Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus)* *2010-2018*

Bibliography

Trevor Riley, Head of Public Services, NOAA Central Library

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Background & Scope

Atlantic sturgeon live in rivers and coastal waters from Canada to Florida. Hatched in the freshwater of rivers, Atlantic sturgeon head out to sea as juveniles, and return to their birthplace to spawn, or lay eggs, when they reach adulthood. The Atlantic sturgeon has five rows of bony plates known as scutes that run along its body and a snout with four slender, soft tissue projections, called barbels, in front of its mouth. In addition, the tail is like a shark's where one side, or lobe, is larger than the other. All of these features give the fish its unique look. Atlantic sturgeon are slow-growing and late-maturing, and have been recorded to reach up to 14 feet in length and up to 60 years of age. Atlantic sturgeon were once found in great abundance, but their populations have declined greatly due to overfishing and habitat loss. Atlantic sturgeon were prized for their eggs, which were valued as high-quality caviar. During the late 1800s, people flocked to the Eastern United States in search of caviar riches from the sturgeon fishery, known as the "Black Gold Rush." By the beginning of the 1900s, sturgeon populations had declined drastically. Close to 7 million pounds of sturgeon were reportedly caught in 1887, but by 1905 the catch declined to only 20,000 pounds, and by 1989 only 400 pounds of sturgeon were recorded. Today, all five U.S. Atlantic sturgeon distinct population segments are listed as endangered or threatened under the Endangered Species Act. The populations in Canada are not protected. The primary threats currently facing Atlantic sturgeon are entanglement in fishing gear, habitat degradation, habitat impediments such as dams and other barriers and vessel strikes.

This bibliography was developed in support of the 2019 5-year review and focuses on any relevant literature related to Atlantic Sturgeon since 2010. It is intended as a reference resource for ESA staff of NOAA's Atlantic Sturgeon Recovery Program in their work to compile and summarizing any relevant new information. The focus of the literature is on the five distinct population segments (DPS) listed as either endangered or threatened under the ESA in 2012. These DPS include Carolina DPS, Chesapeake Bay DPS, New York Bight DPS, South Atlantic DPS (endangered) and Gulf of Maine DPS (threatened). It is organized into seven sections: Assessment Methodology, Genetic Assessment, Habitat Use and Distribution, Life History Characteristics, Risk Assessment, Stock Status, and Policy, Legal, and Recommendations

Section I – Assessment Methodology

This section contains relevant literature on the evaluation of methodology related to capture, surgical procedures, tagging, surveying, modeling, and threat index analysis. Literature in this category contains relevant data in relation to the scope of other sections including stock status, distribution, etc. However, the focus of the literature is on the assessment of specific methodologies.

Section II – Genetic Assessment

This section contains relevant literature on genetic analysis of relevant Atlantic Sturgeon DPS. The literature contains topics including the evaluation of genetic structure, genetic diversity, mixed-stock analysis, genetic characterization, inbreeding, and future projections. Literature in this category contains relevant data in relation to the scope of other sections, however the focus of the literature is on genetic evaluation.

Section III – Habitat Use and Distribution

This section contains relevant literature on movement, seasonal distribution, behavioral patterns, and habitat use by Atlantic Sturgeon. The geographic scope of the literature search was focused on the United States where Atlantic Sturgeon are present, however literature related to Canadian waters was included when relevant to DPS, which may travel between territories.

Section IV – Life History Characteristics
This section contains relevant literature on age, growth rates, and survival of Atlantic Sturgeon. Literature in this section contains relevant information on stock status and distribution.

Section V – Risk Assessment
This section contains relevant literature on potential risks to Atlantic Sturgeon including trawling, vessel strikes, chemical contaminants, parasitic infections, etc.

Section VI – Stock Status
This section contains relevant literature on the status, composition, abundance, spawning, and population origin of Atlantic Sturgeon. The geographic scope of the literature search was focused on the United States where Atlantic Sturgeon are present, however literature related to Canadian waters was included when relevant to DPS, which may travel between territories.

Section VII – Policy, Legal, and Recommendations
This section contains relevant literature pertaining to the Atlantic Sturgeon's classification under the ESA. It includes Final Rules, state and federal governance reports, management plans, status reviews, and recommendations.

Sources Reviewed
The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; Lexis Advance; ProQuest's Science and Technology; JSTOR; EBSCO's Academic Search Complete, EconLit, and Environment Complete; NOAA's Institutional Repository; ASFA; and BioOne. Only English language materials were included.

Section I: Assessment Methodology

Balazik, M., McIninch, S., Garman, G., Fine, M., & Smith, C. (2012). Using energy dispersive x-ray fluorescence microchemistry to infer migratory life history of Atlantic sturgeon. *Environmental Biology of Fishes, 95*(2), 191-194 https://doi.org/10.1007/s10641-012-9979-3.

Atlantic sturgeon migrate between ocean and freshwater habitats to spawn, and juveniles spend several years in fresh/brackish water before returning to the ocean. Because strontium/calcium (Sr/Ca) ratios are diagnostic for freshwater and marine environments, we examined the utility of energy-dispersive x-ray fluorescence (EDXRF) to quantify Sr/Ca ratios of Atlantic sturgeon pectoral fin spines. Atlantic sturgeon spines from wild adults and experimental juveniles were analyzed along a linear transect from the primordium to the outermost point. To verify the technique hatchery juvenile Atlantic sturgeon were held in experimental tanks at <0.5, 13-15, or 33-35‰ and sampled after 5 months. Sr/Ca ratios of experimental hatchery fish increased with salinity, and Sr/Ca ratios in wild adults varied predictably along the measurement transect. However, the ratio decreased in the outermost region of the spine in mature fish collected during a return to freshwater for spawning. Therefore EDXRF is a useful tool to track individual movements of Atlantic sturgeons and other diadromous fish. [ABSTRACT FROM AUTHOR]

Balazik, M. T. (2015). Capture and Brief Invasive Procedures Using Electronarcosis Does Not Appear to Affect Postrelease Habits in Male Atlantic Sturgeon During the Spawning Season. *North American Journal of Fisheries Management, 35*(2), 398-402 https://doi.org/10.1080/02755947.2015.1011358.

With advances in technology and demand for life history information, researchers are increasingly conducting invasive procedures on fish that require an anesthetic. This study examined the effectiveness of electronarcosis as a field anesthetic on Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus during the spawning season in the James River, Virginia. Concerns about sampling Atlantic Sturgeon during spawning runs prompted our examining whether movements after capture, narcosis, and tagging were noticeably modified. An electronarcosis system, which consisted of a power supply, fiberglass tank, and hardware cloth, were set up both on land and on a sampling boat. During the spawning season Atlantic Sturgeon were caught and implanted with Vemco V16 telemetry tags using electronarcosis as an anesthetic. Anesthesia induction, surgery, and recovery averaged 5 min. Telemetry data from the tagging year was compared with returning fish tagged in previous years. This showed movements during the spawning season and spawning exit dates were similar between the two groups, suggesting that electronarcosis was effective and time-efficient for conducting invasive procedures. Capturing and implanting transmitters in Atlantic Sturgeon during spawning runs does not appear to modify spawning movements. Managers may benefit from targeting adult Atlantic Sturgeon and other iteroparous anadromous fishes in rivers during spawning periods, which is typically very efficient due to high densities of fish during that period.

Breece, M. W., Fox, D. A., Haulsee, D. E., Wirgin, II, & Oliver, M. J. (2018). Satellite driven distribution models of endangered Atlantic sturgeon occurrence in the mid-Atlantic Bight. *Ices Journal of Marine Science, 75*(2), 562-571 https://doi.org/10.1093/icesjms/fsx187.

Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) is an endangered species that migrate through, and occupy the coastal waters of the mid-Atlantic Bight where they interact with anthropogenic activities. Measures to understand and avoid Atlantic sturgeon that take into consideration the dynamic nature of their habitat may reduce harmful interactions. In this study, we matched fisheries independent biotelemetry observations of Atlantic sturgeon with daily satellite observations to construct a time resolved spatial distribution model of Atlantic sturgeon. We determined that depth, day-of-year, sea surface temperature, and light absorption by seawater were the most important predictors of Atlantic sturgeon occurrence. Demographic factors, such as sex and river-of-origin were of secondary importance. We found strong spatial differences in spring and fall migration patterns, when anthropogenic interactions peak. Our cross-validated models correctly identified > 88% of biotelemetry observations in our study region. Our models also correctly identified similar to 64% of bycatch observations throughout the year. However, during their migrations, when harmful interactions were highest, our models correctly identified similar to 90% of fisheries dependent observations. We suggest that this model can be used for guidance to managers and stakeholders to reduce interactions with this highly imperiled species, thereby enhancing conservation and recovery efforts.

Crossman, J. A., Hammell, K. L., & Litvak, M. K. (2013). Experimental Examination of Surgical Procedures for Implanting Sonic Transmitters in Juvenile Shortnose Sturgeon and Atlantic Sturgeon. *North American Journal of Fisheries Management, 33*(3), 549-556 https://doi.org/10.1080/02755947.2013.785994.

Acoustic telemetry has become a leading tool for monitoring the movements of and habitat use by many sturgeon species worldwide; however, procedures for internal tagging of small juvenile sturgeon (<55cm TL) are lacking. We examined effects of implantation technique on growth, tag retention, and survival of juvenile (<55cm) Shortnose Sturgeon Acipenser brevirostrum and Atlantic Sturgeon A. oxyrinchus by using dummy acoustic tags. Two implantation techniques were used: (1) anchoring the tag to the wall of the peritoneal cavity and (2) no internal anchoring of the tag. These treatment groups were compared with two control groups: fish that received anesthetic only and fish that received anesthetic and an incision. Retention rate was significantly higher for anchored tags (88%) than for nonanchored tags (25%) in Shortnose Sturgeon juveniles, while Atlantic Sturgeon juveniles retained 100% of tags regardless of treatment. Nonanchored tags that were lost during the second week were expelled through the incision site, whereas later tag expulsions (during weeks 7 and 8) occurred through the anus. There was no significant difference in absolute growth and specific growth rates between the treatment groups throughout the 8-week study for either species. Growth of both species was significantly lower in the first week after surgery but increased and remained constant for the remainder of the experiment. Use of nonanchored tags significantly increased incision healing times for both species; however, Atlantic Sturgeon healed significantly faster (35 d) than Shortnose Sturgeon (42 d). No mortality occurred in any of the treatment groups. Results of this study suggest that juvenile Shortnose Sturgeon and Atlantic Sturgeon can undergo internal tag implantation resulting in long retention times with largely unaffected growth and no mortality. Received May 21, 2012; accepted March 6, 2013

Erickson, D. L., Kahnle, A., Millard, M. J., Mora, E. A., Bryja, M., Higgs, A., . . . Pikitch, E. K. (2011). Use of pop-up satellite archival tags to identify oceanic-migratory patterns for adult Atlantic Sturgeon,

Acipenser oxyrinchus oxyrinchus Mitchell, 1815. *Journal of Applied Ichthyology, 27*(2), 356-365 https://doi.org/10.1111/j.1439-0426.2011.01690.x.

Oceanic-migratory behavior of adult Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus, was examined using pop-up satellite archival tags (PSAT). Twenty-three Atlantic Sturgeons were caught and tagged with PSATs in the Hudson River, New York during 2006 and 2007. Fifteen of those fish returned to the ocean (with PSATs attached) 6-132 days after tagging. These PSATs remained attached to fish for a period of 108-360 days archiving light, temperature, and depth, before releasing from fish, ascending to the surface, and transmitting data to satellites. The location of PSATs was measured to within +/- 150 m by satellites using Doppler shift of radio transmissions within hours after tags reached the surface. Positions prior to pop up were initially estimated using only archived-light data and the tag manufacturers' proprietary software. Positional error associated with light-based estimates is high, especially with regard to latitude. This error was reduced by applying depth, distance, and temperature filters. Thirteen of the 15 Atlantic Sturgeons that left the Hudson River with PSATs attached remained within the Mid-Atlantic Bight for up to 1 year after tagging. Their geographic distributions generally extended from Long Island, New York to Chesapeake Bay at depths between 5 and 40 m. Aggregation areas were identified off southwest Long Island, along the New Jersey coast, off Delaware Bay, and off Chesapeake Bay. Depth distribution was seasonal; fish inhabited deepest waters during winter and shallowest waters during summer and early fall. Two Atlantic Sturgeons traveled outside of the Mid-Atlantic Bight. One migrated north to Cobequid Bay (terminal end of the Bay of Fundy, Nova Scotia), whereas the other traveled south to the coast of Georgia.

Flowers, H. J., & Hightower, J. E. (2013). A Novel Approach to Surveying Sturgeon Using Side-Scan Sonar and Occupancy Modeling. *Marine and Coastal Fisheries, 5*(1), 211-223 https://doi.org/10.1080/19425120.2013.816396.

Technological advances represent opportunities to enhance and supplement traditional fisheries sampling approaches. One example with growing importance for fisheries research is hydroacoustic technologies such as side-scan sonar. Advantages of side-scan sonar over traditional techniques include the ability to sample large areas efficiently and the potential to survey fish without physical handlingimportant for species of conservation concern, such as endangered sturgeons. Our objectives were to design an efficient survey methodology for sampling Atlantic Sturgeon Acipenser oxyrinchus by using side-scan sonar and to develop methods for analyzing these data. In North Carolina and South Carolina, we surveyed six rivers thought to contain varying abundances of sturgeon by using a combination of side-scan sonar, telemetry, and video cameras (i.e., to sample jumping sturgeon). Lower reaches of each river near the saltwater-freshwater interface were surveyed on three occasions (generally successive days), and we used occupancy modeling to analyze these data. We were able to detect sturgeon in five of six rivers by using these methods. Side-scan sonar was effective in detecting sturgeon, with estimated gear-specific detection probabilities ranging from 0.2 to 0.5 and river-specific occupancy estimates (per 2-km river segment) ranging from 0.0 to 0.8. Future extensions of this occupancy modeling framework will involve the use of side-scan sonar data to assess sturgeon habitat and abundance in different river systems.

Flowers, H. J., & Hightower, J. E. (2015). Estimating Sturgeon Abundance in the Carolinas Using Side-Scan Sonar. *Marine and Coastal Fisheries, 7*(1), 1-9 https://doi.org/10.1080/19425120.2014.982334.

Sturgeons (Acipenseridae) are one of the most threatened taxa worldwide, including species in North Carolina and South Carolina. Populations of Atlantic Sturgeon Acipenser oxyrinchus in the Carolinas have been significantly reduced from historical levels by a combination of intense fishing and habitat loss. There is a need for estimates of current abundance, to describe status, and for estimates of historical abundance in order to provide realistic recovery goals. In this study we used N-mixture and distance models with data acquired from side-scan sonar surveys to estimate abundance of sturgeon in six major sturgeon rivers in North Carolina and South Carolina. Estimated abundances of sturgeon greater than 1 m TL in the Carolina distinct population segment (DPS) were 2,031 using the count model and 1,912 via the distance model. The Pee Dee River had the highest overall abundance of any river at 1,944 (count model) or 1,823 (distance model). These estimates do not account for sturgeon less than 1 m TL or occurring in riverine reaches not surveyed or in marine waters. Comparing the two models, the N-mixture model produced similar estimates using less data than the distance model with only a slight reduction of estimated precision.

Kapusta, A., Duda, A., Wiszniewski, G., & Kolman, R. (2015). Preliminary evaluation of the effectiveness of visible implant elastomer and coded wire tags for tagging young-of-the-year Atlantic sturgeon, Acipenser oxyrinchus. *Archives of Polish Fisheries / Archiwum Rybactwa Polskiego, 23*(4), 227-230 https://doi.org/10.1515/aopf-2015-0026.

The aim of the study was to determine the retention rates of visible implant elastomer (VIE) and coded wire tags (CWT) and the impact tagging had on the growth of Atlantic sturgeon, Acipenser oxyrinchus Mitchill, during an eight-week rearing period under laboratory conditions. Two size groups of young-of-the-year (YOY) sturgeon were used in the study. The tagging was not found to have a significant impact on the final total length or body weight or the condition coefficient of the sturgeon from either size group. Sturgeon survival in the different groups ranged from 90.6 to 100%. Mortality was not noted until two (CWT) and four (VIE) weeks following tagging and was probably not linked to tagging. The retention rate for VIE tags implanted in the rostrum in both size groups was 100%, while for tags implanted at the base of the pectoral fin was 93.5%. The retention of CWT in the smaller fish was 90%, and in the larger sturgeon it was 100%. Tagging small sturgeon with CWT and VIE is minimally invasive, and it did not impact the growth or condition of the tagged fish. [ABSTRACT FROM AUTHOR]

Matsche, M. A. (2011). Evaluation of tricaine methanesulfonate (MS-222) as a surgical anesthetic for Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus. *Journal of Applied Ichthyology, 27*(2), 600-610 https://doi.org/10.1111/j.1439-0426.2011.01714.x.

Dose-response experiments were conducted at 14 and 24°C to evaluate the efficacy and physiological effects of tricaine methanesulfonate (MS-222) to induce and maintain surgical anesthesia in juvenile Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). Anesthetic induction time, duration of hyperactivity, recovery time and total handling time of fish were inversely related to MS-222 concentration and water temperature. Minimum effective concentration of MS-222 to maintain anesthesia with fewest signs of stress was 85 mg L. Sensitivity to stimuli and body movements progressively increased when fish were exposed to a lower maintenance concentration (70 mg L) of MS-222, resulting in reduced biopsy success rates and traumatic injury to internal organs during laparoscopy as fish regained consciousness. Anesthesia with MS-222 resulted in bradychardia, near medullary collapse, elevated signs of stress (plasma cortisol and reddening of the skin) and a generalized hemo-concentration consisting of erythrocyte swelling and increased protein and monovalent ion concentrations. Magnitude of hematologic changes and stress indicators increased with decreasing MS-222 concentration and increased water temperature while plasma chemistry changes increased in magnitude with decreasing MS-222 concentration. This study demonstrates that rapid induction of surgical anesthesia with a relatively high concentration of MS-222 results in reduced signs of physiological stress, and that empirical evaluation of maintenance dosage is important to achieve the best balance between safety, efficacy and stressful side effects for invasive surgical procedures.

