared to sawfish from more pristine nurseries (Prohaska et al. 2018). The protection afforded by Everglades National Park, both in terms of the lack of commercial fishing and protection of nursery habitat (i.e., red mangroves and shallow, euryhaline waters) has probably been an important factor in ensuring the population was not extirpated from U.S. waters before other protections were implemented (Wiley and Simpfendorfer 2010).

Smalltooth sawfish have used additional nursery habitats throughout their historic range, and the recovery plan (NMFS 2009a) indicates that nursery areas outside of southwest Florida must be established for the species to recover. However, the spatial or temporal distribution of any nursery areas outside of southwest Florida cannot be determined because the habitat features of the areas historically used by juveniles are unknown. Additionally many of the areas known to have been used historically by juveniles have been drastically modified.

The following subsections review potential stressors that could affect coastal areas and habitats used (or previously used) by smalltooth sawfish.

Agriculture

Agricultural activities convert wetlands, and shed nutrient, pesticide, and sediment-laden runoff. These in turn lead to excessive eutrophication, hypoxia, increased sedimentation and turbidity, stimulation of hazardous algal blooms, and delivery of chemical pollutants (SAFMC 1998). Freshwater wetlands associated with southeastern rivers have been extensively converted to agriculture or degraded by flood control and diversion projects in support of agriculture. Likewise, coastal wetlands have been converted to agricultural fields and degraded by flow alterations linked to agriculture. Agriculture is the single largest contributor of nutrients in southeastern watersheds (SAFMC 1998). Animal wastes and fertilizers are the largest sources of non-point source nutrient loading (USGS 1997). Agricultural non-point discharges are responsible for the introduction of a wide range of toxic chemicals into habitats important to smalltooth sawfish (Scott 1997). Even areas not immediately adjacent to agricultural areas can be affected by these activities. For example, all of Florida Bay has undergone biological, chemical, and physical change due to large scale agricultural practices and hydrologic modifications in the Everglades (Fourqurean and Robblee 1999).

Urban development

The Pew Oceans Commission (2003) reports that over 20,000 acres of coastal habitat disappear each year. Threats from development include loss of wetlands, point and non-point sources of toxins, eutrophication, and hydrologic modification. The destruction of wetlands by filling for urban and suburban development is major concern (SAFMC 1998), especially as it relates to smalltooth sawfish. In addition, seawalls and canals for waterfront homes have replaced marsh and mangrove intertidal shorelines and shallow estuarine waters. In Florida, between 1943 and 1970, approximately 10,000 hectares (ha) of this habitat were lost due to dredge fill and other activities related to accommodating the increasing human population. While loss of mangrove ecosystems throughout Florida is not overwhelming, losses at specific locations have been substantial (Odum et al. 1982). Between 1998 and 2004, approximately 2,450 ac (3.8 mi^2) of intertidal wetlands consisting of mangroves or other estuarine shrubs were lost along the Atlantic and Gulf coasts of the United States (Stedman and Dahl 2008). Direct destruction of mangrove habitat is no longer allowed without a permit, but indirect damage to mangrove habitat from increased urbanization and the resulting overall habitat degradation still occurs. Given the documented losses that occurred during early developmental phases in Florida (1940-1970), we can assume losses have continued, and the amount of available mangrove habitat is likely less than documented by these older studies.

Of particular concern are sawfish habitats in places such as the Indian River Lagoon (Gilmore 1995) where the species was once abundant but now appears to have been extirpated (Snelson and Williams 1981). Many of the wetland habitats in the Indian River Lagoon were impounded for mosquito control (Brockmeyer et al. 1997), and the effects of these alterations on the smalltooth sawfish there are unknown.

The construction of fishing piers in urban areas has also affected smalltooth sawfish. Fishing piers can subsequently result in the incidental capture of smalltooth sawfish by recreational anglers. Since 2009, NMFS has completed 10 Biological Opinions on the development and management of fishing piers in Florida that have the potential to result in smalltooth sawfish capture. All but one of these projects authorized two or less non-lethal takes per year (NMFS unpublished data). The remaining project authorized 10 over any consecutive 5-year period (NMFS unpublished data). NMFS also completed numerous consultations for the development of fishing piers in other Gulf States but in each case concluded that incidental capture was extremely unlikely at these locations due to the very low abundance of sawfish outside of Florida.

Commercial activities

Commercial development affects sawfish habitat in many ways. Loss of wetlands, non-point and point sources of pollution and atmospheric deposition of industrial emissions are major impacts of commercial activities (SAFMC 1998). Evidence from other elasmobranchs suggests that pollution disrupts endocrine systems and potentially leads to reproductive failure (Gelsleichter et al. 2006). Sawfish may also alter seasonal migration patterns in response to warm water discharges from power stations (Simpfendorfer and Wiley 2005a). The total amount of marine and estuarine fish habitat eliminated and degraded by commercial activities in the southeast is unknown but considered substantial (SAFMC 1998). Between 1956 and 1978, about 875 square miles of marsh were lost along Louisiana’s coast, mostly through subsidence, rising sea level, and construction of oil and gas infrastructure, which cumulatively resulted in conversion of wetlands to open water. During those years, another 1,234 square miles of Louisiana coastal lands were converted to agricultural, urban, or industrial uses

(Boesch et al. 1994). The smalltooth sawfish's decline may be in part attributable to these habitat losses.

Channel dredging

Riverine, nearshore, and offshore areas are dredged for navigation, construction of infrastructure, and marine mining. The total environmental impact of dredging in the southeast is unknown, but undoubtedly great (SAFMC 1998). An analysis of 18 major southeastern estuaries (Orlando et al. 1994) recorded over 703 miles of navigation channels and 9,844 miles of shoreline modifications. Habitat effects of dredging include the loss of submerged habitats by disposal of excavated materials, turbidity and siltation effects, contaminant release, alteration of hydrodynamic regimes, and fragmentation of physical habitats (SAFMC 1998). Cumulatively, these effects have degraded habitat areas used by juvenile and adult smalltooth sawfish.

Modification of freshwater flows

Modifications of natural freshwater flows into estuarine and marine waters through construction of canals and other controlled devices have changed temperature, salinity, and nutrient regimes; reduced both wetlands and submerged aquatic vegetation; and degraded vast areas of coastal habitat (Gilmore 1995; Reddering 1988; Whitfield and Bruton 1989). Profound impacts to hydrological regimes have been produced in south Florida through the construction of a 1,400-mile network of canals, levees, locks, and other water control structures that modulate freshwater flow from Lake Okeechobee, the Everglades, and other coastal areas (Serafy et al. 1997). The Comprehensive Everglades Restoration Project (CERP) is a major reconstruction project jointly led by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD), which has the potential to restore habitats and hydrological regimes in South Florida. Of particular concern are Biscayne Bay (Serafy et al. 1997), Florida Bay, the Ten Thousand Islands (Fourqurean and Robblee 1999), and Charlotte Harbor, the areas most affected by discharge through the Everglades. Water management practices will have effects on smalltooth sawfish as the use of estuarine nursery areas, including those with salinities much lower than those used by shark species, may reduce the risk of predation and competition for food, hence increasing survival (Wiley and Simpfendorfer 2010).

Climate change

The Intergovernmental Panel on Climate Change (IPCC) has stated that global climate change is unequivocal and its impacts to coastal resources may be significant (IPCC 2007). An updated report by the IPCC (2013) is more explicit, stating that, "science now shows with 95% certainty that human activity (e.g., burning of fossil fuels) is the dominant cause of observed warming since the mid-twentieth century." Some of the anticipated outcomes are (1) sea level rise, (2) increased frequency of severe weather events, (3) changes in air and water temperature, and (4) ocean acidification. NOAA's climate change web portal provides information on the climate-related variability and changes that are exacerbated by human activities (http://www.climate.gov/#understandingClimate).

Sawfish are assumed to be at risk from climate change due to low intrinsic rates of population growth and slow rates of evolution (Field et al. 2009, Chin et al. 2010). The impacts of climate change on smalltooth sawfish cannot, for the most part, be predicted with any degree of certainty; yet we can project some effects to sawfish habitat. As stated previously, red mangroves and shallow (<3 ft), euryhaline waters have been identified as habitat features essential for the conservation of smalltooth sawfish. Climate change will impact both essential features, most notably through sea level rise which is expected to exceed 3.3 ft (1 m) globally by 2100 (Meehl et al. 2007; Pfeffer et al. 2008; Rahmstorf et al. 2009).

Sea level increases would affect the amount of shallow water available for juvenile smalltooth sawfish. A 2010 climate change study by the Massachusetts Institute of Technology (MIT) forecasted sea level rise in a study area with significant overlap with the range of smalltooth sawfish (Vargas-Moreno and Flaxman 2010). The study used sea level modeling data to forecast a range of sea level rise trajectories from low, to moderate, to high predictions (IPCC 2007, Figure 6). The effects of sea level rise on available shallow-water habitat for smalltooth sawfish would be exacerbated in areas where there is shoreline armoring (e.g., seawalls). This is especially true in canals where shallow areas (specifically <3 ft) along the edges of the canals will become deeper and cease to function as critical habitat as sea level rises (Figure 7).

