Evaluation of Shortnose Sturgeon Spawning Habitat, Savannah River, Georgia and South Carolina

Submitted in support of waterway operations, and funded by the American Recovery and Reinvestment Act of 2009

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers, Savannah District (USACE) operates three large dams and one low-head dam on the Savannah River. Although the reservoirs created by the dams provide water for certain uses during droughts, there may be insufficient water for other purposes, particularly in downstream, free-flowing portions of the river. Potential impacts to migratory fish species resulting from reduced discharges during the spring spawning period is a major concern. The extent of those impacts is dependent upon the amount of suitable spawning habitat downstream of the dams which would not be adversely affected by decreased discharges (USACE 2009). The shortnose sturgeon (*Acipencer brevirostrum*), a species endemic to the Savannah River, is listed as “endangered” by the Endangered Species Act (ESA) of 1973. The Savannah River population segment may be affected by water levels and flows related to reservoirs and dams in the upper river. Recruitment, or the number of viable young produced following spawning, is of major concern for this system. Recruitment may be limited by available spawning habitat. This investigation assessed the quantity and quality of shortnose sturgeon (SNS) spawning habitats downstream of two dams on the Savannah River: the New Savannah Bluff Lock & Dam (NSBL&D) and the Augusta Diversion Dam (ADD), both located near Augusta, Georgia. Collected benthic habitat, bathymetric, and current velocity data were examined relative to habitat suitability model data from NOAA (2007). Approximately 120-125 acres of benthic habitat were identified as potentially suitable for SNS spawning in the study area between NSBL&D and U.S. Highway 301. Also, it was calculated that in the Augusta Shoals portion of the study area (i.e., downstream of the ADD), 77% of observed benthic substrates were either suitable or marginally suitable for use by SNS for spawning. Current velocity and bathymetric data were not collected or examined for that portion of the study. The study was funded by the American Recovery and Reinvestment Act of 2009.

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers, Savannah District (USACE) operates three large dams and one low-head dam on the Savannah River. Although the reservoirs created by the dams provide water for certain uses during droughts, there may be insufficient water for other purposes, particularly in downstream, free-flowing portions of the river. Potential impacts to migratory fish species resulting from reduced discharges during the spring spawning period is a major concern. The extent of those impacts is dependent upon the amount of suitable spawning habitat downstream of the dams which would not be adversely affected by decreased discharges (USACE 2009).

The shortnose sturgeon (*Acipencer brevirostrum*), a species endemic to the Savannah River, was listed as “endangered” on March 11, 1967 (32 FR 4001), and remained on the endangered species list following legislation of the Endangered Species Act (ESA) of 1973. The range of shortnose sturgeon (SNS) extends from of New Brunswick (Canada) to north Florida. The major rivers of South Carolina and Georgia that empty to the Atlantic comprise seven distinct SNS population segments recognized by the National Marine Fisheries Service (NMFS).

NMFS (1998) provides the following overview of habitat use and limiting factors: “Shortnose sturgeon inhabit the main stems of their natal rivers, migrating between freshwater and mesohaline river reaches. Spawning occurs in upper, freshwater areas, while feeding and overwintering activities may occur in both fresh and saline habitats. Habitat degradation or loss (resulting, for example, from dams, bridge construction, channel dredging, and pollutant discharges), and mortality (for example, from impingement on cooling water intake screens, dredging, and incidental capture in other fisheries) are principal threats to the species' survival.”

The Savannah River population segment is the subject of the investigation detailed on the following pages. Recruitment, or the number of viable young produced following spawning, is of major concern for this system. Recruitment may be limited by available spawning habitat, among other factors (e.g., egg production rates, mortality, spawner abundance, etc.). NMFS (1998) offered the following assessment: “During 1984-1992, over 600 adults were collected by shad fishermen and researchers using gillnets and trammel nets (Collins and Smith 1993). The ratio of adults to juveniles in this study was very high, indicating that recruitment is low in this river (Smith et al. 1992).” This investigation assessed the quantity and quality of SNS spawning habitats downstream of two dams on the Savannah River: the New Savannah Bluff Lock & Dam (NSBL&D) and the Augusta Diversion Dam (ADD). USACE intends to use this information to assess potential impacts of reduced river flows on those habitats.