Matsche, M. A. (2013). Relative physiological effects of laparoscopic surgery and anesthesia with tricaine methanesulfonate (MS-222) in Atlantic sturgeon Acipenser oxyrinchus oxyrinchus. *Journal of Applied Ichthyology, 29*(3), 510-519 https://doi.org/10.1111/jai.12158.

Laparoscopy is a reliable, minimally-invasive technique to obtain reproductive information from wild and captive sturgeon. While generally considered safe, the physiological consequences of laparoscopy in sturgeon are unknown. Therefore clinical pathology changes in juvenile, Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) following experimental laparoscopy at 10 and 22 degrees C were described. Control fish were anesthetized with MS-222 according to the same protocols as surgical fish, but were not incised. Surgical procedures did not affect heart and ventilation rates, signs of stress (skin redness) or time to recover from anesthesia in comparison to control fish. Anesthesia with MS-222 produced a transient (by 1h) hemo-concentration (elevated protein and electrolytes), erythrocyte swelling (increased PCV and MCV) and stress response (elevated cortisol and glucose); and a delayed (by 24h) increase in RBC, leukopenia and increased N:L ratio. Surgical procedures resulted in a delayed (by 24h) decrease in plasma proteins, electrolytes, RBC and PCV relative to control fish, which may have resulted from surgically-induced hemorrhage. Plasma enzyme activities increased in response to anesthesia and surgery and may indicate general stress and tissue damage. Anesthesia had a greater effect on blood value response than surgery, and the proportion of effect increased with temperature as MS-222 potency and toxicity increases with water temperature. Repeated handling and blood draws within 24h resulted in a 7% increase in cortisol, 1014% increase in CK and 911% increase in LDH values. Except for plasma enzyme activities, blood values of all fish recovered within 1week following anesthesia and surgeries. Relative experience of surgeons had no effect on hematology and biochemistry of fish, but healing rates of incisions were improved with better suture technique. Results of this study conclude that the physiological effects of laparoscopy are largely related to the anesthetic, MS-222, and are generally mild and short-lived. Improvements in laparoscopic technique might be gained by exploring alternate anesthetic protocols with faster induction and recovery times and reduced physiological effects.

Matsche, M. A., Bakal, R. S., & Rosemary, K. M. (2011). Use of laparoscopy to determine sex and reproductive status of shortnose sturgeon (Acipenser brevirostrum) and Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). *Journal of Applied Ichthyology, 27*(2), 627-636 https://doi.org/10.1111/j.1439-0426.2011.01679.x.

Sex and reproductive maturity of Atlantic and shortnose sturgeon were determined by visual examination of the gonads using laparoscopy, and were validated by histological examination of gonadal biopsies. Surgical anesthesia was induced in all fish with 250 mg L tricaine methanesulfonate (MS-222) and maintained throughout procedures with 85 mg L MS-222 on a mobile surgical cart. A pair of Ternamian EndoTip cannulae installed through the ventral body wall in each fish, allowed access for a 5-mm rigid laparoscope and biopsy forceps. Video endocamera use with the laparoscope, following air insufflation of the coelom, provided detailed, high quality imagery to aspirate the swim bladder, examine the gonad and collect biopsies without inducing iatrogenic trauma. Germinal tissue of all immature males, 25% of immature female shortnose sturgeon and 45% of immature female Atlantic sturgeon were concealed by fat preventing sex determination by visual assessment. Morphological features of gonads were used to determine sex in all remaining fish and were 100% in concordance with histological findings. Relative amount of gonadal fat; gonad size and color; presence of testicular lobes or ovarian lamellae; and color, size and density of oocytes were useful in determining reproductive stage. Gonad morphology of each reproductive stage was similar in Atlantic and shortnose sturgeon. All captive Atlantic sturgeon survived laparoscopy, gained weight at the same rate as unexamined fish and scars from incisions were no longer evident 9-12 months after surgery. Laparoscopic procedures presented here offer a safe and highly reliable way to determine sex and reproductive status for Atlantic and shortnose sturgeon.

Oliver, M. J., Breece, M. W., Fox, D. A., Haulsee, D. E., Kohut, J. T., Manderson, J., & Savoy, T. (2013). Shrinking the Haystack: Using an AUV in an Integrated Ocean Observatory to Map Atlantic Sturgeon in the Coastal Ocean. *Fisheries, 38*(5), 210-216 https://doi.org/10.1080/03632415.2013.782861.

Physical processes in the coastal Mid-Atlantic create a complex and dynamic seascape. Understanding how coastal fishes respond to this complexity has been a major motivation in establishing coastal biotelemetry arrays. Most coastal arrays maximize the probability offish detection by positioning hydrophones near geophysical bottlenecks. The development of a real-time ocean observatory allows for synchronous mapping of dynamic hydrographic structures important to coastal fishes. These observations provide important context for interpreting the impact of oceanographic features on the behavior of telemetered animals. In a proofofconcept mission, we deployed a Slocum glider in a real-time ocean observatory to demonstrate how mobile listening assets could be dynamically reallocated in response to the mesoscale physics of the coastal ocean. The Slocum glider detected four Atlantic Sturgeon Acipencer oxyrinchus oxyrinchus that were in a shallow, well-mixed, and relatively warm and fresh water mass in a region of historic Atlantic Sturgeon bycatch.

Panagiotopoulou, H., Popovic, D., Zalewska, K., Weglenski, P., & Stankovic, A. (2014). Microsatellite multiplex assay for the analysis of Atlantic sturgeon populations. *Journal of Applied Genetics, 55*(4), 505-510 https://doi.org/10.1007/s13353-014-0216-y.

We have developed a multiplex assay covering 16 microsatellite loci, amplified in four polymerase chain reaction (PCR) assays, and loaded on the ABI DNA Analyzer in two separate panels. The assay was tested on 603 individuals originating from wild populations and hatchery stocks of Atlantic sturgeon. The assay was also tested on 12 individuals of European sturgeon and appeared to be almost equally useful. The multiplex assay designed in this study can be successfully applied in studies requiring high genetic resolution, such as relatedness analysis, selective breeding programs, and stock identification of Atlantic sturgeon.

Stokesbury, K. D. E., Stokesbury, M. J. W., Balazik, M. T., & Dadswell, M. J. (2014). Use of the SAFE Index to Evaluate the Status of a Summer Aggregation of Atlantic Sturgeon in Minas Basin, Canada, and the Implication of the Index for the USA Endangered Species Designation of Atlantic and Shortnose Sturgeons. *Reviews in Fisheries Science & Aquaculture, 22*(3), 193-206 https://doi.org/10.1080/23308249.2014.913005.

Sturgeon species worldwide have undergone population declines due to habitat alteration and overexploitation and many are listed by the International Union for Conservation of Nature (IUCN) and national agencies. Atlantic and shortnose sturgeon on the east coast of North America are listed as "endangered" or "threatened" over most of their ranges. It has been proposed, however, that IUCN risk categories are ambiguous and do not consider the threat status of a species in relation to a minimum viable population level. Here, we examine the Species Ability to Forestall Extinction (SAFE) Index, which is a heuristic measure of a species relative distance from extinction, and other available information on Atlantic and shortnose sturgeon with regard to the risk status of the two species. To move beyond a 'tipping point' designation of threatened, the SAFE Index requires a species abundance of 5000 adults (SAFE Index D 0.0). DNA and mark-recapture data for Atlantic sturgeon in Minas Basin, Canada indicates a USA/Canada mixed stock of similar to 10,000 fish aggregate there in summer. The SAFE Index for this population is 0.28 indicating abundance is within the "vulnerable" threshold range for the Index although it includes but a small portion of the Atlantic sturgeon in the western Atlantic. Estimates for the east coast of North America suggest the Atlantic sturgeon population could consist of similar to 177,000 sub adults and adults for a SAFE Index of 1.55. Additionally, the present spawning range of Atlantic sturgeon in North America is similar to 99% of the historically known range and the number of stocks is near the historic level (33+) which means the species does not meet IUCN criteria for listing. Similarly, shortnose sturgeon has an Atlantic coast population of similar to 96,800 adults (SAFE Index of 1.29) and a species range and number of stocks (26+) that has not changed substantially from the historical situation. Since the abundance of Atlantic and shortnose sturgeon are well above the SAFE threshold for "threatened" and they lack other accepted criteria for endangered or threatened designation, we conclude that the risk status of both species should be reconsidered.

Section II: Genetic Assessment

Balazik, M. T., Farrae, D. J., Darden, T. L., & Garman, G. C. (2017). Genetic differentiation of spring-spawning and fall-spawning male Atlantic sturgeon in the James River, Virginia. *PLoS One, 12*(7) https://doi.org/10.1371/journal.pone.0179661.

Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus, Acipenseridae) populations are currently at severely depleted levels due to historic overfishing, habitat loss, and pollution. The importance of biologically correct stock structure for effective conservation and management efforts is well known. Recent improvements in our understanding of Atlantic sturgeon migrations, movement, and the occurrence of putative dual spawning groups leads to questions regarding the true stock structure of this endangered species. In the James River, VA specifically, captures of spawning Atlantic sturgeon and accompanying telemetry data suggest there are two discrete spawning groups of Atlantic sturgeon. The two putative spawning groups were genetically evaluated using a powerful microsatellite marker suite to determine if they are genetically distinct. Specifically, this study evaluates the genetic structure, characterizes the genetic diversity, estimates effective population size, and measures inbreeding of Atlantic sturgeon in the James River. The results indicate that fall and spring spawning James River Atlantic sturgeon groups are genetically distinct (overall F-ST = 0.048, F'(ST) = 0.181) with little admixture between the groups. The observed levels of genetic diversity and effective population sizes along with the lack of detected inbreeding all indicated that the James River has two genetically healthy populations of Atlantic sturgeon. The study also demonstrates that samples from adult Atlantic sturgeon, with proper sample selection criteria, can be informative when creating reference population databases. The presence of two genetically-distinct spawning groups of Atlantic sturgeon within the James River raises concerns about the current genetic assignment used by managers. Other nearby rivers may also have dual spawning groups that either are not accounted for or are pooled in reference databases. Our results represent the second documentation of genetically distinct dual spawning groups of Atlantic sturgeon in river systems along the U.S. Atlantic coast, suggesting that current reference population database should be updated to incorporate both new samples and our increased understanding of Atlantic sturgeon life history.

Dunton, K. J., Chapman, D., Jordaan, A., Feldheim, K., O'Leary, S. J., McKown, K. A., & Frisk, M. G. (2012). Genetic mixed-stock analysis of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus in a heavily exploited marine habitat indicates the need for routine genetic monitoring. *Journal of Fish Biology, 80*(1), 207-217 https://doi.org/10.1111/j.1095-8649.2011.03151.x.

Although a previous genetic mixed-stock analysis (gMSA) conducted in the early 1990s showed that marine-captured New York Bight Atlantic sturgeon Acipenser oxyrinchus oxyrinchus almost exclusively originated from the Hudson River, fish from southern U.S. rivers were well represented within this contemporary sample (n = 364 fish), at least during the autumn. Widely distributed spawning stocks are therefore exposed to heavy fishing activity and habitat degradation in this relatively small area, illustrating the need for spatial management across multiple management jurisdictions and routine gMSA to account for temporal change.

Farrae, D. J., Post, W. C., & Darden, T. L. (2017). Genetic characterization of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus, in the Edisto River, South Carolina and identification of genetically discrete fall and spring spawning. *Conservation Genetics, 18*(4), 813-823 https://doi.org/10.1007/s10592-017-0929-7.

Once widely abundant, most subpopulations of the endangered Atlantic sturgeon are now estimated to be only 1-10% of their historical levels. The Edisto River has been sampled for a long period and extensively for juvenile Atlantic sturgeon from separate spring- and fall-spawned cohorts. Our objectives are to characterize the genetic diversity, stability, adaptive potential, and potential genetic structure of Atlantic sturgeon in the Edisto River and to identify any past bottlenecks experienced by this species, as well as to conduct forward simulation modeling of the population under multiple population trajectories. Our results indicate that fall- and spring-spawned Atlantic sturgeon in the Edisto River are genetically distinct (overall = 0.092) with little gene flow or admixture between groups, both of which are diverse from a neutral genetic marker standpoint. Genetic diversity of both groups is on the higher end of published population diversity values. A lack of inbreeding and recent bottlenecks also bode well for these two groups of sturgeon, although future projections indicate a loss of allelic richness and genetic diversity even with population stability. Our effective population size estimates are moderate compared to published estimates for other Atlantic sturgeon populations. The most significant finding of our research is the genetic distinctness of the fall- and spring-spawned Atlantic sturgeon in the Edisto River, which may have several important ramifications for management of the species, including re-evaluating the demarcation of distinct population segments.

Moyer, G. R., Sweka, J. A., & Peterson, D. L. (2012). Past and Present Processes Influencing Genetic Diversity and Effective Population Size in a Natural Population of Atlantic Sturgeon. *Transactions of the American Fisheries Society, 141*(1), 56-67 https://doi.org/10.1080/00028487.2011.651073.

Threats such as habitat loss, invasive species, and overexploitation cause species extinctions; however, stochastic processes can accelerate extinction rates as census sizes decline. Using molecular and ecological data, we explored the influence of these processes on the demography of a candidate species under the U.S. Endangered Species Act—the Atlantic sturgeon Acipenser oxyrinchus oxyrinchus. We used molecular microsatellite markers to estimate the effective population size (Ne) and effective number of breeders (Nb) and we used mark–recapture data to estimate the number of spawners (Na) for Atlantic sturgeon of the Altamaha River, Georgia. We found that estimates of Nb were 7–45% less than the estimated Na over four consecutive cohorts and that skewed sex ratios could explain the relative decrease of Nb to Na . Our estimate of contemporary Ne was 125 (95% confidence interval = 75–348) and was at least an order of magnitude less than our estimate of historical Ne . To explain the large discrepancy between these estimates, we tested several alternative evolutionary scenarios that might explain the observed pattern of genetic diversity. Our results indicated that the observed genetic data were indeed best explained (i.e., 0.998 posterior probability of the data given the hypothesis) by overexploitation during the last half of the 20th century. Received October 4, 2010; accepted June 28, 2011 [ABSTRACT FROM PUBLISHER]

Nikulina, E. A., Schmölcke, U., & Austin, J. (2016). Reconstruction of the historical distribution of sturgeons (Acipenseridae) in the eastern North Atlantic based on ancient DNA and bone morphology of archaeological remains: implications for conservation and restoration programmes. *Diversity & Distributions, 22*(10), 1036-1044 https://doi.org/10.1111/ddi.12461.

Aim In the 19th/early 20th century, overfishing caused a drastic decline and finally extinction of the local sturgeon populations in the eastern Atlantic. To date, it is not known whether it was Acipenser sturio or the primarily North American Acipenser oxyrinchus that occurred here. The aim of the study was to show the historical pattern of sturgeon distribution and their diversity in this area over the last 2500 years. This question is essential for international restoration programmes. Location North-east Atlantic. Methods The study is based on 438 archaeological sturgeon remains from the estuaries of the rivers Rhine, Ems, Weser, Elbe and Eider. All bones were analysed morphologically and in 38 cases genetically by the amplification of two mitochondrial DNA fragments. Results The data from the bones older than 1000 years show that only 1.4% derive from A. sturio. In the south, this species was slightly more frequent. From the Elbe northwards, A. oxyrinchus was for a long time by far the dominant sturgeon species. Main conclusions The genetic identification of the oldest sturgeon bone shows A. oxyrinchus occurred in the north-eastern Atlantic already 6000 years ago. Consequently, the immigration of this species from North America to Europe occurred even earlier, potentially during the last glacial. The north-south occurrence of the two sturgeon species suggests that the distribution was the result of interspecific competition under different and changing environmental conditions. As previously published, genetic data from about 100- to 200-year-old museum specimens show strong dominance of A. sturio in the North

Sea area, obviously A. oxyrinchus has been replaced in the time between 1000 and 200 years ago. Therefore, the Holocene distribution of sturgeons in the north-east Atlantic had a complex pattern. Determining the ecological bases of this distribution is important for the justification and success of restoration programmes. [ABSTRACT FROM AUTHOR]

O'Leary, S. J., Dunton, K. J., King, T. L., Frisk, M. G., & Chapman, D. D. (2014). Genetic diversity and effective size of Atlantic sturgeon, Acipenser oxyrhinchus oxyrhinchus river spawning populations estimated from the microsatellite genotypes of marine-captured juveniles. *Conservation Genetics, 15*(5), 1173-1181 https://doi.org/10.1007/s10592-014-0609-9.