A rise in sea level along the coasts of south Florida will also affect mangrove resources. As sea levels rise, mangroves will be forced landward in order to remain at a preferred water inundation level and sediment surface elevation necessary for successful growth (Field 1995). This retreat landward will not keep pace with conservative projected rates of elevation in sea level (Gilman et al. 2008). Forced landward progression poses the greatest threat to mangroves in areas where there is limited or no room for landward or lateral migration due to shoreline armoring and coastal development (Semeniuk 1994).

Climate change is anticipated to increase the severity of storms and hurricanes (Knutson and Tuleya 2004, Emanuel 2005). Tropical storms are expected to increase in intensity and/or frequency (Mann and Emanuel 2006), which may directly affect existing mangroves that are already adversely impacted by increased seawater temperatures, CO_2, and changes in precipitation (Cahoon et al. 2003; Trenberth 2005). The combination of all of these factors may lead to reduced mangrove height (Ning et al. 2003) and productivity (Field 1995). Further, intense storms could result in more severe storm surges and lead to potential changes in mangrove community composition, mortality, and recruitment (Gilman et al. 2006).

Changes in the amount and distribution of precipitation as a result of climate change may also affect sawfish habitat. A 25% increase in precipitation globally is predicted by 2050 (McLeod and Salm 2006), but the specific geographic distribution will vary, leading to increases and decreases in precipitation at the regional level. Changes in precipitation may affect the physiochemical environment (Chin et al. 2010), notably salinity, and the resources that rely on these environments. Generally, precipitation will influence salinity in nearshore estuarine areas which in turn affects the flora and fauna of the ecosystem. Juvenile smalltooth sawfish have an affinity for a specific salinity range (Poulakis et al. 2011) and thus increased or decreased salinity could result in a habitat shift. Similarly, changes in salinity could also affect available prey resources found within sawfish habitats. Reduced precipitation leads to increased salinity, which can inhibit mangrove productivity, growth, seedling survival, and spatial coverage (Burchett et al. 1984). It may also result in a shift in mangrove species composition, favoring more salt-tolerant types (Ellison 2010). Increases in precipitation may benefit some species of mangroves, increasing spatial coverage and allowing them to out-compete other salt marsh vegetation (Harty 2004). However, any potential expansion of mangrove habitats is heavily dependent on patterns and intensity of coastal development (e.g., bulkheads, seawalls).

Ocean acidification or the change in ocean chemistry driven by the oceanic uptake of atmospheric CO_2, is another result of climate change (IPCC 2013). While effects of ocean acidification are more clear for calcifying organisms that build skeletons, shells, and tests (Orr et al. 2005, Guinotte and Fabry 2008), it is less clear how this may affect elasmobranchs such as sawfish. Rosa et al. (2017) indicates that ocean acidification may adversely impact shark body condition, growth, aerobic potential and behavior. Given the smalltooth sawfish's close relationship to sharks, acidification of the water may similarly affect sawfish.

Lastly, increased air and water temperature associated with climate change will have effects on smalltooth sawfish habitat. Sawfish and the mangroves they rely on are restricted based on thermal tolerances so increased water temperature may allow for range expansion to more temperate regions. However, temperature increases may also adversely affect mangrove habitat. Many species of mangroves show an optimal shoot density in sediment temperatures between 59-77 degrees Fahrenheit (°F) (15-25 degrees Celsius [°C]) (Hutchings and Saenger 1987). Yet, at temperatures between 77-95°F (25-35°C), many species begin to show a decline in leaf structure and root and leaf formation rates (Saenger and Moverley 1985). Temperatures above 95°F lead to adverse effects on root structure and survivability of seedlings (UNESCO 1992) and temperatures above 100.4°F (38°C) lead to a cessation of photosynthesis and mangrove mortality (Andrews et al. 1984). Although impossible to forecast precisely, sea surface ocean temperatures are predicted to increase 1.8-3.6°F (1-2°C) by 2060 (Chapter 11 (IPCC 2013)), which will in turn impact underlying sediment temperatures along the coast. Ultimately some uncertainty remains in how red mangroves will respond to physiochemical changes to the environment as a result of climate change.

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

The primary reason for the decline in smalltooth sawfish abundance has been incidental capture in various commercial fisheries, including gillnets, otter trawls, trammel nets, and seines. Smalltooth sawfish have also been caught incidentally and landed in recreational fisheries.

Commercial fisheries

Historically, smalltooth sawfish were often taken incidentally in various fishing gears, including otter trawl, trammel net, seine, and, to a lesser degree, hand line. Reports of smalltooth sawfish becoming entangled in fishing nets are common in early literature from areas where smalltooth sawfish were once common, but are now rare. Henshall (1895) described smalltooth sawfish as being common along both coasts of Florida and noted that the smalltooth sawfish does considerable damage to turtle nets and other set nets by becoming entangled in the meshes, and is capable of inflicting severe wounds with its saw if interfered with. Henshall further reported that smalltooth sawfish were always killed by fishermen when captured because of this problem. Baughman (1943) discussed, documented, and reported accounts of smalltooth sawfish being taken in shrimp trawls along the Texas coast. Bigelow and Schroeder (1953), who described smalltooth sawfish as plentiful in Florida waters, noted they were of considerable concern to fishermen as nuisances because of the damage they do to drift- and turtle-nets, to seines, and to shrimp trawls in which they often become entangled and because of the difficulty of disentangling them without being injured by their rostra.

Evermann and Bean (1898) noted that smalltooth sawfish were an abundant, permanent resident in the Indian River Lagoon on the east coast of Florida and also noted that they did considerable damage to fishing gear by becoming entangled in nets. Larger smalltooth sawfish tore or cut the nets, while the smaller individuals became entangled and were difficult to remove. Large catches of smalltooth sawfish occurred sporadically; one fisherman interviewed by Evermann and Bean (1898) reported taking an estimated 300 smalltooth sawfish in just one netting season on the Indian River Lagoon. Smalltooth sawfish are now nearly extirpated from the Indian River Lagoon (Snelson and Williams 1981, Schmid et al. 1988) with only a few recent records (Simpfendorfer and Wiley 2005a). Snelson and Williams (1981) attributed the loss of smalltooth sawfish in the Indian River Lagoon to heavy mortality associated with incidental captures by commercial fishermen.

Large-scale directed fisheries for smalltooth sawfish have not existed; however, sawfish bycatch has been documented in commercial landings in various regions, with the greatest amount of data available from Louisiana (this does not imply that the greatest catches were made in Louisiana, rather this is a reflection of enhanced data gathering). The majority of the documented landings of smalltooth sawfish were from otter trawl fisheries (categorized as other, shrimp, or fish). There were also landings from trammel nets, beach haul seines, pelagic longlines, cast nets, trap float lines, and hand lines. Total Gulf of Mexico landings dropped continually from 1950 to 1978 from around 5 metric tons to less than 0.2 metric tons during this time period. NMFS does not have any records of landings since 1978. A list of fisheries that interact with smalltooth sawfish and the associated take estimates from each respective biological opinion can be found in Table 1.

Simpfendorfer (2002) extracted a data set from Fisheries Statistics of the United States, taken from 1945–1978 of smalltooth sawfish landings in Louisiana by shrimp trawlers. The data set contains both landings data and crude information on effort (number of vessels, vessel tonnage, number of gear units). Smalltooth sawfish landings in Louisiana reported over time declined from a high of 34,900 lbs in 1949 to less than 1,500 lbs in most years after 1967. Drastic reductions in the species' abundance in Louisiana waters are demonstrated by the lack of landings since 1978.

Anecdotal information collected by NMFS port agents indicates that smalltooth sawfish are now taken very rarely in the shrimp trawl fishery. The most recent records from Texas are from the 1980s. However, smalltooth sawfish are still caught in shrimp trawls in Florida; including nine documented captures from 2009 to 2015 (Figure 4, NMFS unpublished data).

Smalltooth sawfish are incidentally taken in two federal shark fisheries: the shark drift gillnet fishery (n=1 since 1994) and the shark bottom longline fishery (n=34 since 1994). Interactions are low, averaging 1-2 per year (J. Carlson, unpublished data). The long, toothed rostrum of the smalltooth sawfish causes this species to be particularly vulnerable to both gear types. The large gillnet mesh size used to catch sharks allows the rostrum to easily penetrate through nets, causing the sawfish to become entangled when it attempts to escape. The toothed rostrum makes it difficult to easily remove the fishing gear without either killing the sawfish or damaging the gear. Entangled specimens frequently have to be cut free, causing extensive damage to nets and presenting a substantial hazard if brought on board. When captured on longlines, the gangion frequently becomes wrapped around the rostrum (saw). This may be due to slashing during the fight, from spinning on the line, or any other action that brings the rostrum in contact with the line. Lactate and HCO_3 levels measured from the blood of sawfish, as an indication of physiological stress, were very low for sawfish captured on longlines and gill nets (Figure 5, Prohaska et al. 2018). The low stress response to these capture methods indicates the species is resilient and when considered in conjuction with information from ongoing tagging and telemetry studies post-release survival is expected to be high.