Dial Cordy and Associates (DC&A) was contracted by the USACE under contract W912HN-05-D-0014, delivery order 0066, to investigate benthic substrates in the project area (Appendix A, Figure Series A). The study was funded by the American Recovery and Reinvestment Act of 2009.

2.0 STUDY FRAMEWORK AND TECHNICAL APPROACH

2.1 Shortnose Sturgeon Habitat Use

SNS spawn in early spring (early February to mid-March) in the upper reaches of the Savannah River (Hall et al. 1991). Environmental conditions suitable for spawning may be available for only 3 to 6 days (Taubert 1980b, and Buckley and Kynard 1985b, as cited in Crance 1986). Hall et al. (1991) noted spawning in Savannah River channels, commonly in bends where gravel/sand/log substrates exist. NMFS (2007) provided a concise description of spawning habitat use for SNS in the southeastern United States, including the study area. Due to its direct relevance to the Savannah River system in particular, it is transcribed below:

> "…optimal spawning habitat conditions for shortnose and Atlantic sturgeon may consist of extensive reaches of high-gradient, rocky shoal habitats in major rivers of the east. Southeastern Piedmont river basins contain extensive main stem and tributary reaches of rocky shoal habitat, often extending for hundreds of miles from the coast. For example the Savannah River historically had a nearly continuous series of rapids and shoals from just below Augusta at river mile 180 upstream to river mile 384 at Tallulah Falls. All but a few miles of this habitat is now blocked by dams and inundated by large reservoirs.
>
> "Rocky shoals and outcrop sites may contain cobble-gravel mixtures, large and small boulders, bedrock ledges interspersed with sand or gravel runs and riffle-pool complexes. The coarse substrates and higher gradient reaches provide a diversity of microhabitats for invertebrate fauna and an infinite variety of well-oxygenated refugia for sturgeon eggs and larvae. These shoal, or "rapids complex" habitats are generally present at the moderate to high gradient transition between Coastal Plain and Piedmont physiographic provinces, and at other locations well into the Piedmont sections of these rivers. Gravel and rock outcrops, and point-bars with similar habitat characteristics may occur in Coastal Plain sections of some rivers. In nearly all river basins the majority of rapids-complex spawning habitat is blocked by major hydropower and navigation dams and is no longer accessible to spawning sturgeon and other diadromous species."

While the above provides an excellent overview, to better quantitatively evaluate and manage potential SNS habitat, USFWS and NMFS, respectively, published *Habitat Suitability Index Models and Instream Flow Suitability Curves: Shortnose Sturgeon* in 1986, and *Draft Spawning Habitat Suitability Index Models and Instream Flow Suitability Curves, Model I: Shortnose Sturgeon, Southeastern Atlantic Coast River Basins* in 2003 (revised 2 January 2007). The latter focused on only spawning habitat for rivers in the southeastern United States, whereas the former was drafted for general use, as it was based on biological and ecological data from across the wide range of the species. The 1986 habitat suitability index (HSI) model comprised two major components: adult summer feeding habitat quality and spawning/incubation habitat quality. Three measurable/observable habitat variables informed the quality of each of the two major components: water temperature, stream velocity, and substrate. In essence, certain temperatures, velocities, and substrates were conducive to adult feeding, and certain (perhaps different) temperatures, velocities, and substrates were conducive to spawning.

The 2007 HSI (NMFS 2007) spawning model updated the spawning components of the 1986 HSI (Crance 1986) model. Notably, water depth was added as a fourth critical variable. As noted above, the 2007 spawning model was intended for application to southeastern Atlantic coast rivers only. Furthermore, Crance (1986) and NMFS (2007) intended all HSIs to be used as “starting points” which would be modified “in response to project-specific conditions and needs.” Finally, NMFS (2007) cautioned that although the criteria used for HSI were considered to be preliminary, they had utility for habitat characterization.