Juvenile Atlantic sturgeon (Acipenser oxyrhinchus oxyrhinchus) forming aggregations at coastal sites in the mid-Atlantic Bight were subjected to a mixed stock analysis (MSA) and individual-based assignment using twelve microsatellite loci. We confirmed earlier findings from an analysis of mitochondrial DNA that three river spawning populations (Hudson, James and Delaware Rivers) are the primary sources of these particular marine aggregations. Of the 460 individuals sampled 322, 36 and 47 were assigned to the Hudson, James and Delaware Rivers, respectively. MSA estimated that the New York Bight Distinct Population Segment (Hudson River and Delaware River) contributed 83-90 % of individuals to the marine aggregations and the Chesapeake (James River) and Southeast Distinct Population Segments contributed 5.5-11 %. Mean M-ratios were lower than expected at equilibrium in all three rivers (Delaware = 0.726, Hudson = 0.748, James = 0.664), indicative of genetic bottlenecks affecting all three spawning populations. Further, there were low but detectable levels of inbreeding in all three rivers populations. Effective population size (Ne) was estimated for three populations: Hudson River (172-230 individuals), James River (40-100 individuals) and Delaware River (75-186 individuals). Despite these issues, simulations based on life-history information and the Ne estimates suggest that if ongoing management measures are effective, contemporary levels of population genetic diversity are likely to be retained over the next century.

Wirgin, I., Maceda, L., Waldman, J. R., Wehrell, S., Dadswell, M., & King, T. (2012). Stock Origin of Migratory Atlantic Sturgeon in Minas Basin, Inner Bay of Fundy, Canada, Determined by Microsatellite and Mitochondrial DNA Analyses. *Transactions of the American Fisheries Society, 141*(5), 1389-1398 https://doi.org/10.1080/00028487.2012.700899.

Five distinct population segments of Atlantic sturgeon Acipenser oxyrinchus were recently listed (April 2012) as endangered or threatened under the U. S. Endangered Species Act. Atlantic sturgeon are anadromous, spawning occurs in rivers from the St. Lawrence River, Quebec, to the Satilla River, Georgia, and subadults and adults undertake extensive coastal migrations. Bycatch of Atlantic sturgeon in coastal fisheries may have resulted in the slowed or failed rebuilding of many populations despite the imposition of a U. S. federal moratorium on their harvest in 1998. Canada's Bay of Fundy hosts weir and trawl fisheries which bycatch Atlantic sturgeon of unknown origin. Additionally, tidal power development projects for the Bay of Fundy have been proposed which could detrimentally impact migratory sturgeon. We hypothesized that the Atlantic sturgeon that occur in Minas Basin in the Bay of Fundy are of local Saint John River, New Brunswick, origin with little or no U. S. contribution. We used microsatellite DNA (11 loci) and mitochondrial DNA control region sequence analysis along with previously determined characterizations of nine reference spawning populations to quantify their stock origin. We determined that the summer assemblage of Atlantic sturgeon collected within Minas Basin was of mixed origin, with a greater than 60%

contribution from the nearby Saint John River but with a substantial (34-36%) contribution from the Kennebec River, Maine, and a smaller (1-2%) contribution from the Hudson River, New York. There was significant genetic heterogeneity between smaller (<130 cm) and larger individuals (>= 130 cm) in Minas Basin; however, the smaller specimens were not exclusively of proximal Saint John River origin. Our results indicate that Atlantic sturgeon of U. S. origin are vulnerable to anthropogenic impacts in the Bay of Fundy, particularly those of Kennebec River origin.

Section III: Habitat Use and Distribution

Altenritter, M. N., Zydlewski, G. B., Kinnison, M. T., & Wippelhauser, G. S. (2017). Atlantic Sturgeon Use of the Penobscot River and Marine Movements within and beyond the Gulf of Maine. *Marine and Coastal Fisheries, 9*(1), 216-230 https://doi.org/10.1080/19425120.2017.1282898.

Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus were recently listed as threatened in the Gulf of Maine and endangered in the rest of their U.S. range. Continued research priorities include long-term population monitoring, identifying the species' spawning and nursery grounds, and determining its use of estuaries and marine coastal waters. Although recent and ongoing research is filling in knowledge gaps, the Atlantic Sturgeon's life history and its severely depleted populations make this a challenging species to fully characterize. Our goal was to compile data collected over 7 years from fish captured in the Penobscot River estuary, Maine, to inform management decision making. Atlantic Sturgeon were captured (n = 199), recaptured (n = 16), and passively telemetered (n = 32 that were analyzed here) from 2006 to 2013. Captured individuals were predominantly subadults, and data from telemetry indicated repeated use of a 5-km reach of the mesohaline portion of the estuary. Subadults predictably emigrated from the river each fall (mean date +/- SD, August 31 +/- 43.5 d) and immigrated back each spring to early summer (May 15 +/- 27.8 d), with most individuals (>95% [31 of 32]) returning one or more years after tagging. Marine detections of these subadults were common (81.25% [26 of 32]) and spanned the geographic extent of both the threatened and endangered U.S. distinct population segments and into international waters, e.g., from the Hudson River, New York, to Minas Basin, Nova Scotia. However, they were more typically detected by receivers in the Gulf of Maine; 77% (20 of 26) were only detected in the Gulf of Maine when not in the river. These data indicate that, based on the temporal and spatial predictability of habitat use, the estuary of the Penobscot River is important for subadult Atlantic Sturgeon of the Gulf of Maine. The wider movement patterns emphasize the need for conservation and management across regions and international boundaries.

Beardsall, J. W., Stokesbury, M. J. W., Logan-Chesney, L. M., & Dadswell, M. J. (2016). Atlantic sturgeon Acipenser oxyrinchus Mitchill, 1815 seasonal marine depth and temperature occupancy and movement in the Bay of Fundy. *Journal of Applied Ichthyology, 32*(5), 809-819 https://doi.org/10.1111/jai.13175.

Pop-up satellite archival tags were used to collect fisheries-independent data that characterized the seasonal habitat occupancy and movement of Atlantic sturgeon Acipenser oxyrinchus Mitchill, 1815 in the Bay of Fundy (BoF). Atlantic sturgeon from Canadian and United States stocks aggregate annually for feeding in Minas Basin, inner BoF (45.28N, 64.18W), during May to September but depart to other locations from October to April. Sixteen PSAT tags were applied to sturgeon ranging from 152 to 203cm total length captured and released in Minas Basin during May to August. Ten of the tags were reported after 1year at large and provided pop-off locations. Seven were recovered with archived data, or provided transmitted data sets, which were analyzed for depth and temperature occupancy from June 2011 to August 2013. During June to August while in the Minas

Basin the sturgeon spent >90% of time at depths <10m and temperatures of 16-22 degrees C. Departure from Minas Basin through the Minas Passage was in September and October, when depth occupancy varied from <10 to 120m. From November to April sturgeon were in the outer BoF, where mean depth occupancies ranged from 40 to 100m at mean temperatures of 3-14 degrees C. Deepest mean depth occupancy of 60 to 90m was recorded during December 2011 and 2012, and coldest mean temperature occupancy of 0-4 degrees C in March 2011 and 2012. During April and May mean depth and temperature occupancy ranges shallowed from 40 to <10m and increased from 4 to 15 degrees C, respectively. Tag pop-off locations indicated that sturgeon spent the winter season in the outer BoF but by June had either migrated back to the Minas Basin or off the mouth of the Saint John River, a known spawning location.

Breece, M. W., Fox, D. A., Dunton, K. J., Frisk, M. G., Jordaan, A., & Oliver, M. J. (2016). Dynamic seascapes predict the marine occurrence of an endangered species: Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus. *Methods in Ecology and Evolution, 7*(6), 725-733 https://doi.org/10.1111/2041-210x.12532.

Categorical landscapes are powerful environmental partitions that index complex biogeochemical processes that drive terrestrial species distributions. However, translating landscapes into seascapes requires that the dynamic nature of the fluid environment be reflected in spatial and temporal boundaries such that seascapes can be used in marine species distribution models and conservation decisions. A seascape product derived from satellite ocean colour and sea surface temperature partitioned mid-Atlantic coastal waters on scales commensurate with the Atlantic Sturgeon migration. The seascapes were then matched with acoustic telemetry records of Atlantic Sturgeon to determine seascape selectivity. To test for selectivity, we used real-time satellite seascape maps to normalize the sampling of an autonomous underwater vehicle that resampled similar geographic regions with time varying seascape classifications. Our findings suggest that Atlantic Sturgeon prefer one seascape class over those available in the coastal ocean, indicating selection for covarying environmental properties rather than geographical location. The recent listing of Atlantic Sturgeon as Endangered throughout much of their United States range has highlighted the need for improved understanding of marine habitat requirements to reduce interactions with anthropogenic stressors. Narrow dynamic migration corridors may enable seascapes to be used as a daily decision tool by industry and managers to reduce interactions with this imperilled species during coastal migrations.

Breece, M. W., Fox, D. A., & Oliver, M. J. (2018). Environmental Drivers of Adult Atlantic Sturgeon Movement and Residency in the Delaware Bay. *Marine and Coastal Fisheries, 10*(2), 269-280 https://doi.org/10.1002/mcf2.10025.

Animals utilize various habitats throughout their life to optimize growth, fitness, and survival. Identifying environmental conditions and locations where animals exhibit different movement behaviors can be used to infer the relative importance of habitat types. In the case of threatened and endangered species, such as the Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus, critical habitat designations are a tool used to promote conservation and recovery. We utilized an extensive passive acoustic telemetry array, observed atmospheric conditions and river flow, modeled seawater conditions, and used generalized additive mixed modeling to determine environmental predictors of Atlantic Sturgeon movement and residency in the Delaware Bay on the U.S. East Coast. Our results suggested that shallower waters, warmer bottom temperatures, and areas toward the eastern portion of the Delaware Bay were predictive of residency, while movement was predicted by increased depth, cooler bottom temperatures, and areas toward the western portion of the bay. Our findings add to a growing body of evidence highlighting habitats at the Delaware Bay mouth, where Atlantic Sturgeon occur at heightened concentrations from late spring through fall. The Delaware River estuary once supported the largest population of Atlantic Sturgeon in North America, but that population is now critically imperiled (or endangered). Atlantic Sturgeon spend the vast majority of their life in marine, polyhaline waters, and without enhanced protection for these habitats, their recovery may never be realized.

Breece, M. W., Oliver, M. J., Cimino, M. A., & Fox, D. A. (2013). Shifting Distributions of Adult Atlantic Sturgeon Amidst Post-Industrialization and Future Impacts in the Delaware River: a Maximum Entropy Approach. *PLoS One, 8*(11) https://doi.org/10.1371/journal.pone.0081321.

Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) experienced severe declines due to habitat destruction and overfishing beginning in the late 19th century. Subsequent to the boom and bust period of exploitation, there has been minimal fishing pressure and improving habitats. However, lack of recovery led to the 2012 listing of Atlantic sturgeon under the Endangered Species Act. Although habitats may be improving, the availability of high quality spawning habitat, essential for the survival and development of eggs and larvae may still be a limiting factor in the recovery of Atlantic sturgeon. To estimate adult Atlantic sturgeon spatial distributions during riverine occupancy in the Delaware River, we utilized a maximum entropy (MaxEnt) approach along with passive biotelemetry during the likely spawning season. We found that substrate composition and distance from the salt front significantly influenced the locations of adult Atlantic sturgeon in the Delaware River. To broaden the scope of this study we projected our model onto four scenarios depicting varying locations of the salt front in the Delaware River: the contemporary location of the salt front during the likely spawning season, the location of the salt front during the historic fishery in the late 19th century, an estimated shift in the salt front by the year 2100 due to climate change, and an extreme drought scenario, similar to that which occurred in the 1960's. The movement of the salt front upstream as a result of dredging and climate change likely eliminated historic spawning habitats and currently threatens areas where Atlantic sturgeon spawning may be taking place. Identifying where suitable spawning substrate and water chemistry intersect with the likely occurrence of adult Atlantic sturgeon in the Delaware River highlights essential spawning habitats, enhancing recovery prospects for this imperiled species.

Dadswell, M. J., Wehrell, S. A., Spares, A. D., McLean, M. F., Beardsall, J. W., Logan-Chesney, L. M., . . . Stokesbury, M. J. W. (2016). The annual marine feeding aggregation of Atlantic sturgeon Acipenser oxyrinchus in the inner Bay of Fundy: population characteristics and movement. *Journal of Fish Biology, 89*(4), 2107-2132 https://doi.org/10.1111/jfb.13120.

Atlantic sturgeon Acipenser oxyrinchus aggregate to feed from May to October in Minas Basin (45 degrees N; 64 degrees W), a large, cul-de-sac embayment of the inner Bay of Fundy. The aggregation consists mainly of migrants from the Saint John, NB and Kennebec Rivers, ME (99%). During 2004-2015, 4393 A. oxyrinchus were taken as by-catch by commercial fish trawlers or at intertidal fishing weirs, and 1453 were marked and/or sampled and released. Fork length (L-F) ranged from 458 to 2670 mm, but 725% were <1500 mm. Mass (M) ranged from 05 to 580 kg. The mass-length relationship for fish 50 kg was log(10)M = 332log(10)L(F) - 571. Observed growth of unsexed A. oxyrinchus recaptured after 1-8 years indicated fish of 90-179 cm L-F grew c. 2-4 cm a year. Ages obtained from pectoral spines were from 4 to 54 years. The Von Bertalanffy growth model predicted K = 001 and L = 5209 mm L-F. Estimated annual mortality was 95-109%. Aggregation sizes in 2008 and 2013 were 8804 and 9244 individuals, respectively. Fish exhibited high fidelity for yearly return to Minas Basin and population estimates indicated the total at-sea number utilizing the Basin increased from c. 10 700 in 2010 to c. 37 500 in 2015. Abundance in the Basin was greatest along the north shore in spring and along the south shore in summer, suggesting clockwise movement following the residual current structure. Marked individuals were recaptured in other bays of the inner Bay of Fundy, north to Gaspe, Quebec, and south to New Jersey, U.S.A., with 26 recoveries from the Saint John River, NB, spawning run. Fish marked at other Canadian and U.S. sites were also recovered in Minas Basin. Since all A. oxyrinchus migrate into and out of the Basin annually they will be at risk of mortality if planned tidal power turbines are installed in Minas Passage. (C) 2016 The Fisheries Society of the British Isles

Fernandes, S. J., Zydlewski, G. B., Zydlewski, J. D., Wippelhauser, G. S., & Kinnison, M. T. (2010). Seasonal Distribution and Movements of Shortnose Sturgeon and Atlantic Sturgeon in the Penobscot River Estuary, Maine. *Transactions of the American Fisheries Society, 139*(5), 1436-1449 https://doi.org/10.1577/t09-122.1.

Relatively little is known about the distribution and seasonal movement patterns of shortnose sturgeon Acipenser brevirostrum and Atlantic sturgeon Acipenser oxyrinchus oxyrinchus occupying rivers in the northern part of their range. During 2006 and 2007, 40 shortnose sturgeon (66-113.4 cm fork length [FL]) and 8 Atlantic sturgeon (76.2-166.2 cm FL) were captured in the Penobscot River, Maine, implanted with acoustic transmitters, and monitored using an array of acoustic receivers in the Penobscot River estuary and Penobscot Bay. Shortnose sturgeon were present year round in the estuary and overwintered from fall (mid-October) to spring (mid-April) in the upper estuary. In early spring, all individuals moved downstream to the middle estuary. Over the course of the summer, many individuals moved upstream to approximately 2 km of the downstream-most dam (46 river kilometers [rkm] from the Penobscot River mouth [rkm 0]) by August. Most aggregated into an overwintering site (rkm 36.5) in mid-to late fall. As many as 50% of the tagged shortnose sturgeon moved into and out of the Penobscot River system during 2007, and 83% were subsequently detected by an acoustic array in the Kennebec River, located 150 km from the Penobscot River estuary. Atlantic sturgeon moved into the estuary from the ocean in the summer and concentrated into a 1.5-km reach. All Atlantic sturgeon moved to the ocean by fall, and two of these were detected in the Kennebec River. Although these behaviors are common for Atlantic sturgeon, regular coastal migrations of shortnose sturgeon have not been documented previously in this region. These results have important implications for future dam removals as well as for rangewide and river-specific shortnose sturgeon management.

Fox, A. G., Stowe, E. S., Dunton, K. J., & Peterson, D. L. (2018). Seasonal occurrence of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) in the St. Johns River, Florida. *Fishery Bulletin, 116*(3-4), 219-227 https://doi.org/10.7755/fb.116.3.1.

The Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) is an anadromous species that historically occurred in the Atlantic Ocean along the North American coast from maritime Canada to the St. Johns River, Florida. A century of overharvesting and habitat loss has resulted in range-wide population declines, and in 2012 the species was listed under the U.S. Endangered Species Act. The extirpation of several individual populations-especially in the southeastern United States-was an important consideration in the final determination to list the species as endangered. Although historical data confirm the presence of Atlantic sturgeon in the St. Johns River, no recent evidence of a viable population exists for that river system. The primary objective of our study was to document the presence or absence of Atlantic sturgeon in the St. Johns River. During 2014-2015, we conducted nearly 200 hours of directed sampling with gill nets of different mesh sizes in the St. Johns River estuary but found no evidence of an extant population within the St. Johns River system. We did document the seasonal presence of several adult and subadult individuals that had been acoustically tagged by researchers working in other coastal systems, and that finding indicates that nonnatal individuals still use this estuary.

Horne, A. N., & Stence, C. P. (2016). Assessment of Critical Habitats for Recovering the Chesapeake Bay Atlantic Sturgeon Distinct Population Segment. Grant number: NA13NMF4720042, Final report. Retrieved from https://dnr.maryland.gov/fisheries/Pages/hatcheries/sturgeon.aspx

This report reviews information collected in the Marshyhope Creek and Nanticoke River. The present research was to determine if there was a population of Atlantic Sturgeon in the Nanticoke River and Marshyhope Creek, and to determine if they were migrants moving through the system or if they were present for the purpose of spawning. This would be the only known spawning population of Atlantic Sturgeon in Maryland waters.