Recreational fisheries
Smalltooth sawfish have historically occurred as occasional bycatch in the hook-and-line recreational fishery (Caldwell 1990). Bigelow and Schroeder (1953) described sawfish as being too sluggish to be held in any regard as game fish by anglers and that once hooked they swim so powerfully, though slowly and are so enduring, that the capture of a large one entails a long and often wearisome struggle. Based on the observations of Caldwell (1990), however, Bigelow and Schroeder may have been too quick to disregard recreational fishing. In Texas, Caldwell (1990) stated that sport fishermen in the bays and surf prior to the 1960s took many sawfish incidentally. A few were retained and displayed as trophy fish, but most were released. Caldwell (1990) noted that the rostra of smalltooth sawfish were consistently removed prior to their live release and marks this as one of the reasons for their decline. Hoover (2008) provides a history of sawfish legend as well as recounting centuries of sawfish fishing tales.

A substantial amount of data has been collected from recreational fisheries (Seitz and Poulakis 2002, Poulakis and Seitz 2004, Simpfendorfer and Wiley 2005a, Wiley and Simpfendorfer 2010, Waters et al. 2014). These data indicate that smalltooth sawfish are still taken as bycatch, mostly by shark, red drum (*Sciaenops ocellatus*), snook (*Centropomus undecimalis*), and tarpon (*Megalops atlanticus*) fishers (Wiley and Simpfendorfer 2010). Wiley and Simpfendorfer (2010) reported that while sawfish sightings and captures occurred during a wide variety of activities, the majority (64.2%) of encounters occurred while people were fishing, and rod and reel was the most common method of capture. Though anglers were not targeting smalltooth sawfish, but instead capturing them incidentally, recreational fishing is currently a major activity that directly interacts with smalltooth sawfish throughout most of its range (Wiley and Simpfendorfer 2010). Expanding and continuing to educate anglers regarding the status of the smalltooth sawfish may help to minimize any negative effects of the recreational fishery on the sawfish population. Historically, recreational catches of sawfish were rare and poorly documented for the most part, except within Everglades National Park. Surveys in the Park indicate that a sustaining population still exists there, with consistent annual catches by private recreational anglers and guide boats (Carlson et al. 2007, Carlson and Osborne 2012). Through the cooperation of fishing guides and anglers, and intensive education and outreach efforts, reports of individual catches have grown markedly in recent years.

Commercial trade

Information regarding the direct commercial utilization of smalltooth sawfish has been limited. McDavitt (2006) reviewed the information related to the commercial trade in sawfish, including the smalltooth sawfish, and identified two forms of trade: whole live sawfish for the aquarium trade and sawfish parts derived mostly from sawfish captured as bycatch in fisheries. Issues related to the aquarium trade are covered in the next section. Below is a list of traded parts as identified by McDavitt (2006) and the citations therein:

> **Fins**. The fins of sawfish are used to produce shark fin soup. Because of their large size and high fin needle content sawfish fins are highly favored in Asian markets and are some of the most valuable shark fins. While slight decreases in demand for shark fin soup and trade have been reported in recent years, demand for sawfish fins can still be considered high with sufficient incentive to kill incidentally caught individuals where protection and enforcement are lacking.
>
> **Whole rostra**. Sawfish rostra are often traded as curios, ceremonial weapons, or for use in traditional medicines. Their trade as ceremonial weapons is focused in Asia where McDavitt (2006) reported that demand is currently outstripping supply, resulting in replica rostra becoming available. The prices of large rostra can reach several thousand dollars given their current rarity. In January 2006, eBay responded to conservationists’ requests and agreed to ban the sale of smalltooth sawfish parts and products on their online auction site in accordance with eBay’s wildlife policies. However, the sale of rostra has resumed on eBay, and sales persist on several other auction sites, including some in foreign

countries where sawfish rostra are regularly offered for sale. These sites will require careful monitoring to ensure no trade is occurring. The use of rostra in traditional medicine includes some use in China, Ethiopia, Mexico, and Brazil. There is no specific information on the trade of smalltooth sawfish rostra from the U.S. DPS.

Rostral teeth. Rostral teeth have been the preferred material for constructing artificial spurs for cock fighting in Peru. The teeth are used as spurs that are strapped to the cock's legs. The teeth are obtained from South American and Caribbean countries and are likely to include smalltooth sawfish teeth. Whether any were historically sourced from the U.S. DPS is unknown. McDavitt (2006) estimated that if all the teeth from a rostrum were used they would be valued from $2,000 to $7,000. Whether the use of rostral teeth in cockfighting extends beyond Peru, and how much demand there is for these products is unclear.

Meat. Sawfish are used for their meat; however, most of the consumption is local and so they appear to be only occasionally traded beyond local markets. Sawfish meat has been used historically in the U.S, though it is believed harvest has declined since listing. Romer (1936, as cited by McDavitt 2006) reported that sawfish were the second most common elasmobranch species taken in the shark fishery in the Florida Keys during the 1930s.

Organs. Chinese traditional medicine also uses other sawfish parts, including liver, ova, and gall bladder. Sawfish liver has also been used as a source of liver oil. The fishery in the Florida Keys described by Romer (1936, as cited by McDavitt 2006) used livers as a source of vitamin A. The use of livers as a source of vitamin A stopped during the late 1940s when cheap synthetic forms became available. There are no data available on the trade in these parts for any species of sawfish.

Skin. Sawfish skin has been used to produce leather, and is considered of very high quality. The leather is used to make belts, boots, purses, and even to cover books. Although historically shark leather (including sawfish) was produced in the United States, there is currently limited demand and little production. Tanneries in other countries, however, continue to produce shark leather, but the use of sawfish is unknown.

The historical trade of parts specific to the U.S. DPS of smalltooth sawfish is largely unknown; however, current commercial trade in parts from the U.S. DPS appears to be minimal. This threat can become increasingly significant as the population recovers and/or the demand for fins and rostra provides a motivation to kill sawfish. Through listings under Appendix I of the Convention on International Trades in Endangered Species (CITES) in 2007 and 2013, international commercial trade in all sawfish species has been essentially banned. This adds an additional layer of protection for all sawfish, including smalltooth.

Public display/aquarium trade
Sawfish have been exhibited in large public aquaria because their large size, bizarre shape, and shark-like features have made them popular additions to shark aquaria exhibits worldwide (Hoover 2008). Currently, there are 13 smalltooth sawfish housed in 4 public aquaria in the world: 4 in the U.S., 8 in the Bahamas, and 1 in Mexico (Choromanski 2016). Since the ESA listing, NMFS has not granted any permits to take live smalltooth sawfish for public display. There has been some trade between institutions that house sawfish, but no new specimens have been added. All sawfish species are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which limits international trade of sawfish.

Scientific research
Scientific study of smalltooth sawfish has yet to pose a significant threat to the U.S. DPS. Current scientific studies are limited to a small number of researchers who carry out non-lethal research in the wild. To date only one smalltooth sawfish had died during the course of scientific field studies. All research carried out on smalltooth sawfish requires a permit from NMFS due to the protections afforded under the ESA. Requests for sawfish research permits are carefully reviewed, and the effects of the research on the population are considered before issuance.

2.3.2.3 Disease or predation:
The final listing rule for the species did not determine that disease or predation was a causal listing factor. However, current data from acoustic monitoring, public encounter database data, and satellite archival tagging data suggests that small juveniles use red mangrove prop root habitat to avoid predators (see Habitat section), and therefore indicate that predation, via habitat loss, is likely a threat to the species. Photographs of bite marks on larger juveniles, taken by researchers C. Simpfendorfer and T. Wiley, suggest this size class of animals is also prey for lemon and bull sharks that co-occur in the same habitats. Crocodiles (Thorburn et al. 2004), large sharks (Compagno 1984, Thorburn et al. 2004), and marine mammals such as dolphins (Bigelow and Schroeder 1953) are known predators of juvenile sawfishes. Data are not available on predation of adult smalltooth sawfish.

There is little information on disease or parasites infecting sawfish. Poulakis et al. (2014) have noted a low intensity of infections and none of these infections appeared to be associated with significant disease or mortalities.

2.3.2.4 Inadequacy of existing regulatory mechanisms:
Prior to listing, existing federal and state laws, regulations, and policies were inadequate to protect smalltooth sawfish throughout their range. There were no federal regulations or state conservation plans specifically for the protection of sawfish. With the exception of Florida and Louisiana, smalltooth sawfish could be harvested in state waters. Smalltooth sawfish bycatch in gillnets has likely been reduced due to recent regulations prohibiting or limiting the use of gillnets in state waters, but bycatch in other gears, such as trawls, still pose a threat to this species. Under Section 7 of the

ESA, NMFS consults on federal fishing activities that may incidentally take smalltooth sawfish. Terms and Conditions resulting from these consultations require fishers to use dehookers to safely remove fishing hooks from the species and also require compliance with the Smalltooth Sawfish Safe Handling Guidelines to insure the safe release of sawfish caught in fishing gears. However, these measures are only applicable to federally-managed fisheries; therefore, large portions of the public are not well-informed about the species and how to release them unharmed after they are captured during recreational fishing. Post-release mortality for sawfish taken in various fisheries is still unknown but expected to be low.