NMFS (2007) utilized four variables in the spawning HSI model. For the substrate variable, it recognized bedrock, gravel, and cobble-gravel benthic types as being related to such critical functions as oxygenation, low substrate embeddedness, egg attachment sites (fertilized SNS eggs are adhesive and demersal, according to Meehan 1910, as cited in Crance 1986), and predator protection. Suitability index (SI) values were assigned to these and other categories, or classes, of substrates for use in the HSI. The SI values are shown in Table 1, where an index value of “1.0” indicates the most conductive class (cobble/gravel). As with the variable characteristics above, NMFS (2007) assigned SI values to minimum water depths associated with spawning and egg development (Table 2). Crance (1986) discussed depth as a potential factor in spawning. Depth can affect water velocities and dissolved oxygen, and is related to water transparency, water temperature at depth, and benthic community composition. Depths of 2.0 to 4.0 meters were considered most typical for spawning. NMFS (2007) also provided SI values for various current velocities (Table 3). Crance (1986) acknowledged the importance of water velocity and temperature, which are highly dependent on depth, and their effects on SNS movement. Velocities of 0.4 to 1.0 meters per second (m/s) were most commonly associated with spawning. It was not stated in NOAA (2007) whether these velocities correspond to bottom or surface currents. A fourth variable utilized in the HSI was temperature (not shown in tables). The optimal range comprised 9-12 degrees Celsius.

Table 1: Suitability index values by substrate type (NMFS 2007)

Class	Benthic substrate	Suitability Index (SI) Value[1]
1	Mud, soft clay/fines	0.0
2	Silt, sand (diameter < 2.0 mm)	0.0
3	Sand, gravel (diameter > or = 2.0 mm)	0.5
4	Cobble/gravel (diameter > 64 mm to < 250 mm)	1.0
5	Boulder (diameter 250 mm to 4,000 mm)	0.8
6	Bedrock with fissures having gravel/cobble mixtures	0.6
7	Bedrock smooth with few fissures or gravel	0.2

[1]1.0 indicates highest suitability; 0.0 the lowest.

Table 2: Suitability index values by water depth (NMFS 2007)

Depth (meters)	Suitability Index (SI) Value[1]
0.3	0.0
0.5	0.2
1.0	0.5
2.0 to 4.0	1.0
5.0	0.8
6.0	0.6
7.0	0.4
> or = 8.0	0.2

[1]1.0 indicates highest suitability; 0.0 the lowest.

Table 3: Suitability index values by water velocity (NMFS 2007)

Water velocity (meters/sec)	Suitability Index (SI) Value[1]
0.1	0.0
0.4 to 1.0	1.0
1.5	0.4
1.7	0.2
> or = 1.9	0.0

[1]1.0 indicates highest suitability; 0.0 the lowest.

2.2 Study Area

This investigation covered two areas (Appendix A, Figure Series A): (1) between the NSBL&D (river mile 187) and the U.S. Highway 301 bridge (river mile 118.7), and (2) Augusta Shoals (also known as the Savannah Rapids), comprising the 7,200 linear meters (4.47 miles) of stream downstream of the ADD. The ADD diverts some water to the historic Augusta Canal approximately three miles north of the Interstate 20 bridge over the Savannah River. The study area excluded the section of river between approximately downtown Augusta and the NSBL&D. The dam creates somewhat "pooled" conditions in this area of the river. The study area comprised the river-associated margins of the following counties: Edgefield, Aiken, Barnwell, and Allendale of South Carolina; and Columbia, Richmond, Burke, and Screven of Georgia. The largest nearby community is the City of Augusta (GA). North Augusta (SC) lies on the opposite side of the river. Land use, but for urban and suburban metropolitan Augusta and several smaller urban areas and towns, comprises agriculture, silviculture, pastures, fields, and forests, including some restricted use areas, such as those associated with U.S. Department of Energy's "Savannah River Site" on the South Carolina side of the river. The Savannah River within the limits of the study area range from typically 250 to 600 feet wide, but occasionally wider in the shoals area, which included some islands.