McLean, M. F., Simpfendorfer, C. A., Heupel, M. R., Dadswell, M. J., & Stokesbury, M. J. W. (2014). Diversity of behavioural patterns displayed by a summer feeding aggregation of Atlantic sturgeon in the intertidal region of Minas Basin, Bay of Fundy, Canada. *Marine Ecology Progress Series, 496*, 59-69 https://doi.org/10.3354/meps10555.

Quantifying animal movements can reveal spatial and temporal patterns of habitat use and may improve our understanding of the foraging strategies of marine predators where direct observations of feeding behaviour are rare or impossible because of turbidity. Fine-scale movement data from 25 acoustically tagged Atlantic sturgeon Acipenser oxyrinchus (Mitchill, 1815) were gathered using a Vemco Positioning System array of hydroacoustic receivers in the intertidal zone of Minas Basin, Bay of Fundy, Canada, during summer 2011. From these data, sturgeon relocations and movement trajectories were determined. Sturgeon movement trajectories were categorized into 3 movement types by analyzing 4 calculated metric variables including (1) mean distance between successive relocations; (2) mean relative angle or 'turning angle'; (3) mean rate of movement (ROM; m s(-1)); and (4) a linearity ratio. Movement Type 1 trajectories were characteristically slow and winding, with short steps between relocation, whereas Type 2 movements were fast and tortuous. Movement Type 3 trajectories were fast and linear, with large steps between relocations. Considerable variability in movement type was recognized with 11 individuals performing all 3 types of movement during the monitoring period. Movement Types 1 and 2 occurred primarily over the intertidal zone, where sediment type was comprised of larger sand and sandy/silt particles. This association with larger grain size may coincide with a diet preference for sand-tube dwelling polychaetes and indicates the importance of the intertidal zone to foraging Atlantic sturgeon. All movement types were equally likely to occur throughout a 24 h day and throughout all tidal stages; however, there was higher overall crepuscular activity which revealed a temporal pattern not previously recognized for Atlantic sturgeon.

Novak, A. J., Carlson, A. E., Wheeler, C. R., Wippelhauser, G. S., & Sulikowski, J. A. (2017). Critical Foraging Habitat of Atlantic Sturgeon Based on Feeding Habits, Prey Distribution, and Movement Patterns in the Saco River Estuary, Maine. *Transactions of the American Fisheries Society, 146*(2), 308-317 https://doi.org/10.1080/00028487.2016.1264472.

An overall lack of information prompted the recent listing of Atlantic SturgeonAcipenser oxyrinchus oxyrinchusunder the Endangered Species Act. Key to the restoration of the species and of particular importance is the need to characterize the use of critical habitat across the region, specifically in the Gulf of Maine, where the population was listed as threatened. Much of the research to date has focused on large river systems able to support remnant spawning populations; however, the role of small coastal river systems for Atlantic Sturgeon is not well documented. Several of these systems are being reinhabited, and to facilitate new knowledge about the Gulf of Maine population, a long-term (2009–2014) acoustic telemetry study for 51 Atlantic Sturgeon tagged in the Saco River was evaluated. Results suggested that the majority of fish were aggregating near the natural mouth of the estuary across the 6 years. Gastric lavage samples from 163 (91 juvenile and 72 adult) fish (65.0–171.5 cm fork length) during 2013 and 2014 demonstrated that American Sand LanceAmmodytes americanuswas the most common prey (the index of relative importance for 2013 and 2014 was 93.5% and 85.4%, respectively), a finding unique to this river system. In addition, benthic sediment grabs, beam trawls, otter trawls, and beach seines conducted in 2013 and 2014 indicated that the distribution of American Sand Lances was comparable to the aggregation area observed for Atlantic Sturgeon. The combined results suggest that the Saco River estuary provides critical foraging habitat imperative for the future recovery of the Gulf of Maine Atlantic Sturgeon population. Received May 24, 2016; accepted November 17, 2016 Published online February 15, 2017

Stokesbury, M. J. W., Logan-Chesney, L. M., McLean, M. F., Buhariwalla, C. F., Redden, A. M., Beardsall, J. W., . . . Dadswell, M. J. (2016). Atlantic Sturgeon Spatial and Temporal Distribution in Minas Passage, Nova Scotia, Canada, a Region of Future Tidal Energy Extraction. *PLoS One, 11*(7) https://doi.org/10.1371/journal.pone.0158387.

In the Bay of Fundy, Atlantic sturgeon from endangered and threatened populations in the USA and Canada migrate through Minas Passage to enter and leave Minas Basin. A total of 132 sub-adult and adult Atlantic sturgeon were tagged in Minas Basin during the summers of 2010-2014 using pressure measuring, uniquely coded, acoustic transmitters with a four or eight year life span. The aim of this study was to examine spatial and seasonal distribution of sturgeon in Minas Passage during 2010-2014 and test the hypothesis that, when present, Atlantic sturgeon were evenly distributed from north to south across Minas Passage. This information is important as tidal energy extraction using in-stream, hydrokinetic turbines is planned for only the northern portion of Minas Passage. Electronic tracking data from a total of 740 sturgeon days over four years demonstrated that Atlantic sturgeon used the southern portion of Minas Passage significantly more than the northern portion. Sturgeon moved through Minas Passage at depths mostly between 15 and 45 m ($n = 10,116$; mean = 31.47 m; SD = 14.88). Sturgeon mean swimming depth was not significantly related to bottom depth and in deeper regions they swam pelagically. Sturgeon predominately migrated inward through Minas Passage during spring, and outward during late summer-autumn. Sturgeon were not observed in Minas Passage during winter 2012-2013 when monitoring receivers were present. This information will enable the estimation of encounters of Atlantic sturgeon with in-stream hydrokinetic turbines.

Taylor, A. D., Ohashi, K., Sheng, J. Y., & Litvak, M. K. (2016). Oceanic Distribution, Behaviour, and a Winter Aggregation Area of Adult Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus, in the Bay of Fundy, Canada. *PLoS One, 11*(4) https://doi.org/10.1371/journal.pone.0152470.

Seasonal distribution of adult Atlantic sturgeon was examined using pop-up satellite archival tags (PSATs) and ultrasonic transmitters deployed in the Saint John River, New Brunswick, Canada. Seven MK10 PSATs programmed for release in June 2012 and seven MiniPAT PSATs programmed for release in February and April 2013 were deployed in August 2011 and 2012, respectively. Eleven of 14 PSATs surfaced and transmitted depth and temperature data archived for the duration of their deployment (121-302 days). Among these eleven PSATs, five were recovered and 15-sec archival data was downloaded. Following exit from the Saint John River in the fall, tagged fish occupied a mean monthly depth of 76.3-81.6 m at temperatures as low as 4.9 degrees C throughout the winter before returning to shallower areas in the spring. The majority of ultrasonic detections occurred in the Bay of Fundy, but fish were detected as far as Riviere Saint-Jean, Quebec, approximately 1500 km from the Bay of Fundy (representing long-distance migratory rates of up to 44 km/day). All PSATs were first detected in the Bay of Fundy. Tags that released in February and April were found 5-21 km offshore of the Saint John Harbour, while tags that released in June were first detected in near shore areas throughout the Bay of Fundy. The substrate at winter tag release locations (estimated from backward numerical particle-tracking experiments) consisted primarily of moraines and postglacial mud substrate with low backscatter strength, indicative of soft or smooth seabed. Based on the proximity of winter tag release locations, the consistent depths observed between fish, and previous research, it is suspected that a winter aggregation exists in the Bay of Fundy. This study expands the understanding of the marine distribution and range of Atlantic sturgeon on the east coast of Canada.

Wippelhauser, G. S., Sulikowski, J., Zydlewski, G. B., Altenritter, M. A., Kieffer, M., & Kinnison, M. T. (2017). Movements of Atlantic Sturgeon of the Gulf of Maine Inside and Outside of the Geographically Defined Distinct Population Segment. *Marine and Coastal Fisheries, 9*(1), 93-107 https://doi.org/10.1080/19425120.2016.1271845.

Identification of potential critical habitat, seasonal distributions, and movements within and between river systems is important for protecting the Gulf of Maine (GOM) distinct population segment of Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus. To accomplish these objectives, we captured Atlantic Sturgeon from four GOM rivers (Penobscot, Kennebec system, Saco, and Merrimack) and tagged 144 individuals (83.3-217.4 cm TL) internally with uniquely coded acoustic transmitters. Tagged fish were detected from 2006 to 2014 by primary receiver arrays that were deployed in the four GOM rivers or were detected opportunistically on a secondary group of receivers deployed within the GOM and along the continental shelf. Tagged Atlantic Sturgeon were documented at three spawning areas in the Kennebec system in June and July, including an area that became accessible in 1999 when Edwards Dam was removed. The majority (74%) of tagged fish were detected in the estuaries of the four GOM rivers, primarily in May-October. They spent most of their time in a 45-km reach within the Kennebec system but occupied more limited areas (<= 5-km reach) within the Penobscot, Saco, and Merrimack rivers. Approximately 70% of the tagged fish were detected in GOM coastal waters and aggregated in the Bay of Fundy (May-January), offshore of the Penobscot River (September-February and May), offshore of the Kennebec River (September-February), in Saco Bay and the Scarborough River (July-November), and along the eastern Massachusetts coast between Cape Ann and Cape Cod (April-February). Nine tagged

Atlantic Sturgeon (7%) left the GOM; three of those individuals moved north as far as Halifax, Nova Scotia, Canada, and six moved south as far as the James River, Virginia. Information obtained in this study has been used to make recommendations to avoid or reduce the impacts of in-water projects on Atlantic Sturgeon.

Section IV: Life History Characteristics

Allen, P. J., Mitchell, Z. A., DeVries, R. J., Aboagye, D. L., Ciaramella, M. A., Ramee, S. W., . . . Shartau, R. B. (2014). Salinity effects on Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus Mitchill, 1815) growth and osmoregulation. *Journal of Applied Ichthyology, 30*(6), 1229-1236 https://doi.org/10.1111/jai.12542.

The Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus Mitchill, 1815) is an anadromous sturgeon species, yet little is known with regard to its osmoregulatory ability and habitat use at early life stages. In order to examine whether salinity poses a physiological challenge to juvenile Atlantic sturgeon near the sizes where they may begin to move into saline habitats, growth and osmoregulatory ability were tested. Juvenile Atlantic sturgeon (mean initial weight: 440 g) were acclimated to one of three salinity conditions (0, 10, or 33 ppt) representing the range of salinities they would be expected to encounter. Growth was measured over a 6-month period, and osmoregulatory ability (i.e. blood plasma osmolality and ionic concentrations) was measured after 4 months. Mean weight and length increased in all treatments, but fish in 0 and 10 ppt grew more than fish in 33 ppt. Blood plasma osmolality was regulated at similar levels regardless of salinity. Therefore, juvenile Atlantic sturgeon have the physiological capability to move between salinity habitats, but grow faster in low salinities. [ABSTRACT FROM AUTHOR]

Balazik, M. T., McIninch, S. P., Garman, G. C., & Latour, R. J. (2012). Age and Growth of Atlantic Sturgeon in the James River, Virginia, 1997-2011. *Transactions of the American Fisheries Society, 141*(4), 1074-1080 https://doi.org/10.1080/00028487.2012.676590.

Historically the Chesapeake Bay supported a large population of Atlantic sturgeon Acipenser oxyrinchus, but loss of suitable spawning habitat and overfishing coincided with dramatic in-system declines throughout the 20th century. Atlantic sturgeon harvest moratoriums were implemented in 1974 for Virginia waters and were expanded coastwide in 1998. In 1997, researchers became aware that commercial fishers in the James River, a tributary of the Chesapeake Bay, were catching juvenile and subadult Atlantic sturgeon as bycatch in various fisheries. Genetic studies showed that the Chesapeake Bay population has maintained genetic integrity and qualifies as a distinct population segment. Between 2007 and 2011, almost 150 adults have been caught in the tidal-freshwater portion of the James River during putative spawning runs. Pectoral fin spines from juveniles and subadults collected in the Burwell Bay (rkm 40) and Cobham Bay (rkm 60) areas and mature adult samples from vessel strikes in freshwater around or above rkm 120 were analyzed to create a length-at-age curve for Atlantic sturgeon in the James River. Five models were used to analyze the data, and the double von Bertalanffy (k(1) = 0.054, k(2) = 0.097, t(1) = -2.85, t(2) = 1.09, t(p) = 6.03 years, L-infinity = 2241 mm) provided the best fit to the observed data. We estimated an increase in growth coefficient at t(p), which could be an artifact of low sample size or due to ontogenetic changes in habitat use as older fish spend more time in oceanic waters than younger fish. Atlantic sturgeon in the 6-9 year age range are rarely encountered in the James River compared with younger and older age-classes, so a more in-depth analysis of the increased growth coefficient would require ocean sampling.

Dunton, K. J., Jordaan, A., Secor, D. H., Martinez, C. M., Kehler, T., Hattala, K. A., . . . Frisk, M. G. (2016). Age and Growth of Atlantic Sturgeon in the New York Bight. *North American Journal of Fisheries Management, 36*(1), 62-73 https://doi.org/10.1080/02755947.2015.1103820.

Accurate estimates of age and growth of fishes are important in the management and conservation of species and for the development of modeling approaches. Assessments of endangered or rare species typically are limited by poor or inadequate data owing to low abundance, unrepresentative sampling, and/or restrictions on sampling. Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus, which occurs along the east coast of North America, has five distinct population segments (DPSs) listed under the U.S. Endangered Species Act. The New York Bight (NYB) DPS is listed as endangered and represents the largest DPS in the United States. Coastal trawl surveys from 2005 to 2012 were used to evaluate the current age structure of the NYB DPS. A total of 21 year-classes (mean age = 8.89 years, n = 742 fish) were observed. Age data for the NYB DPS were combined with other available age estimates from multiple research laboratories and sources (n = 2,774) in the Hudson River and Delaware River as well from the coastal regions of New York, New Jersey, and Delaware from 1975 to 2012. Collectively, the combined data set captured much of the age range of the species, minimizing age biases and resulting in improved von Bertalanffy parameter estimates (L-infinity = 278.87, K = 0.057, t(0) = -1.27) with high overall model fit (r(2) = 0.87). We assessed the effects of individual data sets through a series of leave-one-out bootstrap routines that evaluated the influence of each data set on growth parameter estimates. The parameter estimates of the von Bertalanffy growth function were influenced by sampling location and/or researcher effects. Despite these differences, the combined data set approach used here represents the most comprehensive study on the age-and-growth relationship of Atlantic Sturgeon and provides parameter estimates for the development of population dynamics models and valuable information for future management.

Hightower, J. E., Loeffler, M., Post, W. C., & Peterson, D. L. (2015). Estimated Survival of Subadult and Adult Atlantic Sturgeon in Four River Basins in the Southeastern United States. *Marine and Coastal Fisheries, 7*(1), 514-522 https://doi.org/10.1080/19425120.2015.1088491.

Prompted by concerns about the status of Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus, in 2012 the National Oceanic and Atmospheric Administration listed one distinct population segment (DPS) as threatened (Gulf of Maine) and listed the remaining four DPSs as endangered (New York Bight, Chesapeake Bay, Carolina, and South Atlantic). To provide information for recovery planning, we estimated the survival of subadult and adult Atlantic Sturgeon in two river basins within the Carolina DPS (Roanoke and Cape Fear rivers, North Carolina) and two basins within the South Atlantic DPS (Ashepoo-Combahee-Edisto rivers [ACE], South Carolina; Altamaha River, Georgia). Estimated detection probability varied strongly by season but was similar among river basins, likely reflecting a winter migration into marine waters with minimal receiver coverage. Apparent monthly survival was very high and precisely estimated for the Roanoke River (0.985; 95% credible interval [CI] = 0.970-0.995), Cape Fear River (0.979; 95% CI = 0.971-0.986), ACE (0.989; 95% CI = 0.979-0.993), and Altamaha River (0.985; 95% CI = 0.973-0.994) basins. A pooled estimate for 87 adults from all four basins was 0.988 (95% CI = 0.982-0.992). The monthly rates implied annual apparent survival rates of 0.839 (Roanoke River basin), 0.778 (Cape Fear River basin), 0.871 (ACE basin), and 0.842 (Altamaha River basin); the pooled estimate for adults was 0.860. Our estimated survival rates were similar to other recent estimates for Atlantic Sturgeon but lower than recent estimates for several populations of Gulf Sturgeon A. oxyrinchus desotoi. Recovery of Atlantic Sturgeon in these southeastern rivers will occur more quickly if survival can be increased to a level that is consistent with published estimates of true natural mortality (0.03-0.07; annual survival >= 0.93).

Kehler, T., Sweka, J. A., Mohler, J., Higgs, A., & Kenney, G. (2018). Age and Growth of Juvenile Atlantic Sturgeon in the Lower Hudson River. *North American Journal of Fisheries Management, 38*(1), 84-95 https://doi.org/10.1002/nafm.10032.

The precipitous decline of Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus coupled with their recent listing under the U.S. Endangered Species Act necessitates investigations into their population dynamics. Our objectives were to (1) estimate age of juvenile Atlantic Sturgeon by using pectoral spine sections; (2) determine annual growth periodicity in hatchery-reared and recaptured wild Atlantic Sturgeon to validate our aging method; (3) determine growth rates for recaptured juveniles; and (4) back-calculate lengths from ages estimated by using pectoral spine sections from captured juveniles. Fish were captured via gillnetting in Newburgh and Haverstraw bays, Hudson River, during fall 2003, spring and fall 2004, and spring and fall 2005. Two readers agreed upon 91% (n=474) of ages estimated for juvenile Atlantic Sturgeon, establishing a coefficient of variation of 1.7%. Eight year-classes (ages 1-8) were represented, with age-4 fish making up the largest age-class (39%; n=203) and age-1 fish being the least represented (<1%; n=4). Multi-annual oxytetracycline injections in four cohorts of hatchery-reared Atlantic Sturgeon (n=34) demonstrated a two-part zone for each year of growth, as did four recaptured juveniles that were at liberty for a least 1year, which exhibited mean growth rates of 0.3mm/d and 2.4g/d. We back-calculated median FLs from annulus positioning in ages 2-8 by using dorsal and ventral lobes of pectoral spine sections and compared the results to actual reported lengths. Dorsal and ventral lobes underestimated the median FLs of all age-classes except ages 3 and 7, for which lengths were overestimated. We found statistical differences between dorsal- and ventral-derived median FLs, suggesting that both regions must be evaluated. Our overall goal is to provide researchers with a baseline of age and growth data for future work on juvenile Atlantic Sturgeon.