Numerous international, federal, state, and inter-jurisdictional laws, regulations, and policies have the potential to affect the abundance and survival of smalltooth sawfish in U.S. waters. While many state measures may lead to overall environmental enhancements indirectly aiding smalltooth sawfish recovery, only a few state prohibitions have been applied specifically for the protection of smalltooth sawfish. Following the ESA listing, Alabama prohibited the catch of smalltooth sawfish in 2004 and Texas followed in 2006. It is also necessary to promote the conservation and recovery of smalltooth sawfish through proper, global implementation of the 2007 and 2013 CITES Appendix I listings for all sawfish and the enforcement of associated regulations. Smalltooth sawfish, along with the other sawfish species, were listed on Appendix I and II of the Convention on Conservation of Migratory Species (CMS) in 2014, and added to the scope of the non-binding CMS Memorandum of Understanding for Migratory Sharks (Sharks MOU) in 2016. Whereas CMS Appendix I listings obligate Parties to grant species strict national protection, compliance mechanisms are lacking. The U.S. is a signatory to the CMS Sharks MOU, but is not a Party to CMS. The IUCN Shark Specialist Group has produced a Global Conservation Strategy for Sawfishes (Harrison and Dulvy 2014) which reviews the species' population and legal status throughout the world, and lists countries considered priorities in terms of the need for sawfish protections.

Section 7(a)(1) of the Endangered Species Act (ESA) directs all federal agencies to work to conserve endangered and threatened species and to use their authorities to further the purposes of the Act. Section 7(a)(2) of the Act is the mechanism by which federal agencies ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any listed species. Based on the species' presence in the Gulf of Mexico and South Atlantic Exclusive Economic Zone, and its documented capture in otter trawls, NMFS determined smalltooth sawfish may be adversely affected by shrimp trawling, thus formal consultation was required. NMFS completed a Biological Opinion that considered the effects associated with the shrimp fishing industry in both the Gulf of Mexico and the South Atlantic most recently in 2014. While the Biological Opinion concluded that shrimp trawling may result in the mortality of smalltooth sawfish (Table 1), the continued authorization of the fishery was not likely to jeopardize the continued existence of the species (NMFS 2014). However, concerns remain as observer coverage in this fishery is low and interactions with this species are rarely reported.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Life history limitations

Smalltooth sawfish have a life history characterized by slow growth, late maturity, a long life span, and a small brood size (Scharer et al. 2012). Combined, these characteristics result in a very low intrinsic rate of population increase and are associated with the life history strategy known as k-selection. K-selected animals are usually successful at maintaining relatively small, persistent population sizes in relatively constant environments. However, they are not able to sustain additional and new sources of mortality resulting from changes in their environment, such as overexploitation and habitat degradation (Musick 1999). Smalltooth sawfish have been subjected to both overexploitation (primarily bycatch but some limited directed fishing) and habitat degradation. The survival and recovery potential of smalltooth sawfish is limited by these threats, their life history characteristics, and the current size of the population. Recovery to a level where the risk of extinction is low will likely take decades.

Marine pollution and debris

Because of their toothed rostra, smalltooth sawfish are susceptible to entanglement in a variety of marine debris. Examples include mooring lines, discarded fishing gear (e.g., monofilament line, braided line) and various cylindrical objects, such as polyvinyl chloride pipe and elastic bands (Seitz and Poulakis 2006). The impact of these types of interactions on the survival of the population is unknown, but has the potential to be significant given the importance of coastal habitats to the species.

Boating activities

Several environmental impacts have been associated with boating activities. These include pollutants associated with boat use and maintenance, pollutants carried by storm water runoff from marinas, boating support facilities, and physical alteration and destruction of estuarine and marine habitats by boat propellers and dredging for canals and navigation channels. Boat registrations have increased dramatically in Florida (e.g., Figure 8), and new boat designs allow ever faster boats to use ever shallower waters. Smalltooth sawfish have been observed with propeller injuries, likely caused when vessels drive over shallow areas when sawfish are present with their dorsal fins and upper caudal lobe out of the water or near the surface.

Stochastic events

Stochastic events, such as hurricanes, red tides, and extreme cold events are common throughout the range of the smalltooth sawfish, especially in the current core of its range (i.e., south and southwest Florida). These events are by nature unpredictable and their effect on the survival of the species is unknown; however, they have the potential to impede both survival and recovery directly if animals die as a result of them or indirectly if important habitats are damaged as a result of these disturbances.

Simpfendorfer et al. (2005) reported on the effects of Hurricane Charley on smalltooth sawfish habitat in Charlotte Harbor. It was unclear if the damage to the mangrove shoreline habitats in Charlotte Harbor had, or would have in the future, negative impacts on its ability to act as a sawfish nursery area. Survey and telemetry studies are assessing the habitat use patterns of juvenile sawfish in this region. The impact of the damage to the shoreline mangrove habitats on smalltooth sawfish is likely to depend on which components of the habitat are most important. For example, if it is the shallow depth of the habitats that sawfish prefer, then the mangrove damage may have limited impact unless the degradation of the old trees leads to erosion. Alternatively if the sawfish prefer the mangroves because of the high prey density that occurs because of the high primary productivity, then impacts would likely be greater until the mangroves recover. Simpfendorfer (2003) has also hypothesized that juvenile sawfish use the prop roots of red mangroves to help in predator avoidance. In this case, immediate impact may be limited as most of the prop root habitat appeared to remain after the storm, but with high mangrove mortality the decay over time may reduce its availability.

In January 2010 water temperatures throughout Florida decreased substantially following the passage of multiple cold fronts and 15 juvenile and one adult smalltooth sawfish were found dead. Water temperatures in the Peace River fell to 8°C, stayed below 12°C for 3 days, and below 15°C for 13 days and cold water temperatures certainly caused the death of these sawfish (Poulakis et al. 2011). These data, which show the thermal limitations of the species, help explain the historical importance of Florida to smalltooth sawfish in the U.S. and may have implications regarding where recovery can be expected.

2.4 Synthesis

Data collected in this review have advanced our overall understanding of smalltooth sawfish life history and habitat needs, as well as the threats that continue to affect the U.S. population. When considered cumulatively, the new information provides optimism for the recovery of smalltooth sawfish in the US. Studies have shown the species is growing faster (Simpfendorfer et al. 2008, Scharer et al. 2012) and maturing earlier (Carlson and Simpfendorfer 2015) than previously thought. These changes in the context of population modeling indicate the population is capable of recovering faster than once calculated—provided threats do not increase (Carlson and Simpfendorfer 2015). New information on diet and habitat use will provide resource managers a greater opportunity to conserve integral habitats while genetic studies (Chapman et al. 2011, Poulakis et al. 2014) have confirmed a single population in the U.S. that has plenty of genetic variability to promote recovery.

We considered and reported on a variety of different threats that have the potential to affect the US population of smalltooth sawfish. Mortality from fisheries and habitat loss likely represent the largest threats continuing to impact smalltooth sawfish recovery. Given sawfish show a degree of site fidelity punctuated by limited migratory movements, the need for conservation and management of existing coastal habitats throughout the species' range is accentuated (Carlson et al. 2013). However, conservation of coastal habitat in south Florida estuaries is especially important as these areas have been identified through field studies as current nursery habitat (Seitz and Poulakis 2002; Poulakis and Seitz 2004; NMFS 2009b; Wiley and Simpfendorfer 2010; Simpfendorfer et al. 2010; Simpfendorfer et al. 2011). The identification and long-term protection of important sawfish habitats is necessary, including those for adults and larger juveniles for which data are currently lacking, for the eventual recovery of this population.

Despite some encouraging signs, there has been no significant change in the range limits of smalltooth sawfish since the listing in 2003. The population continues to be found predominantly in southwest Florida, centered in the protected areas of Everglades National Park and the Ten Thousand Islands. While a smalltooth sawfish recovery team has identified and worked to reduce the impacts from a variety of threats affecting the species, threats persist and will continue to impact the U.S. population. The continuing threats combined with the small population size and the generally slow rate of population increase continue to threaten the existence of this species and will lengthen the period of time necessary to move beyond its endangered status. Continuation of long-term monitoring and relative abundance field studies is necessary to gather biological data on the species, to monitor abundance, and to ensure the goals of the recovery plan are being met. These actions will need to continue into the future to monitor the status of the smalltooth sawfish population in the United States.

The listing of smalltooth sawfish under CITES Appendix I in 2007 has afforded the species an additional layer of protection; however, laws protecting sawfish need to be enforced. Public outreach and education are essential to protecting the species from mortality associated with recreational and commercial fisheries. Sawfish handling and release guidelines have been developed by the Smalltooth Sawfish Recovery and Implementation Team though wide distribution of these materials will need to continue to promote the conservation and recovery of the species.