2.3 Methods

2.3.1 Overview

The primary objective of the present investigation was to assess the two portions of the study area for suitability as SNS spawning habitat. For the study area between NSBL&D and U.S. Highway 301, three (of the four) physical habitat elements presented as primary determinants of SNS success (in NOAA 2007), namely, benthic substrate type, river depth, and current velocity, were assessed. Investigations of the Augusta Shoals portion of the study area considered only bottom type characteristics, as only benthic substrates were sampled. For that area, neither water depths nor current velocities were quantified. Neither portion of the investigation considered the effect of water temperatures, a critical element in the HSI spawning model, as no such data were taken in the field or researched for incorporation in this assessment.

2.3.2 Study Area: New Savannah Bluff Lock and Dam to U.S. Highway 301 Bridge

Overview. For the section of the river between NSBL&D and U.S. Highway 301, bottom substrates were characterized, water depths were measured and documented, and stream flow velocities were measured and recorded.

Benthic substrate characterization. Benthic (bottom) substrate information was obtained using side-scan sonar with a dual frequency sensor. Evaluation of bottom substrates involved three steps. The first was initial data collection using a vessel-towed, 600 kHz side-scan sonar rig (50 meter range) with sub-meter-accurate GPS positioning. Data collection, along three shore-parallel transects spaced approximately 200 feet apart, was performed 15-22 October 2009 and 1-4 November 2009. Collected data typically overlapped by 200% to ensure thorough coverage. Side-scan mosaics, created by SonarWiz 4 software, were created and visually interpreted to determine benthic substrates type and coverage. Draft maps of bottom type based on side-scan indications were created via AutoCAD. The second step involved collecting sediments directly from the riverbed to confirm (ground-truth) sonar signatures or to provide direct observations for areas where questionable side-scan signatures were observed. More than 100 sites were visited for ground-truthing purposes, and 98 sediment samples were collected from that effort using a standard (all stainless steel) Ponar benthic grab (typically, material from multiple attempts was composited and subsampled for analyses). Samples were described in the field and then bagged for subsequent examination. Collected sediments were later oven-dried and sieved, permitting grain-size analyses. The resulting data and descriptions of sediments were compared and verified. Finally, the original benthic habitat maps were corrected, if necessary, using the sediment samples collected *in situ*. Digital substrate map lines/boundaries from CADD files were digitized into polygons using ArcInfo (version 9.2) GIS software, final maps were prepared, and coverage (in acres) by each substrate type was calculated. Furthermore, because side-scan sonar detection methods could capture neither the position or composition of exposed gravel bars, those that were emergent during the ground-truthing efforts were surveyed using a GPS. The bottom substrates on the emergent gravel bars were characterized, quantified, and mapped. Samples of exposed sediments in the exposed sand/gravel bars were taken in order to perform grain-size distribution analyses. Maps showing the distribution of sediment types within the study area were created, and the coverage of each type was calculated using ArcInfo (version 9.2) GIS software. Maps used color-coding to indicate both bottom type and level of suitability of benthic cover for potential spawning habitat (i.e., suitable, marginally suitable, or not suitable).

River depths. Following substrate characterization, a bathymetric survey was conducted during 7-10 July 2010. During this interval, daily mean gauge height was approximately 100 feet (NGVD29) at USGS gauge 02197000, located on the Savannah River at Augusta (33°22'25" -81°56'35"; 95.58 feet above sea level), and daily mean discharge ranged from approximately 5,000 to 6,200 cfs. The bathymetric survey focused only on where side-scan sonar and ground-truthing indicated SNS spawning habitat was present. At least one survey transect was positioned in each SNS habitat polygon identified from the bottom type investigations; more were assigned if the habitat was larger than 1000 feet in diameter. Depth data for 153 transects were collected. Vessel rigs utilized an Odom CV-100 EchoSounder and a Bathy 500 EchoSounder, sub-meter-accurate GPS x-y positioning (in NAD83), and an RTK system in order to provide elevation data (vertical datum in NAVD88). CADD data (xyz format) were transcribed into ArcInfo 9.2 for plotting. Each transect was plotted over the identified potential SNS spawning habitat. Color-coding was used to indicate the depth of water along each transect and to show level of suitability of depths as potential spawning habitat (i.e., suitable, marginally suitable, or not suitable).