Mohler, J. W., Sweka, J. A., Kahnle, A., Hattala, K., Higgs, A., DuFour, M., . . . Fox, D. A. (2012). Growth and Survival of Hatchery-Produced Atlantic Sturgeon Released as Young-of-Year into the Hudson River, New York. *Journal of Fish & Wildlife Management, 3*(1), 23-32 https://doi.org/10.3996/012011-JFWM-005.

In 2007, a team of U.S. scientists performed a status review of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus and concluded that the species would likely become endangered (U.S. Endangered Species Act 1973, as amended) in the foreseeable future over much of its range, including populations of the New York Bight, which is comprised of the Hudson and Delaware rivers. Therefore, we evaluated an experimental release of hatchery-produced Atlantic sturgeon that took place in 1994 to determine the value of using stocked fish as a population recovery tool. We obtained recapture data on hatchery fish (identified by presence of pelvic fin removal) from the Atlantic Coast Sturgeon Tagging Database. Our evaluation of retention for a pelvic fin removal mark on hatchery fish showed that 36% of clipped individuals retained a clean fin clip after 49 d. The minimum survival rate for hatchery fish to age 5 was estimated to be in the range of 0.49-0.66%

using documented recaptures (N = 24), known number of fish stocked, and results of the pelvic fin removal evaluation. Length and weight-at-age for recaptured hatchery fish at known ages 5-17 were within the range of values reported for wild fish whose ages were estimated by pectoral spine analysis. We also report that one ripe male hatchery fish at age 15 was captured along with other spermiating males at its parental spawning area in the Hudson River in 2009. [ABSTRACT FROM AUTHOR]

Section V: Risk Assessment

Balazik, M. T., Reine, K. J., Spells, A. J., Fredrickson, C. A., Fine, M. L., Garman, G. C., & McIninch, S. P. (2012). The Potential for Vessel Interactions with Adult Atlantic Sturgeon in the James River, Virginia. *North American Journal of Fisheries Management, 32*(6), 1062-1069 https://doi.org/10.1080/02755947.2012.716016.

In 2012, all populations of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus were listed as either threatened or endangered under the U.S. Endangered Species Act. During 20072010, researchers documented 31 carcasses of adult Atlantic sturgeon in the tidal freshwater portion of the James River, Virginia. Twenty-six of the carcasses had gashes from vessel propellers, and the remaining five carcasses were too decomposed to allow determination of the cause of death. The types of vessels responsible for these mortalities were not explicitly demonstrated. Most (84%) of the carcasses were found in a relatively narrow reach that was modified to increase shipping efficiency. To explore the number of Atlantic sturgeon being hit and their horizontal and depth distributions in relation to vessel draft, we conducted telemetry experiments on three living fish (all males) and six dead specimens. While staging (holding in an area from hours to days, with minimal upstream or downstream movements), the adult male Atlantic sturgeon spent most (62%) of the time within 1m of the river bottom. Assuming that behavior is not modified by vessel noise, adult male Atlantic sturgeon in the James River would rarely encounter small recreational boats or tugboats with shallow drafts; instead, mortalities are likely caused by deep-draft ocean cargo ships, which have drafts that coincide with the distribution of the tracked adult males. Dead specimens (n = 6) drifted with the current for several hours to almost 4 d before beaching at distances ranging from 0.5 to over 50 river kilometers from the point of release. We estimated that current monitoring in the James River documents less than one-third of vessel strike mortalities. A better understanding of Atlantic sturgeon behavior in the presence of vessels will aid in restoring this federally endangered species. Received February 20, 2012; accepted July 19, 2012

Beardsall, J. W., McLean, M. F., Cooke, S. J., Wilson, B. C., Dadswell, M. J., Redden, A. M., & Stokesbury, M. J. W. (2013). Consequences of Incidental Otter Trawl Capture on Survival and Physiological Condition of Threatened Atlantic Sturgeon. *Transactions of the American Fisheries Society, 142*(5), 1202-1214 https://doi.org/10.1080/00028487.2013.806347.

Atlantic Sturgeon Acipenser oxyrinchus aggregate in Minas Basin in the inner Bay of Fundy, Nova Scotia, during summer, presumably to feed on abundant intertidal invertebrates. The Atlantic Sturgeon aggregation is composed of multiple stocks from Canada and the USA. Government agencies from both nations have recently recognized Atlantic Sturgeon as threatened or endangered due to overfishing and habitat degradation. Little is known about the fate of Atlantic Sturgeon that are captured as bycatch in fisheries targeting other species, making it difficult to determine the extent to which bycatch is contributing to the Atlantic Sturgeon population's decline. To characterize the effects of otter trawl capture and release on Atlantic Sturgeon, we calculated a minimum survival rate for fish after catch and release by using acoustic telemetry, and we examined physiological indicators of stress. The minimum postrelease survival rate from otter trawl capture events was high (94% survival). Results also demonstrated that the magnitude of blood lactate in trawl-captured fish relative to experimental control fish increased with longer handling times. Trawl capture and handling did not cause significantly elevated levels of blood glucose or cortisol relative to those of controls. Minimization of handling time (i.e., time on deck) should be a priority in trawl fisheries that capture Atlantic Sturgeon as bycatch. Future studies should attempt to quantify the postcapture behavior of these fish to better understand whole-organism condition after fisheries encounters. Received August 30, 2012; accepted May 8, 2013

Bouyoucos, I. A. N., Bushnell, P., & Brill, R. (2014). Potential for Electropositive Metal to Reduce the Interactions of Atlantic Sturgeon with Fishing Gear. *Conservation Biology, 28*(1), 278-282 https://doi.org/10.1111/cobi.12200.

Atlantic sturgeon (Acipenser oxyrhynchus) populations have been declared either endangered or threatened under the U.S. Endangered Species Act. Effective measures to repel sturgeon from fishing gear would be beneficial to both fish and fishers because they could reduce both fishery-associated mortality and the need for seasonal and area closures of specific fisheries. Some chondrostean fishes (e.g., sturgeons and paddlefishes) can detect weak electric field gradients (possibly as low as 5 Mv/cm) due to arrays of electroreceptors (ampullae of Lorenzini) on their snout and gill covers. Weak electric fields, such as those produced by electropositive metals (typically mixtures of the lanthanide elements), could therefore potentially be used as a deterrent. To test this idea, we recorded the behavioral responses of juvenile Atlantic sturgeon (31-43 cm fork length) to electropositive metal (primarily a mixture of the lanthanide elements neodymium and praseodymium) both in the presence and absence of food stimuli. Trials were conducted in an approximately 2.5 m diameter × 0.3 m deep tank, and fish behaviors were recorded with an overhead digital video camera. Video records were subsequently digitized (x, y coordinate system), the distance between the fish and the electropositive metal calculated, and data summarized by compiling frequency distributions with 5-cm bins. Juvenile sturgeon showed clear avoidance of electropositive metal but only when food was present. On the basis of our results, we conclude that the electropositive metals, or other sources of weak electric fields, may eventually be used to reduce the interactions of Atlantic sturgeon with fishing gear, but further investigation is needed. El Potencial del Metal Electropositivo para Reducir las Interacciones del Esturión Atlántico con Instrumentos de Pesca Bouyoucos, Bushnell & Brill 13-003 (English) [ABSTRACT FROM AUTHOR]

Brown, J. J., & Murphy, G. W. (2010). Atlantic Sturgeon Vessel-Strike Mortalities in the Delaware Estuary. *Fisheries, 35*(2), 72-83 https://doi.org/10.1577/1548-8446-35.2.72.

The Atlantic Sturgeon Status Review Team has recommended that the Secretary of Commerce list the New York Bight distinct population segment of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), which includes the Delaware River and Hudson River populations, as threatened under the federal Endangered Species Act. Between 2005 and 2008, a total of 28 Atlantic sturgeon mortalities were reported in the Delaware Estuary. Sixty-one percent of the mortalities reported were of adult size and 50% of the mortalities resulted from apparent vessel strikes. The remainder of the mortalities were too decomposed to ascertain the cause of death, but the majority were likely the result of vessel strikes. For small remnant populations of Atlantic sturgeon, such as that in the Delaware River, the loss of just a few individuals per year due to anthropogenic sources of mortality, such as vessel strikes, may continue to hamper restoration efforts. An egg-per-recruit analysis demonstrated that vessel-strike mortalities could be detrimental to the population if more than 2.5% of the female sturgeon are killed annually. We report on our observations of vessel-strike mortalities in the Delaware Estuary, discuss the possible implications for the Delaware River population, and recommend further research.

Chambers, R. C., Davis, D. D., Habeck, E. A., Roy, N. K., & Wirgin, I. (2012). Toxic effects of PCB126 and TCDD on shortnose sturgeon and Atlantic sturgeon. *Environmental Toxicology and Chemistry, 31*(10), 2324-2337 https://doi.org/10.1002/etc.1953.

Exposure to chemical contaminants is often invoked to explain recruitment failures to populations of sturgeon worldwide, but there is little empirical evidence to support the idea that young sturgeon are sensitive at environmentally relevant concentrations. The authors used shortnose sturgeon (Acipenser brevirostum) and Atlantic sturgeon (Acipenser oxyrinchus) as models to investigate the sensitivities of sturgeon to early-life-stage toxicities from embryonic exposures to graded doses of polychlorinated biphenyl 126 (PCB126) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Survival to hatching of shortnose sturgeon decreased with increasing dose, although the duration of the embryonic period was not significantly altered by exposure in either species. Morphometric features of larvae of both species were affected by dose, including shortening of the body, reduction in head size, reduction in quantity of yolk reserves, and reduction in eye size. Eye development in both species was delayed with increasing dose for both chemicals. The persistence of larvae in a food-free environment decreased inversely with dose in both species, with sharp declines occurring at PCB126 and TCDD doses of =1 ppb and =0.1 ppb, respectively. Dose-responsive early-life-stage toxicities reported here are among the more sensitive found in fish and occurred at burdens similar to those found in situ in a sympatric bottom-dwelling bony fish in the Hudson River Estuary. The present study is among the first demonstrating the sensitivity of any sturgeon to the hallmark early-life-stage toxicities induced by aryl hydrocarbon receptor agonists. Environ. Toxicol. Chem. 2012; 31: 23242337. (c) 2012 SETAC

Dadswell, M. J., Spares, A. D., McLean, M. F., Harris, P. J., & Rulifson, R. A. (2018). Long-term effect of a tidal, hydroelectric propeller turbine on the populations of three anadromous fish species. *Journal of Fish Biology, 93*(2), 192-206 https://doi.org/10.1111/jfb.13755.

Tidal hydroelectric power has been proposed as one potential solution for sustainable energy sources. The first tidal turbine in North America began continuous operation in the Annapolis River estuary (44 degrees 45'N; 65 degrees 29'W) in June, 1985. The machine is an axial-flow, hydraulic-lift propeller turbine, a type known to cause fish mortality. Anadromous populations of American shad Alosa sapidissima, striped bass Morone saxatilis and Atlantic sturgeon Acipenser oxyrinchus utilize the Annapolis River for spawning and other life history phases. After power generation commenced obvious turbine mortalities of these fishes began appearing downstream of the turbine. Assessments of the A. sapidissima adult spawning runs during 1981-1982 (pre-operation) and 1989-1996 (operational) indicated significant changes in population characteristics after power generation began. Adult length, mass, age and per cent repeat spawners declined and total instantaneous mortality (Z) increased from 0.30 to 0.55. The pre-turbine spawning runs had older fish with numerous adult cohorts whereas by 12 years after operation began runs consisted of younger fish with fewer adult cohorts. During 1972-1987 numerous studies indicated the Annapolis River had an important angling fishery for M. saxatilis, but detailed annual records kept by a fishing contest during 1983-1987 and an elite angler family during the period 1976-2008 demonstrated a rapid decline in the number of fish >4.0 kg after turbine operation began. Pre-turbine catch by the angling family of fish >4.0 kg accounted for 84.1% of total catch, but declined significantly to 39.6% of total catch from 1986-1999, and to none from 2000-2008. The existence of an A. oxyrinchus stock in the Annapolis River was unknown before turbine operation, but during 1985-2017, 21 mortalities were recovered by chance seaward of the turbine. Mechanical strike and cavitation mortalities consisted of juveniles, mature males and gravid and spent females of ages 10 to 53 years found during June to October, the period when this anadromous species returns to its natal river to spawn. The results of the long-term studies at Annapolis indicate managers should realize substantial risks exist for the fish resources of the world's oceans from deployment of instream propeller turbines.

Dunton, K. J., Jordaan, A., Conover, D. O., McKown, K. A., Bonacci, L. A., & Frisk, M. G. (2015). Marine Distribution and Habitat Use of Atlantic Sturgeon in New York Lead to Fisheries Interactions and Bycatch. *Marine and Coastal Fisheries, 7*(1), 18-32 https://doi.org/10.1080/19425120.2014.986348.

Population declines of Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus prompted initial fisheries closures and an eventual endangered or threatened species listing across the U.S. portion of their range in 2012. Atlantic Sturgeon aggregations and migration routes along the coast of Long Island overlap with commercial fishing activities that may lead to incidental take in nondirected fisheries. Thus, understanding the distribution and movement of Atlantic Sturgeon in relation to commercial fisheries can help management agencies determine impacts and develop bycatch mitigation measures. Stratified random sampling and targeted bottom trawl surveys were used to identify the temporal and spatial use of marine habitat in New York waters. The majority of survey captures were restricted to depths of less than 15 m and known aggregation areas. During the aggregation periods (May, June, September, and October) in known aggregation areas, catches were an order of magnitude higher than in other areas and months of the year. Northeast Fisheries Observer Program bycatch data from 1989 to 2013 was analyzed for the New York region and suggested that bycatch occurs within two main gear types: otter bottom trawls and sink gill nets. Trawling bycatch contained primarily subadult Atlantic Sturgeon and is highest during the Summer Flounder Paralichthys dentatus fishery in New York State waters. Trawling overlaps spatially and temporally with identified Atlantic Sturgeon aggregation areas, while bycatch in gill nets targeted adult fish farther offshore in federal waters. Bycatch in these fisheries may be a regional threat to recovery, and spatial and temporal closures, gear modifications, or other bycatch reduction techniques are suggested to protect aggregating and migrating fish.

Levesque, J. C., Hager, C., Diaddorio, E., & Dickey, R. J. (2016). Commercial fishing gear modifications to reduce interactions between Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus and the southern flounder (Paralichthys lethostigma) fishery in North Carolina (USA). *PeerJ, 4* https://doi.org/10.7717/peerj.2192.

Bycatch of protected species commercial fishing operations is a Primary concern to fishery managers because it threatens the conservation, protection, and recovery of fragile species, such as the Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). One potential solution to reduce the risk associated with commercial fishing operations is to design commercial fishing gear that is more selective in terms of interactions between Atlantic sturgeon and commercial fisheries. Given this conservation and management need, the overarching goal was to reduce Atlantic sturgeon fishery interactions and maintain southern flounder (Paralichthys lethostigma) catch in North Carolina, The specific objectives of this study were to design and evaluate the effectiveness of a modified gillnet. Overall, the results proved that lowering the profile and amount of webbing had a beneficial impact at reducing Atlantic sturgeon incidental encounters and bycatch. The modified gillnet reduced bycatch and Atlantic sturgeon encounters by 39.6% and 60.9%, respectively, Our design entangled 51.6% fewer southern flounder, which corresponded to a 48.9% reduction in total weight; the modified gear entangled slightly larger southern flounder than the control gear, Our findings showed the number of, Atlantic sturgeon encounters was positively associated with mean water depth, with more Atlantic sturgeon encountered in deeper (5.1-6.3 m) than shallower waters; 75% were encountered at depths between 4.6 and 6.1 rn. Most southern flounder (n = 518, 39.7%) were taken at a water depth between 3.76 and 5.0 in. This observation suggests that southern flounder prefer slightly shallower waters than Atlantic sturgeon.

Matsche, M. A., Markin, E., Donaldson, E., Hengst, A., & Lazur, A. (2012). Effect of chloride on nitrite-induced methaemoglobinemia in Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus (Mitchill). *Journal of Fish Diseases, 35*(12), 873-885 https://doi.org/10.1111/j.1365-2761.2012.01418.x.