Under the critical habitat designation, red mangroves were identified as an essential feature of critical habitat that must be protected for the conservation of the species. Accordingly, the critical habitat designation aids in protecting red mangroves in recovery regions G and H. Federal agencies intending to permit, construct, or fund projects that have the potential to affect critical habitat are required to consult with NMFS under Section 7 of the ESA. This has afforded NMFS the opportunity to work with action agencies to reduce and minimize impacts to critical habitat as well as the chance to track habitat loss within each critical habitat unit. Habitat use observations help explain the historical importance of Florida to smalltooth sawfish in the U.S. and may have implications regarding where recovery can be expected.

This review has complied with the statutory requirement of section 4(c)(2) of the ESA. Based on this review, NMFS concludes that the U.S. DPS of smalltooth sawfish remains vulnerable to extinction and the species still meets the definition of endangered under the ESA, in that the species is in danger of extinction throughout its range. Though some studies suggest the population may be stable, the sawfish is still at risk due to its depressed population size, restricted range, and the effects of continuing threats.

In 2009, NMFS published a detailed recovery plan that identifies numerous criteria for delisting or downlisting the species to threatened. However, NMFS and the Smalltooth Sawfish Recovery Implementation Team have determined that while the criteria in the recovery plan are objective, not all are measurable and/or appropriate. More specifically, the criterion for Objective 3 related to a 5% rate of increase in the core juvenile population over a 27 year period is mathematically flawed as this would result in a recovered population that exceeds its known historical size. Another example includes the criteria for Objective 2—protect and/or restore sawfish habitats. While we absolutely want to protect important sawfish habitats, the criteria as written are not measurable so it is difficult to track recovery progress. Therefore, NMFS and the Smalltooth Sawfish Recovery Implementation Team are working to update the recovery plan with the latest available scientific, commercial, and public information to change the recovery criteria accordingly. Very little was known about smalltooth sawfish at the time of listing, but research data obtained since then has changed the thinking about the biological requirements for recovery and the characteristics of a recovered population. Scientific advances in the understanding of the species have made it clear that some recovery criteria are not realistic or achievable, thus the need to update the plan.

3.0 RESULTS

3.1 Recommended Classification: Given your responses to previous sections, particularly section 2.4. Synthesis, make a recommendation with regard to the listing classification of the species

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (Indicate reasons for delisting per 50 CFR 424.11):
____ *Extinction*
____ *Recovery*
____ *Original data for classification in error*
_✓__No change is needed

3.2 New Recovery Priority Number:

Given advances in our understanding of sawfish ecology and the threats facing the species we reassessed the recovery priority number during this review. This updated assessment using the 1990 guidelines (55 FR 24296) leads to a recovery priority number of 5[2]. The recovery priority number is based on the magnitude of threats being "moderate", recovery potential being "high", and the potential for "economic conflicts" while implementing the recovery actions.

[2] NMFS is currently working to finalize new recovery priority number guidelines. Under the new guidelines the U.S. DPS of smalltooth sawfish has a recovery priority number of 1.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Many of the “actions needed” identified in the recovery plan need to be completed or initiated. Priority actions in need of increased funding include: public outreach and education, regulation enforcement, and relative abundance monitoring. Research projects addressing these priority actions should be supported and funded in the future.

The Smalltooth Sawfish Recovery Implementation Team should continue to actively monitor the population status and associated threats to the population, while also prioritizing research and regulatory actions. NMFS and the Smalltooth Sawfish Recovery Implementation Team should finish updating the recovery plan with the latest available scientific, commercial, and public information and develop new recovery criteria which are objective, measurable, and appropriate. The team should then ensure progress toward meeting recovery criteria and advancing priority action items listed in the recovery plan.

The first 5-year ESA review for smalltooth sawfish (NMFS 2010) found there should be no change to the endangered classification or the recovery priority number. It reported that many of the “actions needed” identified in the recovery plan need to be completed or initiated. Since the first review, the Smalltooth Sawfish Recovery Implementation Team has worked to implement a variety of recovery actions that have resulted in increased conservation and a greater knowledge of the species. We believe this success along with a better understanding of current threats will increase our ability to recover this species in the future.

Future actions of priority should include: continued public outreach and education, implementation of a relative abundance monitoring program, and the funding of research projects to address priority concerns. The Smalltooth Sawfish Recovery Implementation Team should also continue to monitor the population status, the continuing threats to the population, and research priorities. The team should ensure that progress is being made at meeting the recovery criteria and advancing the priority action items listed in the recovery plan. Projects aimed at informing the public about complying with sawfish protections and efforts to effectively enforce those rules should be considered high priority.

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6.0 FIGURES

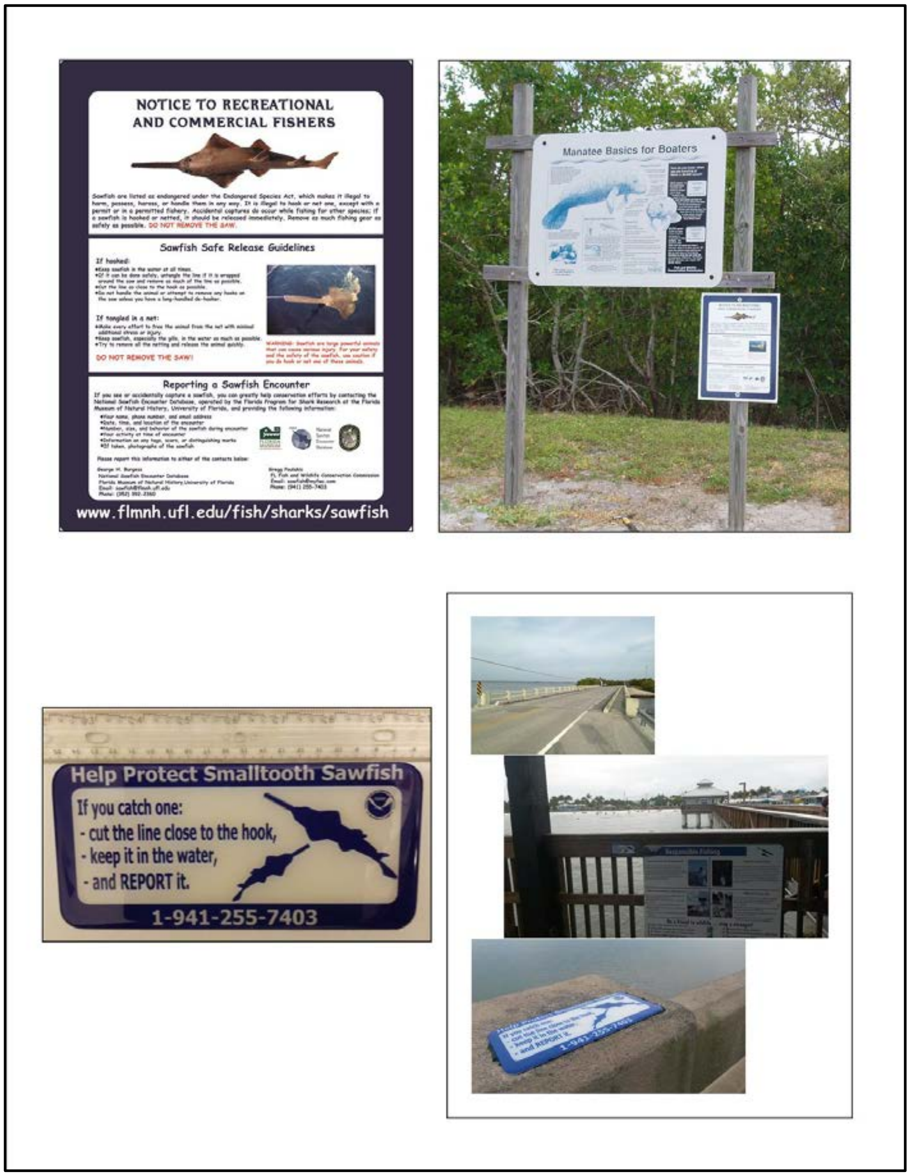
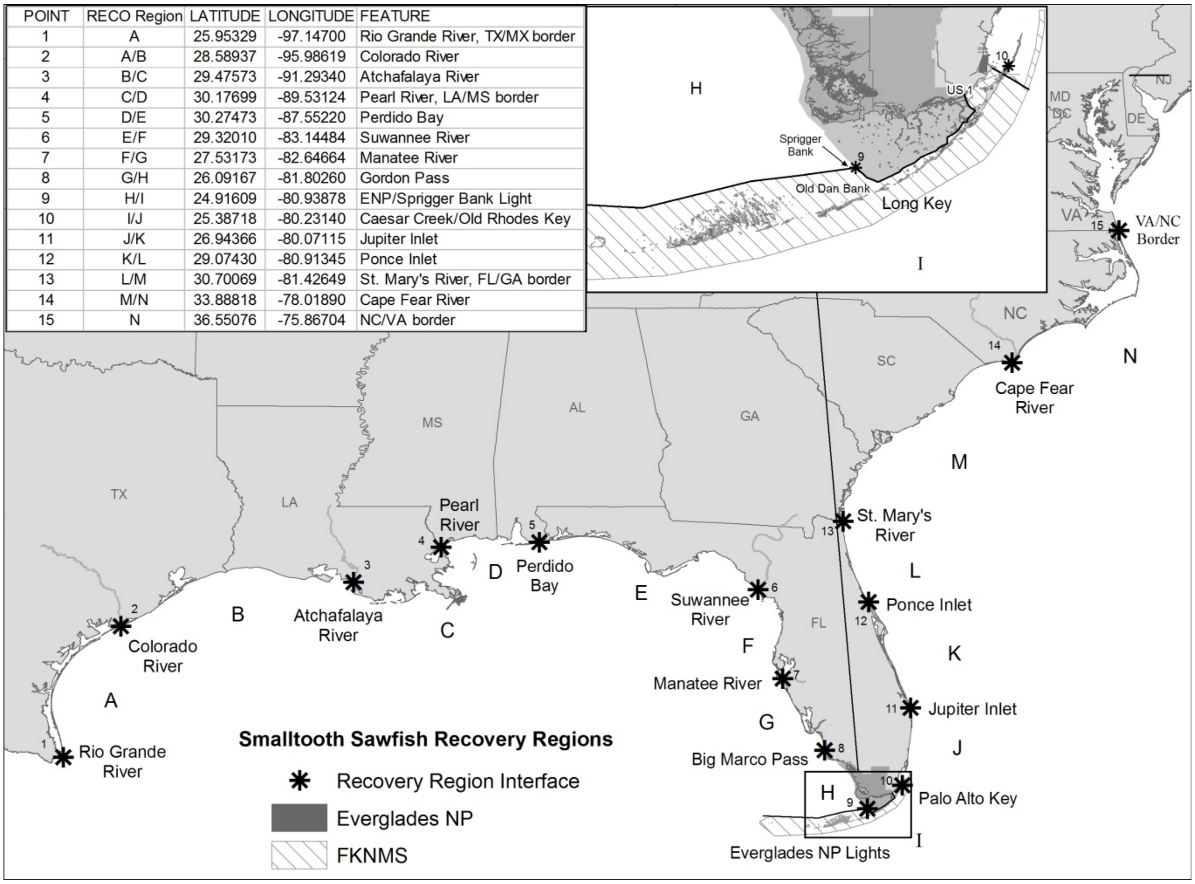