Flow velocities. At approximately the same time as the river depth data were collected, another crew used a boat-mounted acoustic Doppler profiler (SonTek MiniADP River Surveyor system; 1.5 MHz), or "ADP", and a sub-meter-accurate, differentially corrected GPS system (TopCon model GMS-2) connected to a laptop computer to measure the flow velocities on the predetermined 153 transects (noted above) known to correspond to benthic substrates that were potentially beneficial for SNS spawning. Transect coordinates were pre-loaded onto a boat-mounted Garmin GPS 172 map/sounder for navigation to transect start and end points. As much of the wetted width of each transect was sampled as possible. Due to the blanking distance (0.4 m) and mounting depth (0.2 m) of the transducer, measured velocities include all but the top 0.6 m of the water column (the "surface" reading therefore is based on data collected between the upper 0.60 and 0.65 meter of the water column). Survey data was processed using SonTek's RiverSurveyor (v4.60) and ViewADP Pro (v4.03) software. RiverSurveyor was used to create discharge summaries, export transect positional data (profile number, distance, latitude/longitude) and to provide screenshots of cross-sectional velocity profiles for each transect. ViewADP Pro was used to export individual cell velocity data for each transect. Data exported from each of these programs was combined into a single spreadsheet for each transect. Spreadsheets were individually examined. Areas along survey transects where current velocities along the benthic interface were either marginally suitable or unsuitable for spawning and early development were plotted on maps.

Habitat assessment. Using the combined information above, the suitability of the bottom substrates as spawning habitats for shortnose sturgeon (SNS) was assessed based on habitat suitability criteria in NOAA (2007), with the assumption that water temperatures are adequate during spawning and early development.

2.3.3 Study Area: Augusta Shoals

For this reach, only bottom substrate characterization was conducted (no bathymetric, velocity, or temperature data were collected). Investigators attempted to collect sediments from 57 locations along 18 evenly spaced transects (perpendicular to shore) throughout this reach on 16 January 2010 and during 8-10 March 2010. Since low flow periods were the time period of concern, samples were taken during these near-low periods. Throughout most of this area, samples were not obtainable using traditional methods as much of the bottom comprised either bedrock or large boulders. In many locations, substrates were visually observed (and collected by hand if practicable), but in others, an eight-foot-long aluminum pole was used to test substrate consistency. For samples that were obtained and comprised grains less than 10 mm in diameter, grain-size distribution analyses were performed in a laboratory.

The benthic coverage across the shoals area was generally characterized. Approximations (20%, 50%, etc) of benthic habitat coverage were made, based on the relative prevalence of cover types found at the 57 sample stations. Maps showing the locations of samples and bottom type were prepared. Depths were observed during the field effort, but were not measured. Current velocities were likewise noted, but not quantified. Primarily based on resulting benthic habitat data, the suitability of the bottom substrates as spawning habitats for SNS was assessed based on the habitat suitability index values provided for bottom type in NOAA (2007), with the assumption (like that made for the study area between NSBL&D and U.S. Highway 301) that water temperatures are adequate during spawning.

3.0 RESULTS

3.1 Study Area: New Savannah Bluff Lock and Dam to U.S. Highway 301 Bridge

Benthic substrate characterization. The vast majority of benthic habitat (over 95%) in the study area between NSBL&D and U.S. Highway 301 (see Appendix A, Figure Series B) comprises silt and sand (having particles with diameter < 2.0 mm). The relative coverage of the other bottom types is listed in Table 4. The habitats most associated with SNS spawning, cobble/gravel (with particle diameter ranging from 64 to 250 mm) and boulder (rock over 250 mm in diameter), comprised 5.4 and 31.3 acres in this study area, respectively. Combined, these types cover less than 1.4% of this study area. The “boulder” classification appeared to comprise riprap in most cases, and the “cobble” classification appeared at only two locations in the river. The second most common benthic habitat mapped during the survey of this area was sand/gravel (particles with diameter > 2.0 mm to < 64 mm). This is considered marginally suitable as SNS spawning substrate, and comprised 91.0 acres. But for two gravel bars that projected into the center of the channel, all substrates considered suitable or marginally suitable SNS spawning substrates were restricted to the margins of the river. It should be observed that although various substrates may be considered more or less suitable for spawning, and coverage data are provided for each type, the acreages provided do not necessarily correspond to available spawning habitat (see discussion of *habitat assessment* below). If depths or current velocities (or temperature, or dissolved oxygen levels) are not suitable, even though the substrate is, SNS may not spawn.