We evaluated the effects of chloride concentration on the clinical pathology in juvenile Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus (Mitchill) , following semi-static exposures to 1 mg L−1 nitrite for 96 h. In spring water naturally low in chloride (5 mg L−1), plasma nitrite concentrated to more than 40× environmental levels resulting in a severe methaemoglobinemia characterized by torpid behaviour, 30-fold increase in methaemoglobin fraction, anaemia, leucopenia and hyperkalaemia. Loss of intracellular water and potassium to extracellular space may have resulted in hyperkalaemia and haemodilution. Fish survived nitrite exposure, but 60% of torpid fish died following capture and tissue sampling. Fish acclimated to 10-fold higher chloride content (55 mg L−1) did not concentrate nitrite in the plasma above environmental levels or develop methaemoglobinemia, but did exhibit similar haematology and plasma chemistry changes. Plasma nitrite returned to preexposure levels by 14 days following nitrite exposures, but severity of clinical pathology changes persisted or increased, suggesting that Atlantic sturgeon have reduced capacity to recover from methaemoglobinemia. Fish that survive methaemoglobinemia may be susceptible to mortality from the cumulative effects of intoxication, handling and other stresses for two or more weeks following nitrite remediation. Chloride buffering in aquaculture systems reduces the toxic effects of nitrite accumulation. [ABSTRACT FROM AUTHOR]

Roy, N. K., Candelmo, A., DellaTorre, M., Chambers, R. C., Nadas, A., & Wirgin, I. (2018). Characterization of AHR2 and CYP1A expression in Atlantic sturgeon and shortnose sturgeon treated with coplanar PCBs and TCDD. *Aquatic Toxicology, 197*, 19-31 https://doi.org/10.1016/j.aquatox.2018.01.017.

Atlantic sturgeon and shortnose sturgeon co-occur in many estuaries along the Atlantic Coast of North America. Both species are protected under the U.S. Endangered Species Act and internationally on the IUCN Red list and by CITES. Early life-stages of both sturgeons may be exposed to persistent aromatic hydrocarbon contaminants such as PCBs and PCDD/Fs which are at high levels in the sediments of impacted spawning rivers. Our objective was to compare the PCBs and TCDD sensitivities of both species with those of other fishes and to determine if environmental concentrations of these contaminants approach those that induce toxicity to their young life stages under controlled laboratory conditions. Because our previous studies suggested that young life-stages of North American sturgeons are among the more sensitive of fishes to coplanar PCB and TCDD-induced toxicities, we were interested in identifying the molecular bases of this vulnerability. It is known that activation of the aryl hydrocarbon receptor 2 (AHR2) in fishes mediates most toxicities to these contaminants and transcriptional activation of xenobiotic metabolizing enzymes such as cytochrome P4501A (CYP1A). Previous studies demonstrated that structural and functional variations in AHRs are the bases for differing sensitivities of several vertebrate taxa to aromatic hydrocarbons. Therefore, in this study we characterized AHR2 and its expression in both sturgeons as an initial step in understanding the mechanistic bases of their sensitivities to these contaminants. We also used CYP1A expression as an endpoint to develop Toxicity Equivalency Factors (TEFs) for these sturgeons. We found that critical amino acid residues in the ligand binding domain of AHR2 in both sturgeons were identical to those of the aromatic hydrocarbon-sensitive white sturgeon, and differed from the less sensitive lake sturgeon. AHR2 expression was induced by TCDD (up to 6-fold) and by three of four tested coplanar PCB congeners (3-5-fold) in Atlantic sturgeon, but less so in shortnose sturgeon. We found that expression of AHR2 and CYP1A mRNA significantly covaried after exposure to TCDD and PCB77, PCB81, PCB126, but not PCB169 in both sturgeons. We also determined TEFs for the four coplanar PCBs in shortnose sturgeon based on comparison of CYP1A mRNA expression across all doses. Surprisingly, the TEFs for all four coplanar PCBs in shortnose sturgeon were much higher (6.4-162 times) than previously adopted for fishes by the WHO.

Roy, N. K., Walker, N., Chambers, R. C., & Wirgin, I. (2011). Characterization and expression of cytochrome P4501A in Atlantic sturgeon and shortnose sturgeon experimentally exposed to coplanar PCB 126 and TCDD. *Aquatic Toxicology, 104*(1-2), 23-31 https://doi.org/10.1016/j.aquatox.2011.03.009.

The AHR pathway activates transcription of CYP1A and mediates most toxic responses from exposure to halogenated aromatic hydrocarbon contaminants such as PCBs and PCDD/Fs. Therefore, expression of CYP1A is predictive of most higher level toxic responses from these chemicals. To date, no study had developed an assay to quantify CYP1A expression in any sturgeon species. We addressed this deficiency by partially characterizing CYP1A in Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) and shortnose sturgeon (Acipenser brevirostrum)and then used derived sturgeon sequences to develop reverse transcriptase (RT)-PCR assays to quantify CYP1A mRNA expression in TCDD and PCB126 treated early life-stages of both species. Phylogenetic analysis of CYP1A, CYP1B, CYP1C and CYP3A deduced amino acid sequences from other fishes and sturgeons revealed that our putative Atlantic sturgeon and shortnose sturgeon CYP1A sequences most closely clustered with previously derived CYP1A sequences. We then used semi-quantitative and real-time RT-PCR to measure CYP1A mRNA levels in newly hatched Atlantic sturgeon and shortnose sturgeon larvae that were exposed to graded doses of waterborne PCB126 (0.01-1000 parts per billion (ppb)) and TCDD (0.001-10 ppb). We initially observed significant induction of CYP1A mRNA compared to vehicle control at the lowest doses of PCB126 and TCDD used, 0.01 ppb and 0.001 ppb, respectively. Significant induction was observed at all doses of both chemicals although lower expression was seen at the highest doses. We also compared CYP1A expression among tissues of i.p. injected shortnose sturgeon and found significant inducibility in heart, intestine, and liver, but not in blood, gill, or pectoral fin clips. For the first time, our results indicate that young life-stages of sturgeons are sensitive to AHR ligands at environmentally relevant concentrations, however, it is yet to be determined if induction of CYP1A can be used as a biomarker in environmental biomonitoring. (C) 2011 Elsevier B.V. All rights reserved.

Sokolowski, M. S., Allam, B. A., Dunton, K. J., Clark, M. A., Kurtz, E. B., & Fast, M. D. (2012). Immunophysiology of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus (Mitchill), and the relationship to parasitic copepod, Dichelesthium oblongum (Abilgaard) infection. *Journal of Fish Diseases, 35*(9), 649-660 https://doi.org/10.1111/j.1365-2761.2012.01390.x.

The copepod parasite, Dichelesthium oblongum, is known to infect the Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus, within the area near New York city, USA, known as the NY Bight. The gross pathology associated with the juvenile and adult copepod stages along with the parasites link in causing changes in sturgeon osmoregulatory capabilities has led us to investigate the host immunophysiology in relation to this hostparasite system. All the host variables, which included gill Na+-K+-ATPase activity, serum alkaline phosphatase (AP) and white blood cell differential counts, were affected in a non-linear manner by the copepod parasite. The parasites increased the host gill Na+-K+-ATPase activity and serum AP along with the percentage granulocytes while decreasing the percentage lymphocytes. A new method, developed to sample and preserve white blood cells in the field for future flow cytometry analysis, proved adequate. The effects of fish size, location and time of sampling were accounted for by the use of generalized linear models, and their effects on the host variables are discussed.

Section VI: Stock Status

Bahr, D. L., & Peterson, D. L. (2016). Recruitment of Juvenile Atlantic Sturgeon in the Savannah River, Georgia. *Transactions of the American Fisheries Society, 145*(6), 1171-1178 https://doi.org/10.1080/00028487.2016.1209557.

Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus were once abundant along the Atlantic coast of North America from the Saint Lawrence River, Canada, to the St. Johns River, Florida. Severe overfishing, coupled with habitat losses during the 1900s, resulted in major population declines that eventually led to the subspecies' listing under the U.S. Endangered Species Act in 2012. Despite this listing, quantified recruitment data are largely lacking for most Atlantic Sturgeon populations, particularly those within the South Atlantic distinct population segment. The objective of this study was to quantify annual recruitment of Atlantic Sturgeon in the Savannah River, Georgia, by estimating annual abundance of age-1, river-resident juveniles. During the summers of 2013-2015, we used anchored gill nets and trammel nets to sample juvenile Atlantic Sturgeon throughout the Savannah River estuary. Ages of captured juveniles were determined by using length-frequency analysis, and abundance of each juvenile age-class was estimated with Huggins closed-capture models in RMark. We estimated the Savannah River to contain 528 age-1 juveniles in 2013, 589 in 2014, and 597 in 2015. The results from this study indicate that the Savannah River population is likely the second largest within the South Atlantic distinct population segment. Future studies are needed to determine the relative importance of the Savannah River as a natural source of recruitment for smaller, more imperiled populations in adjacent rivers. Consequently, we suggest that management efforts continue to prioritize the protection of both the population and the associated critical habitats within the Savannah River estuary.

Balazik, M. T., Garman, G. C., Van Eenennaam, J. P., Mohler, J., & Woods, L. C. (2012). Empirical Evidence of Fall Spawning by Atlantic Sturgeon in the James River, Virginia. *Transactions of the American Fisheries Society, 141*(6), 1465-1471 https://doi.org/10.1080/00028487.2012.703157.

Due to overfishing and habitat alteration, the anadromous Atlantic sturgeon Acipenser oxyrinchus oxyrinchus is severely depleted across its historic range. The James and York rivers in Virginia are the two rivers comprising the Chesapeake Bay distinct population segment, where Atlantic sturgeon reproduction has been confirmed. It is widely recognized that Atlantic sturgeon spawn in the spring throughout their range; however, there is debate over whether they also spawn in the fall. To determine if Atlantic sturgeon spawn in the fall, independent of the spring spawn, large-mesh gill netting in the freshwater portion of the James River (above river kilometer 108) was conducted in the spring (April-June) and fall (August-October) for 3 years (20092011), resulting in the capture of 125 adult Atlantic sturgeon (three were recaptures) during the fall sampling, but none were captured during the spring. Field examination for sex and stage of maturity identified 106 mature males and one postspawned female. Sex was not determined for four fish, and due to time constraints, 11 were not examined. Forty mature males were externally tagged with Vemco (c) ultrasonic passives tags and movements were monitored with a Vemco (c) VR2W passive receiver array. Collection and tracking data showed that mature Atlantic sturgeon aggregate in the freshwater portion of the James River during the fall season, entering during August and out-migrating by the end of November. No tagged fish were detected in the freshwater area of the river during the subsequent spring months. Though James River Atlantic sturgeon may spawn in the spring, we suggest there is strong evidence for an independent fall spawn, which should be considered in future management and recovery actions.

Balazik, M. T., & Musick, J. A. (2015). Dual Annual Spawning Races in Atlantic Sturgeon. *PLoS One, 10*(5) https://doi.org/10.1371/journal.pone.0128234.

Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus, Acipenseridae) populations in the United States were listed as either endangered or threatened under the Endangered Species Act in 2012. Because of the endangered/threatened status, a better understanding of Atlantic sturgeon life-history behavior and habitat use is important for effective management. It has been widely documented that Atlantic sturgeon reproduction occurs from late winter to early summer, varying clinally with latitude. However, recent data show Atlantic sturgeon also spawn later in the year. The group that spawns later in the year seems to be completely separate from the spring spawning run. Recognition of the later spawning season has drastically modified estimates of the population status of Atlantic sturgeon in Virginia. With the combination of new telemetry data and historical documentation we describe a dual spawning strategy that likely occurs in various degrees along most, if not all, of the Atlantic sturgeon's range. Using new data combined with historical sources, a new spawning strategy emerges which managers and researchers should note when determining the status of Atlantic sturgeon populations and implementing conservation measures.

Damon-Randall, K., Colligan, M., & Crocker, J. (2013). Composition of Atlantic Sturgeon in Rivers, Estuaries and in Marine Waters (National Marine Fisheries Office of Protected Resources white paper). Retreived from https://www.greateratlantic.fisheries.noaa.gov/mediacenter/2013/05/composition_of_atlantic_sturgeon_in_rivers_percentages_by_dps_revised__feb_2013_v2.pdf

This white paper reviews the DPS distrubutions and Life History Characteristics of the Gulf of Maine DPS, New York Bight DPS, Chesapeake Bay DPS, Carolina DPS, and South Atlantic DPS. It includes tagging and Genetic data and effort maps

Dunton, K. J., Jordaan, A., McKown, K. A., Conover, D. O., & Frisk, M. G. (2010). Abundance and distribution of Atlantic sturgeon (Acipenser oxyrinchus) within the Northwest Atlantic Ocean, determined from five fishery-independent surveys. *Fishery Bulletin, 108*(4), 450-465. Retrieved from https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/2010/1084/dunton.pdf

A lack of knowledge of how oceanic habitat is used by juvenile marine migrant Atlantic sturgeon (Acipenser oxyrinchus) is hindering conservation measures directed at restoring severely depleted populations. Identifying the spatial distribution of Atlantic sturgeon is necessary to identify critical habitat and appropriate management actions. We used five fishery-independent surveys to assess habitat use and movement of Atlantic sturgeon during their marine life stage. The size distribution ranged from 56 to 269 cm total length (mean=108 cm). Ninety-eight percent of all Atlantic sturgeon were smaller than 197 cm a size that indicated the majority were immature. The pattern of habitat use revealed concentration areas and potential migration pathways used for northerly summer and southerly winter migrations. Atlantic sturgeon were largely confined to water depths less than 20 m and aggregations tended to occur at the mouths of large bays (Chesapeake and Delaware bays) or estuaries (Hudson and Kennebec rivers) during the fall and spring and to disperse throughout the Mid-Atlantic Bight during the winter. In most surveys depth, temperature, and salinity were significantly related to the distribution of Atlantic sturgeon. Knowledge of their habitat and movements can be used to devise spatially based conservation plans to minimize bycatch and to enhance population recovery.

Fritts, M. W., Grunwald, C., Wirgin, I., King, T. L., & Peterson, D. L. (2016). Status and Genetic Character of Atlantic Sturgeon in the Satilla River, Georgia. *Transactions of the American Fisheries Society, 145*(1), 69-82 https://doi.org/10.1080/00028487.2015.1094131.

The Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus is an important component of biodiversity along the Atlantic coast of North America, but most populations have been decimated by habitat degradation and chronic overfishing. Historically, spawning populations existed in all major Atlantic coast rivers from the St. Lawrence River, Quebec, to the St. Johns River, Florida, but fisheries surveys conducted in the past two decades suggest that several populations at the southern extent of this range are now extirpated or have declined to remnant status. Our objective was to assess the abundance and genetic character of Atlantic Sturgeon in the Satilla River, Georgia. Using entanglement gears, we expended over 2,800 h of sampling effort and captured a total of 193 Atlantic Sturgeon in tidally influenced reaches of the river during 2008-2010. Of the 157 fish that were collected in 2010, 72 were identified as river-resident juveniles (ages 0-1). Genetic analyses of a subset (n = 61) of these juveniles revealed (1) depauperate levels of mitochondrial DNA (mtDNA) haplotype diversity and (2) the presence of large family units based on microsatellite DNA multilocus genotypes, collectively suggesting that very few parents produced the 2008 year-class. The mtDNA and microsatellite analyses both indicated that juveniles in the Satilla River population were genetically distinct from other populations in the South Atlantic Distinct Population Segment. Atlantic Sturgeon life history characteristics and the present results suggest that sampled juveniles from the 2008 year-class were the offspring of a small remnant pool of Satilla River adults;

however, a full description of the population's genetic character and origin will require additional juvenile samples from future year-classes.

Hager, C., Kahn, J., Watterson, C., Russo, J., & Hartman, K. (2014). Evidence of Atlantic Sturgeon Spawning in the York River System. *Transactions of the American Fisheries Society, 143*(5), 1217-1219 https://doi.org/10.1080/00028487.2014.925971.

The National Marine Fisheries Service listed five distinct population segments of Atlantic Sturgeon Acipenser oxyrinchus as threatened and endangered under the Endangered Species Act on February 6, 2012. At that time, the only known spawning population of sturgeon in the Chesapeake Bay was in the James River. The goal of this research was to determine whether reproduction was also occurring in the Chesapeake's York River watershed. Based on the assumption that an early fall spawning event occurs in the upper reaches of the watershed, these waters were sampled in late August of 2013 when water temperatures became appropriate for spawning. During a week of sampling, numerous male sturgeon running milt and one spawned-out female with residual eggs still present were captured. The co-occurrence of reproductively active males and a recently spawnedout female Atlantic Sturgeon in the upper Pamunkey River at temperatures consistent with documented spawning temperatures in other systems indicates that fall spawning occurs in the York River system. Therefore, the population segment of Atlantic Sturgeon distinct to the Chesapeake Bay has at least two spawning populations that managers should consider when protecting this listed species.

Hale, E. A., Park, I. A., Fisher, M. T., Wong, R. A., Stangl, M. J., & Clark, J. H. (2016). Abundance Estimate for and Habitat Use by Early Juvenile Atlantic Sturgeon within the Delaware River Estuary. *Transactions of the American Fisheries Society, 145*(6), 1193-1201 https://doi.org/10.1080/00028487.2016.1214177.

The Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus historically supported a significant commercial fishery along the eastern coast of North America. However, overfishing led to substantial population declines with contributions from other anthropogenic impacts, including vessel strikes and contaminants that continue to impede recovery. Our work is the first to estimate the abundance of early juvenile (age 0-1), resident Atlantic Sturgeon in the Delaware River estuary. Using the Schumacher and Eschmeyer mark-recapture estimator for multiple censuses, we estimated 3,656 (95% CI = 1,935-33,041) individuals used the Delaware River estuary as a nursery in 2014. We found no significant change in mean length during the course of our study (November-December), and lengths of age 0-1 Atlantic Sturgeon ranged from 220 to 515 mm TL. Further, using a passive acoustic receiver array, we identified significant habitat areas where age-0-1 juveniles spend considerable amounts of time; this included the Marcus Hook area and some habitat use downriver and upriver of Marcus Hook at Cherry Island and the Chester Range. Our results support the idea that a spawning population of Atlantic Sturgeon exists in the Delaware River and that some level of early juvenile recruitment is continuing to persist despite current depressed population levels. Understanding trends in abundance, habitat use, and other population metrics for natal river Atlantic Sturgeon will allow for better conservation and management of the species.