Figure 1. Metal boat ramp sign and plastic roadway placard bearing sawfish handling and release information and examples of their deployment at boat ramps, roadway fishing access points, and fishing piers.



POINT	RECO Region	LATITUDE	LONGITUDE	FEATURE
1	A	25.95329	-97.14700	Rio Grande River, TX/MX border
2	A/B	28.58937	-95.98619	Colorado River
3	B/C	29.47573	-91.29340	Atchafalaya River
4	C/D	30.17699	-89.53124	Pearl River, LA/MS border
5	D/E	30.27473	-87.55220	Perdido Bay
6	E/F	29.32010	-83.14484	Suwannee River
7	F/G	27.53173	-82.64664	Manatee River
8	G/H	26.09167	-81.80260	Gordon Pass
9	H/I	24.91609	-80.93878	ENP/Sprigger Bank Light
10	I/J	25.38718	-80.23140	Caesar Creek/Old Rhodes Key
11	J/K	26.94366	-80.07115	Jupiter Inlet
12	K/L	29.07430	-80.91345	Ponce Inlet
13	L/M	30.70069	-81.42649	St. Mary's River, FL/GA border
14	M/N	33.88818	-78.01890	Cape Fear River
15	N	36.55076	-75.86704	NC/VA border

Figure 2. Recovery regions for smalltooth sawfish along the Gulf of Mexico and U.S. Atlantic coast (from NMFS 2009a).

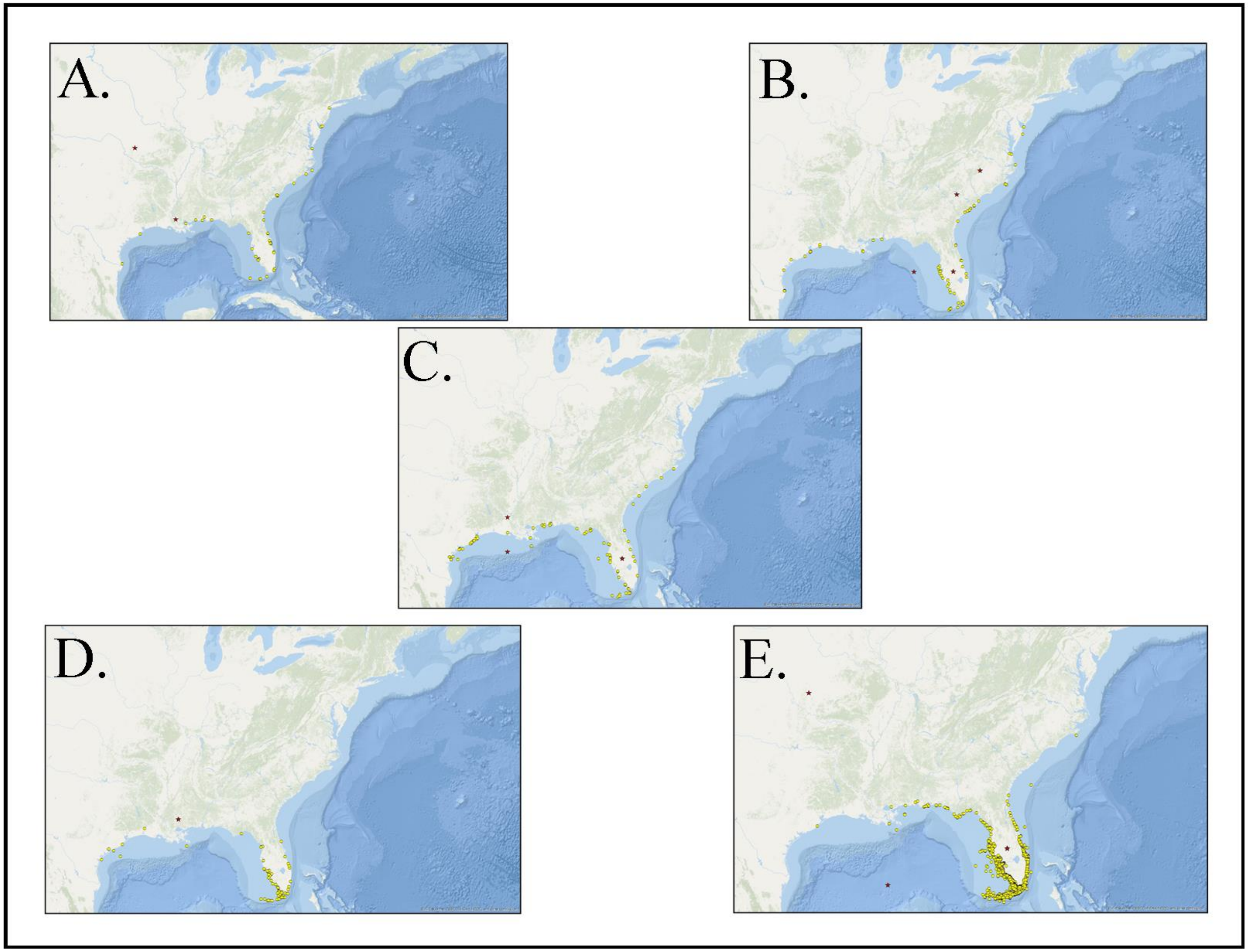


Figure 3. Distribution decline of smalltooth sawfish encounters in the United States (G. Burgess, unpublished data). Panel A: 1782-1899-two generically placed red stars represent three encounters recorded only as “United States” (two encounters) and as “Ohio-

Mississippi River basin" (one encounter) during this time period, N=47 encounters. Panel B: 1900-1949-Four generically placed red stars represent six encounters recorded only as "North Carolina" (two encounters), "South Carolina" (two encounters), "Florida" (one encounter), and "150 miles W of Pas-A-Grille, FL" (one encounter) during this time period, N=85 encounters. Panel C: 1950-1969-Three generically placed red stars represent three encounters recorded only as "Louisiana," "Gulf of Mexico off Louisiana," and "Florida" during this time period, N=104 encounters. Panel D: 1970-1989-Lone generically placed red star represents single encounter recorded only as "Mississippi or Alabama" during this time period, N=81 encounters. Panel E: 1990-2015-Three generically placed red stars represent 14 encounters recorded only as "United States" (two encounters), "Gulf of Mexico" (one encounter), and "Florida" (11 encounters) during this time period. Higher number of generic records in this time period attributable to advent of social media data mining, N= 6,563 encounters. Note: Maps do not include any *Pristis* sp. records from west of the Mississippi delta, an area that historically hosted both *P. pectinata* and *P. pristis*. All Atlantic seaboard and a limited number of eastern Gulf of Mexico *Pristis* sp. records are mapped as *P. pectinata* as *P. pristis* is known from these regions only from a couple of doubtful records.