Table 4: Benthic substrate coverage in New Savannah Bluff Lock and Dam to U.S. Highway 301 study area

Class	Benthic substrate	SI[1]	Total Acreage	Percent Coverage
1	Mud, soft clay/fines	0.0	1.0	< 0.1
2	Silt, sand (diameter < 2.0 mm)	0.0	2505.2	95.1
3	Sand, gravel (diameter > 2.0 mm to < 64 mm)	0.5	91.0	3.5
4	Cobble/gravel (diameter > 64 mm to < 250 mm)	1.0	5.4	0.2
5	Boulder/riprap (diameter 250 mm to 4,000 mm)	0.8	31.3	1.2

[1] 1.0 indicates highest suitability; 0.0 the lowest.

Though many sand bars (exposed and submerged) were observed throughout the study area, only two gravel bars (where sediments were generally characterized as sand/gravel having diameters> 2.0 mm to < 64 mm) were observed and mapped. These bars are shown in Appendix A, Figure Series B and labeled as Gravel Bar 11 (0.4 acres, located at 33 18 10.486 N/ 81 52 53.087 W) and Gravel Bar 14 (1.9 acres, located at 33 22 20.336 N/ 81 56 39.654 W). These gravel beds were included in the acreage/percent coverage listed in Table 4, Class 3, even though these were emergent/exposed at the time of the survey.

River depths. River depths along the transects are represented categorically, according to habitat suitability, in Appendix A, Figure Series B. Depths in the 1.3-to-5.7-meter category were well represented in this study area, regardless of whether they fell within areas of suitable spawning substrates. There were many areas where these depths, which contribute to suitable spawning habitat, overlapped with suitable substrate as well. Slightly deeper or shallower waters were also observed in areas of suitable substrates. This would decrease the suitability of such areas. For example, several areas with depths of 0.71 to 1.3 meters (typically found near shore) were within areas with suitable spawning substrates. SNS might be slightly less apt to spawn in such a location due to marginally suitable depths. A few deeper "holes" in the 5.71-7.30 meter range were also observed in areas with suitable substrates.

Flow velocities. Velocity data were provided according to position within a cross-section created along each transect. This allowed observations of velocity in multiple cells across the section, at various depths and distances from either bank/shoreline. An example of the data output/spreadsheet representing all the observed values in the cross-section is provided in Exhibit 1 below. Data provided in each spreadsheet was provided as follows:

Column A: Vertical#
Column B: Distance from Start (meters)
Column C: Latitude (decimal degrees)
Column D: Longitude (decimal degrees)
Columns E through R: velocity (cm/sec) at depth Y (meters),
where Y is the depth listed at the top of each column.

NOTE: Individual cells coded "3276.7" are blanked regions.