Ingram, E. C., & Peterson, D. L. (2016). Annual Spawning Migrations of Adult Atlantic Sturgeon in the Altamaha River, Georgia. *Marine and Coastal Fisheries, 8*(1), 595-606 https://doi.org/10.1080/19425120.2016.1243599.

The Atlantic Sturgeon Acipenser oxyrinchus has declined throughout its range, and the species is now protected under the U.S. Endangered Species Act. Information on the timing and extent of spawning migrations is essential for the development and implementation of effective management and recovery strategies, yet this information is lacking for most populations. The objectives of this study were to document and identify temporal and spatial patterns in the seasonal movements and spawning migrations of Atlantic Sturgeon in the South Atlantic distinct population segment. A stationary array of acoustic receivers was used to monitor the movements of 45 adults in the Altamaha River system, Georgia, from April 2011 through March 2014. Telemetry data revealed that putative adult spawners exhibited two distinct patterns of upriver migration: a spring two-step migration and a fall one-step migration. During the spring two-step migration, the adults appeared to stage in the upper Altamaha during the spring and early summer, before migrating to suspected spawning habitats in the Ocmulgee and Oconee tributaries during the fall. During the fall one-step migration, fish entered the system in late summer and migrated directly upriver to suspected spawning habitats in the Ocmulgee and Oconee tributaries. Regardless of which pattern was used during the upstream migration, all fish returned downstream and left the system by early January. Although direct evidence of spawning has not yet been obtained, the telemetry and environmental data provide strong circumstantial evidence that Atlantic Sturgeon spawning in the Altamaha population occurs only during the fall months when water temperatures are less than 25 degrees C. These findings further illustrate the clinal variation in the life history of Atlantic Sturgeon and highlight the need to manage the species as distinct population segments with regionally specific recovery goals.

Kahn, J. E., Hager, C., Watterson, J. C., Russo, J., Moore, K., & Hartman, K. (2014). Atlantic Sturgeon Annual Spawning Run Estimate in the Pamunkey River, Virginia. *Transactions of the American Fisheries Society, 143*(6), 1508-1514 https://doi.org/10.1080/00028487.2014.945661.

On February 6, 2012, the National Marine Fisheries Service listed five distinct population segments (DPSs) of Atlantic Sturgeon Acipenser oxyrinchus encompassing their entire U.S. range, including one DPS in Chesapeake Bay, as either threatened or endangered under the Endangered Species Act. Designation of DPSs is a management tool that identifies significant, discrete, geographically defined portions of a species' range, which can be listed as unique management units. At the time of listing, all DPSs except the Chesapeake Bay DPS comprised several rivers with known reproduction. After the Chesapeake Bay DPS was established, an additional spawning population was confirmed in the Pamunkey River, which is part of the York River system. We used the Schumacher-Eschmeyer formula for multiple census to estimate the number of adult Atlantic Sturgeon that spawned in the Pamunkey River during 2013. Gill nets were placed between river kilometers 27 and 67 in the upper Pamunkey River for 10 weeks during spawning season. The Schumacher-Eschmeyer model gave an estimate of 75 adult Atlantic Sturgeon (95% confidence interval = 17-168 adults) for the 2013 spawning population. This study represents the first estimate of annual spawning population abundance for any river in the Chesapeake Bay DPS and is only the third estimate of Atlantic Sturgeon abundance rangewide.

Savoy, T., Maceda, L., Roy, N. K., Peterson, D., & Wirgin, I. (2017). Evidence of natural reproduction of Atlantic sturgeon in the Connecticut River from unlikely sources. *PLoS One, 12*(4) https://doi.org/10.1371/journal.pone.0175085.

Atlantic Sturgeon is listed under the U.S. Endangered Species Act as five Distinct Population Segments (DPS). The "endangered" New York Bight (NYB) DPS is thought to only harbor two populations; one in the Hudson River and a second smaller one in the Delaware River. Historically, the Connecticut River probably supported a spawning population of Atlantic Sturgeon that was believed extirpated many decades ago. In 2014, we successfully collected pre -migratory juvenile specimens from the lower Connecticut River which were subjected to mitochondrial DNA (mtDNA) control region sequence and microsatellite analyses to determine their genetic relatedness to other populations coastwide. Haplotype and allelic frequencies differed significantly between the Connecticut River collection and all other populations coastwide. Sibship analyses of the microsatellite data indicated that the Connecticut River collection was comprised of a small number of families that were likely the offspring of a limited number of breeders. This was supported by analysis of effective population size (Ne) and number of breeders (Nb). STRUCTURE analysis suggested that there were 11 genetic clusters among the coastwide collections and that from the Connecticut River was distinct from those in all other rivers. This was supported by UPGMA analyses of the microsatellite data. In AMOVA analyses, among region variation was maximized, and among population within regions variation minimized when the Connecticut River collection was separate from the other two populations in the NYB DPS indicating the dissimilarity between the Connecticut River collection and the other two populations in the NYB DPS. Use of mixed stock analysis indicated that the Connecticut River juvenile collection was comprised of specimens primarily of South Atlantic and Chesapeake Bay DPS origins. The most parsimonious explanation for these results is that the Connecticut River hosted successful natural reproduction in 2013 and that its offspring were descendants of a small number of colonizers from populations south of the NYB DPS, most notably the South Atlantic DPS. Our results run contrary to the belief that re - colonizers of extirpated populations primarily originate in proximal populations.

Schueller, P., & Peterson, D. L. (2010). Abundance and Recruitment of Juvenile Atlantic Sturgeon in the Altamaha River, Georgia. *Transactions of the American Fisheries Society, 139*(5), 1526-1535 https://doi.org/10.1577/t09-127.1.

Juvenile Atlantic sturgeon Acipenser oxyrinchus remain in natal rivers for several years prior to out-migrating to marine environments during later portions of their life history. Data regarding river-resident juvenile population dynamics are unknown. During the summers of 2004-2007, we performed mark-recapture of juvenile Atlantic sturgeon in the Altamaha River to assess age-specific abundance, apparent survival, per capita recruitment, and factors influencing recruitment. Estimates indicated that juvenile abundance ranged from 1,072 to 2,033 individuals, and age-1 and age-2 individuals comprised greater than 87% of the juvenile population, while age-3 or older individuals constituted less than 13% of the population. Estimates of apparent survival and per capita recruitment from Pradel models indicated that the juvenile population experienced high annual turnover: apparent survival rates were low (<33%), and per capita recruitment was high (0.82-1.38). Fall discharge, which had a positive relationship with recruitment, was the only factor assessed that significantly explained time variation in per capita recruitment. The findings of this study suggest that juvenile populations at the southern extreme of the Atlantic sturgeon's range may remain in natal rivers for less time than northern counterparts. This is further evidence of life history differences between northern and southern populations of Atlantic sturgeon. Potential findings of density dependence could have major implications for both population recovery and management of this species.

Smith, J. A., Flowers, H. J., & Hightower, J. E. (2015). Fall Spawning of Atlantic Sturgeon in the Roanoke River, North Carolina. *Transactions of the American Fisheries Society, 144*(1), 48-54 https://doi.org/10.1080/00028487.2014.965344.

In 2012, the National Oceanic and Atmospheric Administration (NOAA) declared Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus to be threatened or endangered throughout its range in U.S. waters. Restoration of the subspecies will require much new information, particularly on the location and timing of spawning. We used a combination of acoustic telemetry and sampling with anchored artificial substrates (spawning pads) to detect fall (September-November) spawning in the Roanoke River in North Carolina. This population is included in the Carolina Distinct Population Segment, which was classified by NOAA as endangered. Sampling was done immediately below the first shoals encountered by anadromous fishes, near Weldon. Our collection of 38 eggs during the 21 d that spawning pads were deployed appears to be the first such collection (spring or fall) for wild-spawned Atlantic Sturgeon eggs. Based on egg development stages, estimated spawning dates were September 17-18 and 18-19 at water temperatures from 25.3 degrees C to 24.3 degrees C and river discharge from 55 to 297 m(3)/s. These observations about fall spawning and habitat use should aid in protecting critical habitats and planning research on Atlantic Sturgeon spawning in other rivers.

Stewart, N. D., Cormier, Y., Logan-Chesney, L. M., Gibson, G., Wirgin, I., Dadswell, M. J., & Stokesbury, M. J. W. (2017). Natural stranding of Atlantic sturgeon (Acipenser oxyrinchus Mitchill, 1815) in Scot's Bay, Bay of Fundy, Nova Scotia, from populations of concern in the United States and Canada. *Journal of Applied Ichthyology, 33*(3), 317-322 https://doi.org/10.1111/jai.13371.

Natural mortality of Atlantic sturgeon (Acipenser oxyrinchus) has been determined to be low (M=0.07). Reported herein is the mortality by beach stranding of 11 Atlantic sturgeon in Scot's Bay, part of the inner Bay of Fundy in Nova Scotia, Canada on 22 June 2014. Genetic analyses, histological analysis and age determination were performed to determine origin, maturity stage and age of the stranded Atlantic sturgeon. Microsatellite and mitochondrial DNA analyses indicated that four of the Atlantic sturgeon (2 males and 2 females) were from the Saint John River, NB population, which was designated as threatened by the Committee on the Status of Endangered Wildlife in Canada. Seven Atlantic sturgeon (1 male, 5 females, 1 unknown) were from the Kennebec River, Maine population, that was listed as threatened under the Endangered Species Act in the U. S. Ageing of A.oxyrinchus Atlantic sturgeon by pectoral fin spine analysis determined that the mean age of the individuals from the Saint John River (x=24.25years, SD=5.0) and the Kennebec River (x=22.7years, SD=3.5) were not significantly different. This is the first report of a stranding event of Atlantic sturgeon, and describes a source of natural mortality affecting populations of concern in both Canada and the U. S.

Waldman, J. R., King, T., Savoy, T., Maceda, L., Grunwald, C., & Wirgin, I. (2013). Stock Origins of Subadult and Adult Atlantic Sturgeon, Acipenser oxyrinchus, in a Non-natal Estuary, Long Island Sound. *Estuaries and Coasts, 36*(2), 257-267 https://doi.org/10.1007/s12237-012-9573-0.

The anadromous acipenserid Atlantic sturgeon Acipenser oxyrinchus was listed in 2012 under the U.S. Endangered Species Act as having four endangered and one threatened distinct population segment (DPS) in American waters. Anthropogenic activities outside of natal estuaries, particularly bycatch, may hinder the abilities of some populations to rebuild. Most Atlantic sturgeon are residential for their first 2-6 years within their natal estuaries, whereas older subadults and adults may migrate to non-natal estuaries and coastal locations. Previous studies demonstrated that subadults and adults aggregate during summer at locations in Long Island Sound (LIS) and its tributary, the Connecticut River; however, the population origin of these fish is unknown. Because of its geographic proximity and relatively robust population, we hypothesized that the LIS and Connecticut River aggregations were almost solely derived from the Hudson River. We used microsatellite nuclear DNA analysis at 11 loci and mitochondrial DNA control region sequence analyses to estimate the relative contributions of nine Atlantic sturgeon populations and the five DPS to these aggregations using individual-based assignment tests and mixed-stock analysis. From 64 to 73 % of specimens from LIS were estimated to be of Hudson origin. Similarly, 66-76 % of specimens from the Connecticut River were of Hudson origin. However, moderate numbers of specimens were detected from distant spawning populations in the southeastern DPS and from two populations once thought to be extirpated or nearly so, the James River (6-7.3 %), and the Delaware River (7.6-12 %). Additionally, specimens were detected from all five DPS in both the LIS and Connecticut River collections. These results highlight the difficulty of evaluating the status of individual Atlantic sturgeon populations because of the propensity of subadults and adults to migrate for extended duration to distant sites where they may be vulnerable to anthropogenic disturbances.

Wippelhauser, G. S., & Squiers, T. S. (2015). Shortnose Sturgeon and Atlantic Sturgeon in the Kennebec River System, Maine: a 1977-2001 Retrospective of Abundance and Important Habitat. *Transactions of the American Fisheries Society, 144*(3), 591-601 https://doi.org/10.1080/00028487.2015.1022221.

Little was known about the populations of Shortnose Sturgeon Acipenser brevirostrum and Atlantic Sturgeon A. oxyrinchus in the Kennebec, Androscoggin, and Sheepscot River estuaries (the Kennebec system) in Maine, prompting a series of field studies spanning the years 1977-2001. Although the impetus for these studies varied, common objectives were to estimate population abundances and locate habitat important to the conservation of both species. During 16 years of gill-net sampling, we caught 3,372 Shortnose Sturgeon and 403 Atlantic Sturgeon. On the basis of two mark-recapture studies, the adult Shortnose Sturgeon population in the Kennebec system was estimated to be 5,117 (95% confidence interval, 4,206-6,279) for the period 1977-1981 and 9,436 (7,542-11,888) for the period 1998-2000. Gill-net sampling led to the identification of two spawning areas in the Kennebec system. One was an approximately 0.7-km-long reach immediately downstream of Brunswick Dam in the Androscoggin estuary, and the other was an approximately 26-km-long reach immediately downstream of Edwards Dam in the upper Kennebec estuary. Shortnose Sturgeon were caught at both locations, while Atlantic Sturgeon were documented only in the upper Kennebec estuary. Acoustic telemetry was used to identify a wintering site in Merrymeeting Bay that was used by Shortnose Sturgeon.

Wirgin, I., Breece, M. W., Fox, D. A., Maceda, L., Wark, K. W., & King, T. (2015). Origin of Atlantic Sturgeon Collected off the Delaware Coast during Spring Months. *North American Journal of Fisheries Management, 35*(1), 20-30 https://doi.org/10.1080/02755947.2014.963751.

Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus was federally listed under the U.S. Endangered Species Act as five distinct population segments (DPS). Currently, at least 18 estuaries coastwide host spawning populations and the viability of these vary, requiring differing levels of protection. Subadults emigrate from their natal estuaries to marine waters where they are vulnerable to bycatch; one of the major threats to the rebuilding of populations. As a result, identifying the population origin of Atlantic Sturgeon in coastal waters is critical to development of management plans intended to minimize interactions of the most imperiled populations with damaging fisheries. We used mitochondrial DNA control region sequencing and microsatellite DNA analyses to determine the origin of 261 Atlantic Sturgeon collected off the Delaware coast during the spring months. Using individual-based assignment (IBA) testing and mixed stock analysis, we found that specimens originated from all nine of our reference populations and the five DPSs used in the listing determination. Using IBA, we found that the Hudson River population was the largest contributor (38.3%) to our coastal collection. The James (19.9%) and Delaware (13.8%) river populations, at one time thought to be extirpated or nearly so, were the next largest contributors. The three populations combined in the South Atlantic DPS contributed 21% of specimens; the Altamaha River, the largest population in the South Atlantic DPS, only contributed a single specimen to the collection. While the origin of specimens collected on the Delaware coast was most likely within rivers of the New York Bight DPS (52.1%), specimens that originated elsewhere were also well represented. Genetic analyses provide a robust tool to identify the population origin of individual sturgeon outside of their natal estuaries and to determine the quantitative contributions of individual populations to coastal aggregations that are vulnerable to bycatch and other anthropogenic threats.

Wirgin, I., Maceda, L., Grunwald, C., & King, T. L. (2015). Population origin of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus by-catch in US Atlantic coast fisheries. *Journal of Fish Biology, 86*(4), 1251-1270 https://doi.org/10.1111/jfb.12631.

Microsatellite DNA and mitochondrial DNA control-region sequence analyses were used to determine the population and distinct population segment (DPS) origin of 173 Atlantic sturgeon Acipenser oxyrinchus oxyrinchus encountered from the Gulf of Maine to Cape Hatteras, North Carolina, in NOAA's Northeast Fisheries Observer Program. It was found that the Hudson River was by far the greatest contributor to this coastal by-catch, with 422-463% of specimens originating there. Generally, specimens represented the geographic province of the river in which they were spawned, but some specimens, particularly those originating in the South Atlantic DPS, moved to great distances. Genetic mixed-stock analyses provide an accurate approach to determine the DPS and population origin of A. o. oxyrinchus by-catch in coastal waters, but most informative management requires that these results be partitioned by locale, season, target fishery and gear type. (C) 2015 The Fisheries Society of the British Isles

Wirgin, I., Roy, N. K., Maceda, L., & Mattson, M. T. (2018). DPS and population origin of subadult Atlantic Sturgeon in the Hudson River. *Fisheries Research, 207*, 165-170 https://doi.org/10.1016/j.fishres.2018.06.004.

Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus is listed under the U.S. Endangered Species Act as five Distinct Population Segments (DPS). Subadult Atlantic Sturgeon are highly migratory in coastal waters and often move to non-natal estuaries where they encounter a variety of anthropogenic disturbances that may compromise their survival. The Hudson River estuary hosts large numbers of subadult Atlantic Sturgeon seasonally, but their DPS and population origin is unknown. We used microsatellite DNA analysis at 11 loci and sequence analysis of the mitochondrial DNA control region in Individual Based Assignment testing to determine the origin of 148 sub adult Atlantic Sturgeon that were collected in the tidal Hudson River estuary between river kilometers (RKM)5 and RKM 124 north of the Battery in New York City (RKM 0). We also determined the origin of eight dead specimens (subadults and adults) that were likely victims of vessel strikes and found floating between RKM27 and RKM60. We determined that 142 of 148 subadults assigned to the Hudson River (New York Bight DPS), the vast majority (138 of 142) with at least 95%, and usually, 100%, probability. All eight dead specimens assigned to the Hudson River with greater than 99% probability. Of the six subadult specimens that did not assign to the Hudson, two each assigned to the Kennebec River (Gulf of Maine DPS) and Delaware River (New York Bight DPS), one to the Ogeechee River (South Atlantic DPS), and one to the James River (Chesapeake Bay DPS). Our analysis allows the effects of anthropogenic threats in the Hudson River to be apportioned to the DPS and natal river populations of Atlantic Sturgeon found there and serves as a model for genetic population composition analysis for subadult Atlantic Sturgeon in other impacted estuaries.