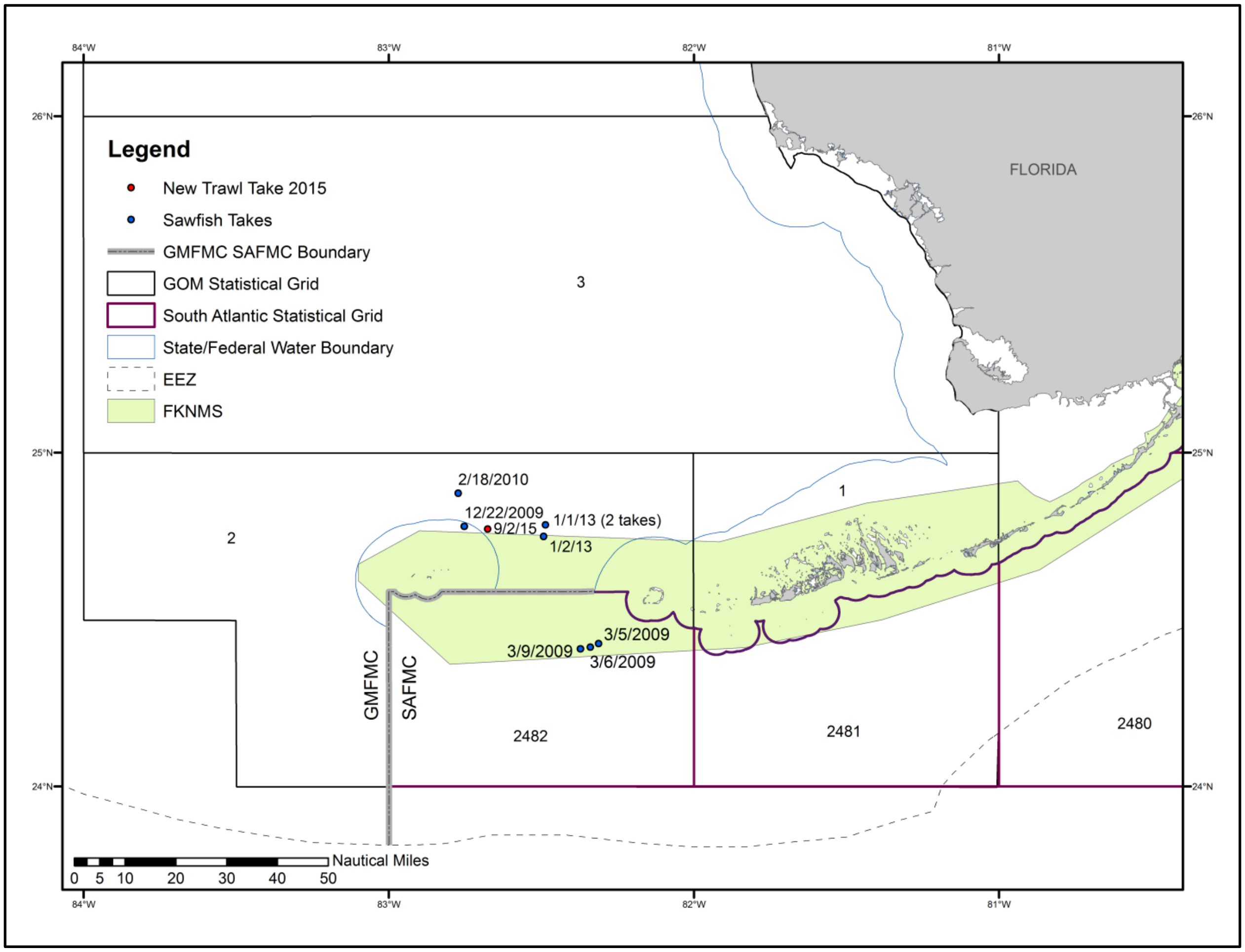


Figure 4. Location of nine shrimp trawl interactions with smalltooth sawfish in Florida from 2009 to 2015. GMFMC – Gulf of Mexico Fishery Management Council; SAFMC – South Atlantic Fishery Management Council; GOM – Gulf of Mexico; EEZ – Exclusive Economic Zone; FKNMS – Florida Keys National Marine Sanctuary

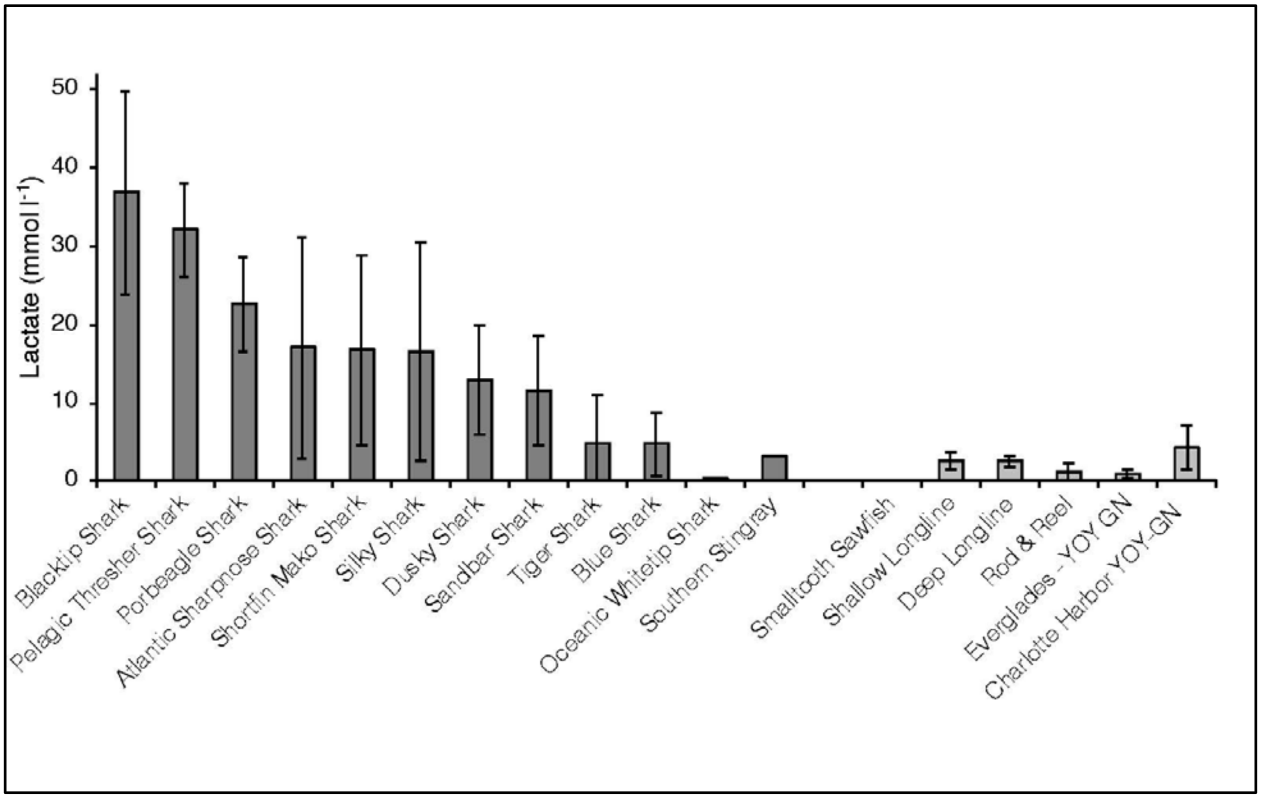


Figure 5. Post-capture lactate levels of longline captured sharks (dark gray bars) and smalltooth sawfish captured by various means (light gray bars) (Prohaska et al. 2018).