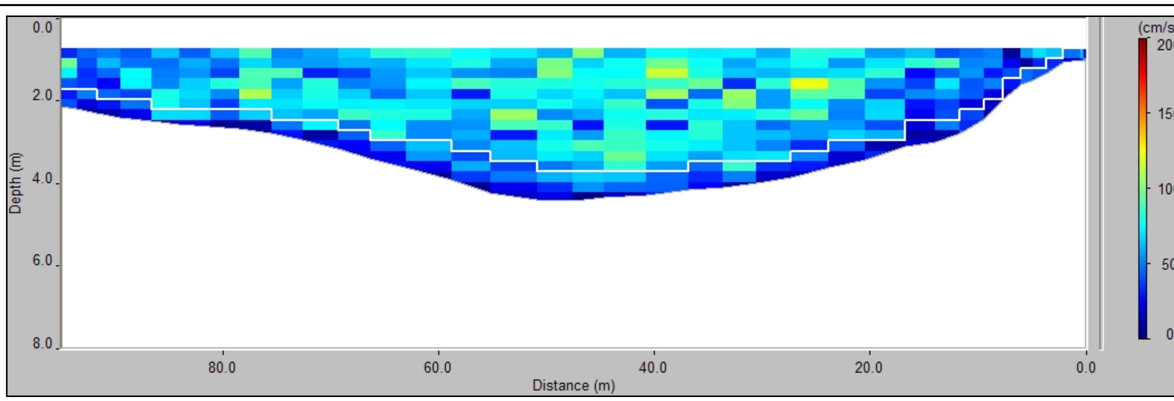
In most cases velocity profiles consisted of vertical cell depths of 0.25 m, with an average of 40 vertical shots per transect. In cases where the maximum depth at a given transect was greater than 6.5 m (e.g., transect 151), cell depths were increased to 0.6 m to allow for a larger profiling range. Data resulting from each transect were also observable via a graphic representation, an example of which is shown in Exhibit 2. The observer views the image as if looking downstream through the cross-section, i.e., the Georgia bank is on the right.

The average water velocity for all 153 transects in this study area, combined, was 0.59 m/sec. A summary of all transect data can be found in Appendix B. Due to low water levels on 12 July 2010 (one of the survey dates), the transect just below the gravel bar at NSBLD (transect 152) could not be surveyed in continuous manner since a portion of it was not submerged. As such, it was surveyed in two pieces: from the GA bank to the edge of the gravel bar (T_152a) and from the SC bank to the edge of the gravel bar (T_152b). To provide additional information, we also conducted a survey along a cross-section just below the gravel bar that allowed us to collect continuous transect data (T_152c).