Section VII: Policy, Legal, and Recommendations

Apostle, R., Dadswell, M. J., Engler-Palma, C., Litvak, M. K., McLean, M. F., Stokesbury, M. J. W., . . . VanderZwaag, D. L. (2013). Sustaining Atlantic Sturgeon: Stitching a Stronger Scientific and Governance Net. *Journal of International Wildlife Law & Policy, 16*(2/3), 170-197 https://doi.org/10.1080/13880292.2013.805062.

The article focuses on the challenges and probable scientific and governance resolutions in context to the protection and sustainability of sturgeon fishes, especially the one that are found in the shared Saint John River population. It informs that it is requisite to develop the Canada-U.S. Atlantic sturgeon strategy and action plan to minimize the risk of their extinction. It discusses the need to ameliorate scientific information regarding the movement of sturgeon fishes and their habitat.

Fox, D., McKown, K., Spells, A., & Waine, M. (2014). *Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) 2012 Fishing Year*. Retrieved from http://www.asmfc.org/species/atlantic-sturgeon

Appelman, M., Fox, D., & McKown, K. (2016). *Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) 2013 and 2014 Fishing Year*. Retrieved from http://www.asmfc.org/species/atlantic-sturgeon

Appelman, M., Fox, D., & McKown, K. (2017). *Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) 2015 Fishing year*. Retrieved from http://www.asmfc.org/species/atlantic-sturgeon

Appelman, M., Fox, D., & McKown, K. (2018). *Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) 2016 Fishing Year*. Retrieved from http://www.asmfc.org/species/atlantic-sturgeon

The above (4) annual reports contain information on the status of the Atlantic Sturgeon fishery management plan, status of the fishery, status of management measures and issues, current state-by-state implementation of compliance requirements, research needs, and recomendations. It also includes data on Atlantic sturgeon catch and bycatch. No reports were found to be issued 2010-2013, 2015.

Atlantic States Marine Fisheries Commission (2017). *Stock Assessment Overview: Atlantic Sturgeon*. Retrieved from http://www.asmfc.org/species/atlantic-sturgeon

The purpose of the 2017 assessment was to evaluate the status of Atlantic sturgeon along the U.S. Atlantic coast. Data from a variety of fisheries-dependent and -independent sources were reviewed and used to develop bycatch, effective population size, and mortality estimates. An egg-per-recruit (EPR) model was developed as well as trend analyses and stock reduction analysis. The Review Panel accepted the suite of analyses presented in the 2017 assessment report as a body of evidence supporting a stable to slowly increasing population of Atlantic sturgeon following the 1998 moratorium. The paucity of data available to develop reliable indices of abundance and the inability to distribute historical catches to specific rivers or DPSs precluded the application of traditional stock assessment methods, except at a coastwide level. The nature of the assessment used (i.e., stock reduction analysis) and the nature of available data did not warrant the determination of conventional fisheries reference points.

Florida Fish and Wildlife Conservation Commission (2011). *Atlantic Sturgeon Biological Status Review Report*. Retrieved from https://myfwc.com/wildlifehabitats/wildlife/biological-status/

The Florida Fish and Wildlife Conservation Commission (FWC) directed staff to evaluate species listed as Threatened or Species of Special Concern as of November 8, 2010 that had not undergone a status review in the past decade. Public information on the status of the Atlantic sturgeon was sought from September 17 to November 1, 2010. The members of the Atlantic sturgeon Biological Review Group (BRG) met on December 6, 2010. Group members were Dr. Mark Peterson (University of Southern Mississippi), Mr. Frank Parauka (United States Fish and Wildlife Service), and Dr. Jeffrey Wilcox (FWC lead) (Appendix 1). In accordance with rule 68A-27.0012, Florida Administrative Code (F.A.C.), the Atlantic sturgeon BRG was charged with evaluating the biological status of the Atlantic sturgeon using criteria included in definitions in 68A-27.001, F.A.C., and following the protocols in the Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0) and Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1).

New York State Department of Environmental Conservation (2018). Atlantic Sturgeon. Accessed 11/26/2018 Retrieved from https://www.dec.ny.gov/animals/37121.html

This webpage is a part of New York State's Department of Environmental Conservation website and includes information on management, salvage program, and general information on Atlantic

Sturgeon in the Hudson region. The page links to related pages, including a Juvenile Atlantic Sturgeon abundance index, information on monitoring, sonic and satelite tagging, and the reporting live or deat sturgeon.

National Marine Fisheries. (2012). Final Rule: Endangered and Threatened Wildlife and Plants; Final Listing Determinations for Two Distinct Population Segments of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) in the Southeast, 50 CFR Part 224. Retrieved from https://www.govinfo.gov/help/cfr

SUMMARY from Federal Register: We, NMFS, issue a final determination to list the Carolina and South Atlantic distinct population segments (DPSs) of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) as endangered under the Endangered Species Act (ESA) of 1973, as amended. We have reviewed the status of the species and conservation efforts being made to protect the species, considered public and peer review comments, and we have made our determination that the Carolina and South Atlantic DPSs are in danger of extinction throughout their ranges, and should be listed as endangered, based on the best available scientific and commercial data.

National Marine Fisheries. (2013). Interim Final Rule: Endangered and Threatened Species; Protective Regulations for the Gulf of Maine Distinct Population Segment of Atlantic Sturgeon, 50 CFR Part 223. Retrieved from https://www.govinfo.gov/help/cfr

SUMMARY from the Federal Register: We, NMFS, are issuing an interim final regulation to conserve the Gulf of Maine Distinct Population Segment (DPS) of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). On February 6, 2012, we listed the Gulf of Maine DPS of Atlantic sturgeon as threatened under the Endangered Species Act (ESA). When a species is listed as threatened under the ESA, we are required to issue protective regulations under section 4(d) of the ESA. Such protective regulations are ones deemed ''necessary and advisable for the conservation of the species'' and may include any act prohibited for endangered species under section 9(a)(1) of the ESA. This regulation extends the prohibitions listed in section 9 of the ESA to Gulf of Maine DPS Atlantic sturgeon. The prohibitions set forth in this rule are considered necessary and advisable for the conservation of this species. Given that the changes made to this rule are based on the new information that was not submitted as public comment on the proposed rule, we are publishing this rule as an interim final rule and are soliciting additional public comment. This document also announces the availability of a final Environmental Assessment that analyzes the environmental impacts of promulgating this interim final regulation.

National Marine Fisheries. (2014). Final Rule: Endangered and Threatened Wildlife and Plants; Marine and Anadromous Taxa: Additions, Removal, Updates, and Corrections to the List of Endangered and Threatened Wildlife, 50 CFR Part 17 . Retrieved from https://www.govinfo.gov/help/cfr

SUMMARY from Federal Register: We, the U.S. Fish and Wildlife Service (Service), are amending the List of Endangered and Threatened Wildlife (List) by adding several marine taxa, removing one species, and revising the entries of many more in accordance with the Endangered Species Act of 1973, as amended (Act). These amendments are based on previously published determinations by the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration, Department of Commerce, which has jurisdiction for these species.

National Marine Fisheries. (2017). Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon and the Threatened Gulf of Maine Distinct Population Segment of Atlantic Sturgeon, 50 CFR Part 226. Retrieved from https://www.govinfo.gov/help/cfr

SUMMARY from the Federal Register: We (NMFS) are issuing this final rule to designate critical habitat for the threatened Gulf of Maine distinct population segment (DPS) of Atlantic sturgeon, the endangered New York Bight DPS of Atlantic sturgeon, the endangered Chesapeake Bay DPS of Atlantic sturgeon, the endangered Carolina DPS of Atlantic sturgeon and the endangered South Atlantic DPS of Atlantic sturgeon pursuant to the Endangered Species Act (ESA). Specific occupied areas designated as critical habitat for the Gulf of Maine DPS of Atlantic sturgeon contain approximately 244 kilometers (km; 152 miles) of aquatic habitat in the following rivers of Maine, New Hampshire, and Massachusetts: Penobscot, Kennebec, Androscoggin, Piscataqua, Cocheco, Salmon Falls, and Merrimack. Specific occupied areas designated as critical habitat for the New York Bight DPS of Atlantic sturgeon contain approximately 547 km (340 miles) of aquatic habitat in the following rivers of Connecticut, Massachusetts, New York, New Jersey, Pennsylvania, and Delaware: Connecticut, Housatonic, Hudson, and Delaware. Specific occupied areas designated as critical habitat for the Chesapeake Bay DPS of Atlantic sturgeon contain approximately 773 km (480 miles) of aquatic habitat in the following rivers of Maryland, Virginia, and the District of Columbia: Potomac, Rappahannock, York, Pamunkey, Mattaponi, James, Nanticoke, and the following other water body: Marshyhope Creek. Specific occupied areas designated as critical habitat for the Carolina DPS of Atlantic sturgeon contain approximately 1,939 km (1,205 miles) of aquatic habitat in the following rivers of North Carolina and South Carolina: Roanoke, Tar-Pamlico, Neuse, Cape Fear, Northeast Cape Fear, Waccamaw, Pee Dee, Black, Santee, North Santee, South Santee, and Cooper, and the following other water body: Bull Creek. Specific occupied areas designated as critical habitat for the South Atlantic DPS of Atlantic sturgeon contain approximately 2,883 km (1,791 miles) of aquatic habitat in the following rivers of South Carolina, Georgia, and Florida: Edisto, CombaheeSalkehatchie, Savannah, Ogeechee, Altamaha, Ocmulgee, Oconee, Satilla, and St. Marys Rivers.

National Marine Fisheries Service Southeast Regional Office Protected Resoruces Division (2017). *Impacts Analysis of Critical Habitat Designation for the Carolina and South Atlantic Distinct Population Segments of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus)*. Retrieved from https://repository.library.noaa.gov/view/noaa/18672

This report describes baseline economic and regulatory conditions, overall economic impacts, impacts on national security, and other relevant impacts associated with the designation of fourteen separate occupied critical habitat units for the Carolina and South Atlantic distinct population segments (DPSs) of Atlantic sturgeon and three unoccupied units of critical habitat. Many impacts of the designation have not been quantified or monetized and so are described qualitatively. Information about numbers and types of past consultations in each critical habitat unit and input from federal agencies provided a basis for estimating the likely numbers of future consultations and related costs in different areas. This report also includes a discretionary exclusion analysis pursuant to section 4(b)(2) of the Endangered Species Act (ESA).

National Marine Fisheries Greater Atlantic Regional Fisheres Office (2017). *Designation of Critical Habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay Distinct Population Segments of Atlantic Sturgeon*. Retrieved from

The National Marine Fisheries Service (NMFS) designated critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay Distinct Population Segments (DPSs) of Atlantic sturgeon that were listed under the Endangered Species Act (ESA) on February 6, 2012 (77 FR 5880). This report describes the approach, the available information, and the required analyses used to identify critical habitat areas for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs based on the information available at the time. The report includes information on the economic, national security, and other relevant impacts anticipated as a result of designating the identified areas.

Hilton, E. J., Kynard, B., Balazik, M. T., Horodysky, A. Z., & Dillman, C. B. (2016). Review of the biology, fisheries, and conservation status of the Atlantic Sturgeon, (Acipenser oxyrinchus oxyrinchus Mitchill, 1815). *Journal of Applied Ichthyology, 32*(1), 30-66 https://doi.org/10.1111/jai.13242.

The Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus, is a large member of the family Acipenseridae, historically reaching lengths of at least 4.6 m in length (with some estimates of 5-6 m). In North America, A. o. oxyrinchus occurs in major rivers and coastal environments along the east coast from Labrador, Canada to Florida, USA; there are also naturally occurring European populations in the Baltic and North Seas. There is evidence that at least 35 North American rivers historically supported spawning populations, although only about 27 rivers are currently known or suspected to support spawning populations. All North American populations are greatly reduced from their historical levels of abundance. The commercial fishery for A. o. oxyrinchus reached its height in the late 1800s, and, in part, caused a population crash from which the species has not yet recovered. In 2012, the species was listed as threatened or endangered under the US Endangered Species Act throughout its range in the United States. It remains unlisted under the Species At Risk Act in Canada although two populations are listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada. Nevertheless, the Atlantic Sturgeon remains the subject of a regulated commercial fishery in Canada. There is a growing understanding of the biology of A. o. oxyrinchus, and this paper reviews the current state of knowledge of its biology, ecology, life history, conservation, and recovery, and provides an overview of the historical fisheries for this species. [ABSTRACT FROM AUTHOR]

Jager, Y., Forsythe, P. S., McLaughlin, R. L., Joseph J. Cech, Jr., Parsley, M., Elliott, R. F., & Pracheil, B. M. (2016). Reconnecting fragmented sturgeon populations in North American rivers. *Fisheries, 41*(3), 140-148 https://doi.org/10.1080/03632415.2015.1132705.

The majority of large North American rivers are fragmented by dams that interrupt migrations of wide-ranging fishes like sturgeons. Reconnecting habitat is viewed as an important means of protecting sturgeon species in U.S. rivers because these species have lost between 5% and 60% of their historical ranges. Unfortunately, facilities designed to pass other fishes have rarely worked well for sturgeons. The most successful passage facilities were sized appropriately for sturgeons and accommodated bottom-oriented species. For upstream passage, facilities with large entrances, full-depth guidance systems, large lifts, or wide fishways without obstructions or tight turns worked well. However, facilitating upstream migration is only half the battle. Broader recovery for linked sturgeon populations requires safe round-trip passage involving multiple dams. The most successful downstream passage facilities included nature-like fishways, large canal bypasses, and bottom-draw sluice gates. We outline an adaptive approach to implementing passage that begins with temporary programs and structures and monitors success both at the scale of individual fish at individual dams and the scale of metapopulations in a river basin. The challenge will be to learn from past efforts and reconnect North American sturgeon populations in a way that promotes range expansion and facilitates population recovery.

Melnychuk, M. C., Dunton, K. J., Jordaan, A., McKown, K. A., & Frisk, M. G. (2017). Informing conservation strategies for the endangered Atlantic sturgeon using acoustic telemetry and multi-state mark-recapture models. *Journal of Applied Ecology, 54*(3), 914-925 https://doi.org/10.1111/1365-2664.12799.

To better understand seasonal migration patterns along coastal Long Island and variation in weekly mortality, we applied multi-state mark–recapture models to detection data of Atlantic sturgeon tagged with acoustic transmitters. Accounting for time-varying detection probabilities at receiver stations allows time-varying movement rates among stations and time-varying survival rates to be quantified, thereby identifying high mortality periods, which should be the focus of conservation efforts. Areas of distribution of sturgeon populations often span hundreds of kilometres of coastline , but we focus on detailed movements along coastal Long Island at temporal scales directly relevant to the management of fishing activity in which sturgeon are caught incidentally. The research provides the application of acoustic telemetry to estimate ecological rates that can inform spatio-temporal management strategies for species of conservation concern.

National Marine Fisheries Office of Protected Resources. *Recovery Outline for the Atlantic Sturgeon Distinct Population Segments*. Retrieved from https://www.greateratlantic.fisheries.noaa.gov/protected/atlsturgeon/

This document presents the broad, preliminary outline for the recovery of all five DPSs of Atlantic sturgeon. A recovery team will likely be assembled for these species to inform the Recovery Plan, which will provide a complete roadmap for activities necessary to recover the DPSs so they no longer need the protections of the Endangered Species Act (ESA). Meanwhile, this outline will serve to guide recoveryplanning efforts and provide information for ESA Section 7 consultations, permitting activities, and conservation efforts until the formal Recovery Plan has been developed, finalized, and approved.

Rosenthal, H., Gessner, J., & Bronzi, P. (2014). Conclusions and recommendations of the 7th International Symposium on Sturgeons: Sturgeons, Science and Society at the cross-roads – Meeting the Challenges of the 21st Century. *30*(6), 1105-1108 https://doi.org/doi:10.1111/jai.12614.

The International Symposium on Sturgeons is held every 4 years, bringing together scientists working on sturgeons and paddlelfishes around the world to update the state of knowledge on this ancient but highly endangered species group, share their experiences and identify research needs, as well as identifying cooperation options for both conservation and sustainable cultivation of these unique species. They also bring together members of the affiliated sturgeon societies, including the Society to Save the Sturgeon and the North American Sturgeon and Paddlefish Society.

Wippelhauser, G. S. (2012). *A Regional Conservation Plan For Atlantic Sturgeon in the U. S. Gulf of Maine*. Augusta, ME Retrieved from https://www.maine.gov/dmr/science-research/species/documents/I%20-%20Atlantic%20Sturgeon%20GOM%20Regional%20Conservation%20Plan.pdf

In 2006, Maine, New Hampshire, and Massachusetts received a grant from NMFS (NA06NMF4720249) to conduct research on two species of concern, rainbow smelt and Atlantic sturgeon, and develop a conservation plan for each of them. Studies on Atlantic sturgeon were initiated in 2009, and were conducted only in Maine. In 2012, Atlantic sturgeon were listed under the federal Endangered Species Act (ESA) with the Gulf of Maine (GoM) distinct population segment (DPS) listed as threatened. In this Conservation Plan we briefly review the basic biology of Atlantic sturgeon, provide detailed information from research on Atlantic sturgeon in the GoM for the period 1977-2001 and 20092012, summarize the status of the GoM Atlantic sturgeon, identify threats, and include management recommendations.