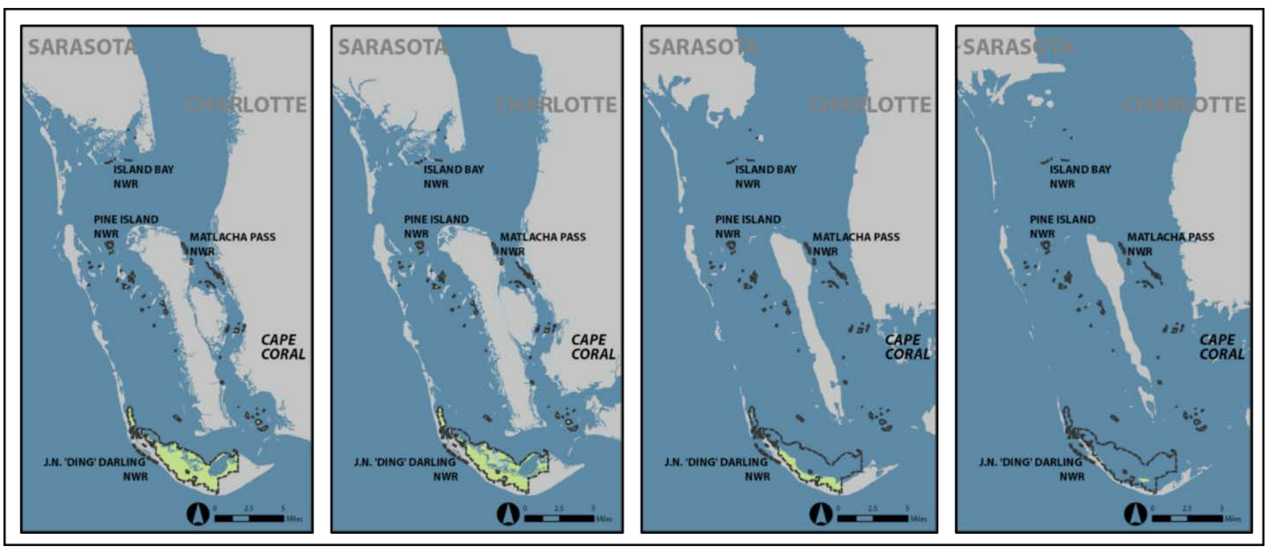


Figure 6. From left to right: current shoreline, + 3.5 in (+ 9 cm); + 18.5 in (+ 47 cm); and + 38.97 in (+ 99 cm) sea level rise by 2060.[3]

[3] Adapted from Vargas-Moreno, J.C., and M. Flaxman. 2010. Addressing the challenges of climate change in the greater Everglades landscape. Massachusetts Institute of Technology, Cambridge, Massachusetts.

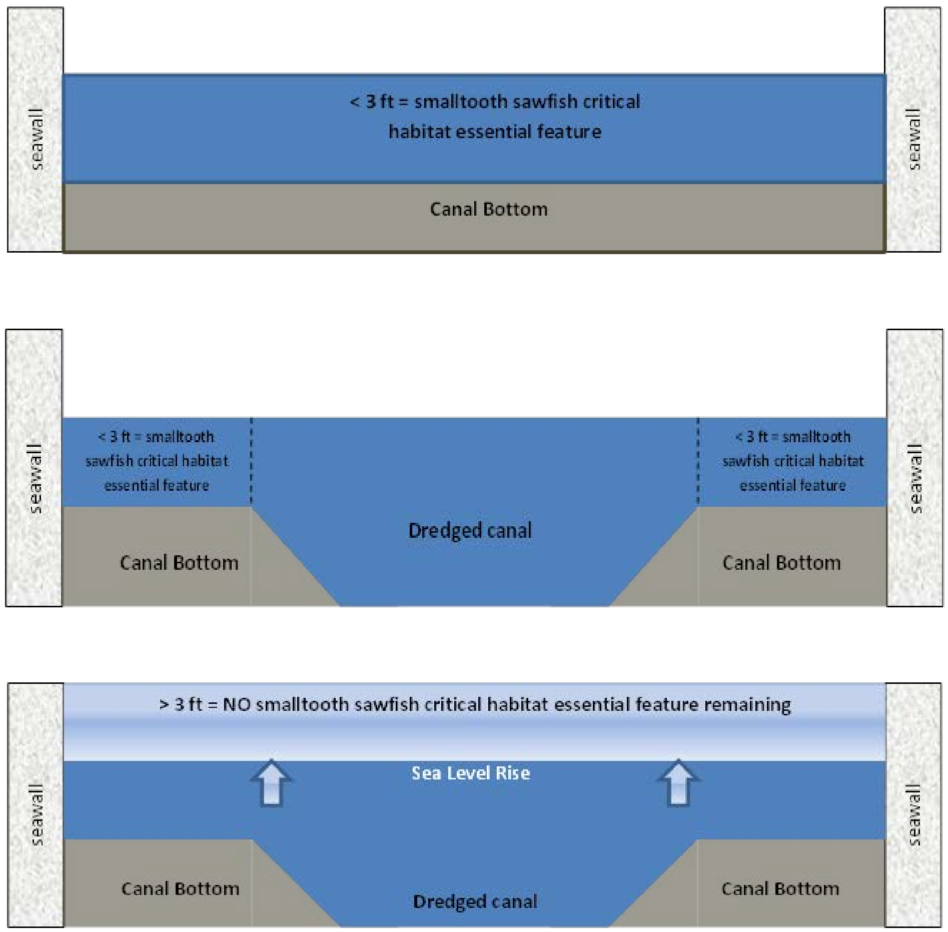


Figure 7. Diagram A depicts a cross section of a historically dredged channel/canal within the boundaries of the critical habitat units that has not been maintained. Diagram B depicts the typical cross section of a maintenance-dredged channel/canal. Diagram C depicts a cross section of a maintained dredged channel/canal after sea level rise of > 1 ft.

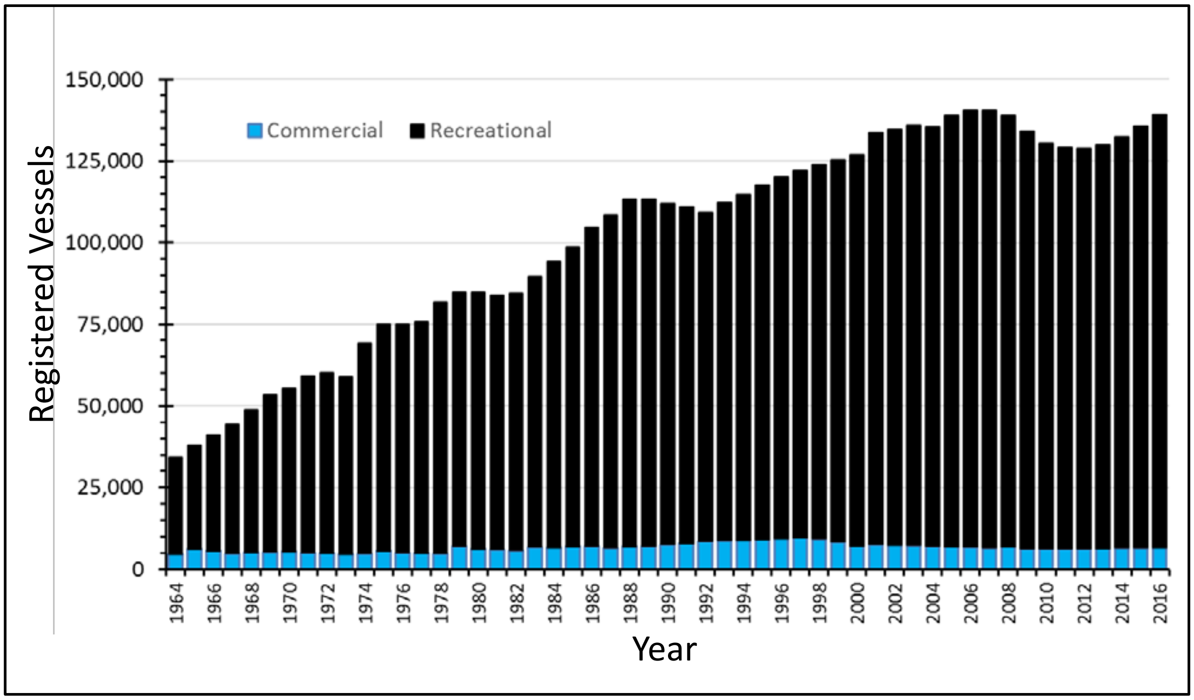


Figure 8. Registered recreational and commercial vessels in Miami-Dade, Broward, and Monroe counties from 1964-2016. (Source: Ault et al. 2017 summary of Florida Department of Highway Safety & Motor Vehicles statistics).

7.0 TABLES

Table 1. Fisheries that interact with smalltooth sawfish and the associated take estimates from each respective biological opinion. Biological opinions can be found at http://sero.nmfs.noaa.gov/protected_resources/section_7/freq_biop/index.html

Fishery	3-Year Incidental Take of Smalltooth Sawfish
Atlantic HMS-Shark Fisheries	32– No more than 7 lethal takes
Coastal Migratory Pelagics	2 Nonlethal takes
Gulf of Mexico/South Atlantic spiny lobster fishery	2 Nonlethal takes
Gulf of Mexico Reef Fish	8 Nonlethal takes
South Atlantic Snapper-Grouper	8 Nonlethal takes
Southeastern U.S. Shrimp	288– No more than 105 lethal takes

8.0 APPENDIX 1 – Smalltooth Sawfish Recovery Implementation Team

CURRENT MEMBERSHIP AS OF APRIL 2018:

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Smalltooth Sawfish *(Pristis pectinata)*

Current Classification: Endangered

JUL 10 2018

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_✓_ No change is needed

Review Conducted By:
Tonya Wiley, Haven Worth Consulting (now Havenworth Coastal Conservation)

Adam Brame, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office, 263 13th Avenue South, Saint Petersburg, Florida 33701; 727-209-5958; adam.brame@noaa.gov

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

Approve: [signature] Date: July 10, 2018

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

_✓_ Concur ____ Do Not Concur

Signature [signature] Date 9/7/18