Exhibit 1: Example of processed single-transect data in spreadsheet format

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Vertical#	Distance (m)	Lat	Lon	0.65	0.9	1.15	1.4	1.65	1.9	2.15	2.4	2.65	2.9	3.15	3.4	3.65	3.9
2	1	0.2	32.93908392	-81.50324724	20.6	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
3	2	0.2	32.93909884	-81.50325479	49.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
4	3	0.4	32.93910061	-81.50326537	57.6	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
5	4	0.5	32.93909741	-81.50326112	67.1	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
6	5	2.1	32.9391014	-81.50325874	65	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
7	6	3.7	32.9391115	-81.50323681	94.6	60.6	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
8	7	4.9	32.93911448	-81.50322069	82.8	39.9	57.1	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
9	8	6.0	32.93911492	-81.50320237	73.9	27	64	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
10	9	7.7	32.93911315	-81.5031773	33.8	19.9	66.1	62.2	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
11	10	9.5	32.93910908	-81.50315336	68.9	70.7	49.1	57.3	51.4	24.3	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
12	11	11.7	32.93910261	-81.50312328	69	50.8	59.8	68	44.7	34.2	6.1	20.1	3276.7	3276.7	3276.7	3276.7	3277	3277
13	12	13.9	32.93907906	-81.5031018	12.7	101.1	41.9	57.3	51.4	39.4	34.6	44.3	46.5	3276.7	3276.7	3276.7	3277	3277
14	13	16.7	32.93906464	-81.50307715	91.1	92	69.8	56.7	56.1	45.2	54.3	47.6	48.7	3276.7	3276.7	3276.7	3277	3277
15	14	20.4	32.93905283	-81.50303924	88.5	103.2	84.3	85.3	84.7	82	74.5	73.4	94.5	72.6	3276.7	3276.7	3277	3277
16	15	23.8	32.93904234	-81.50301643	82.9	67.7	80.8	81.6	103.9	62.8	56.7	52.5	84.8	51.4	51.6	3276.7	3277	3277
17	16	27.3	32.93902831	-81.50297559	102.6	81.6	72.2	119.8	76.5	50.4	96.8	63.3	75.4	65.9	36.8	68.5	3277	3277
18	17	30.5	32.9390157	-81.50294722	72.4	67.3	60.7	64.6	77.2	89.3	86.2	47.7	65.8	71.3	80.3	51.6	49.9	3277
19	18	33.7	32.93900142	-81.50291797	56.5	68.7	80.5	42.4	118.2	78.1	72.2	34.8	66.8	77.5	82	112.3	97.1	3277
20	19	36.9	32.93898598	-81.50289127	82	83.1	50.5	78.7	31.4	48	78.8	66	68.2	65.9	54.1	34.3	61.1	3277
21	20	40.7	32.93897537	-81.50285189	96	106.6	135	92	102.5	80.3	104.4	92.4	97.6	111.4	100.4	98.5	73.5	73.9
22	21	44.7	32.93896672	-81.50281315	71.6	104.3	103.1	97.3	93	101.9	99.4	88.7	111.7	94.4	110.8	111.8	91.1	64.6
23	22	47.6	32.93895428	-81.5027816	107.5	75.1	81.1	92.6	69.7	57.2	52.5	51.3	55.7	84.5	53.8	54.9	61.4	79.6
24	23	50.8	32.93894066	-81.50275118	77	88.1	102.5	99	84.8	87.4	54.4	99	73.4	51.4	46.4	67.6	50.7	49.7
25	24	55.1	32.93893912	-81.50270819	108.1	123.6	117.9	132.1	112.4	88.9	150.6	132.4	86.3	118.3	107.2	56.1	98.8	3277
26	25	58.7	32.93893868	-81.50267421	95.7	118.1	87.8	128.3	81.8	120	107.5	97.8	85	90.7	59.1	101.1	3277	3277
27	26	62.9	32.93893843	-81.50262384	126.5	128.6	82.5	122.6	101	118.4	103.6	116.4	113.6	110.6	30	3276.7	3277	3277
28	27	66.3	32.9389391	-81.50258693	130.5	93.2	88.5	89.6	81.9	113	112.2	98.3	88.2	72.5	3276.7	3276.7	3277	3277
29	28	69.3	32.93893733	-81.50255486	96	86.6	73.5	86.6	82.1	104.6	123.7	78.4	85.2	3276.7	3276.7	3276.7	3277	3277
30	29	72.5	32.9389368	-81.50251897	79.2	92	74.7	93.5	101.3	116.4	96.5	82.1	3276.7	3276.7	3276.7	3276.7	3277	3277
31	30	75.4	32.93893246	-81.50249507	62.1	85.8	102.3	70.3	82.4	81.6	92.4	106.6	3276.7	3276.7	3276.7	3276.7	3277	3277
32	31	78.4	32.93893525	-81.50245179	113.2	84.8	116.4	129.5	136.4	94.3	79.2	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
33	32	81.1	32.93893311	-81.50242245	65.6	67.1	56.7	112.1	71.2	77.9	73.2	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
34	33	84.0	32.93893622	-81.50238902	79.2	64.5	73.5	90.9	91.2	72.8	31.1	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
35	34	86.6	32.93893717	-81.50235911	86.3	51.5	65.9	91.7	89.5	92.9	78.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
36	35	89.5	32.93894207	-81.50233168	83.9	85.6	96.2	96.6	66.1	68.3	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
37	36	91.6	32.93894317	-81.50230025	79.1	64.2	64.1	61.1	48.2	36.1	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
38	37	93.5	32.93894035	-81.50228003	51.4	55.4	38	29.1	42.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277
39	38	95.0	32.93893649	-81.5022643	82.9	73.5	15.2	36.8	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3276.7	3277	3277

Exhibit 2: Example of graphic representation of cross-section data for a single transect



Because benthic habitats are critical for SNS, we examined current velocities at/near the bottom of the water column to assess whether velocities were suitable, marginally suitable, or not suitable according to NOAA (2007). The vast majority of measured velocities along the bottom of the river (bank to bank) among all transects were considered suitable (between 0.3 and 1.3 meters/second), but there were many positions within areas having suitable SNS spawning substrates where velocity was either unsuitable or marginally suitable (these locations are noted by black cross-hatching on maps of Figure Series B in Appendix A). Due to this, it might be reasonable to assume that current velocity may limit the amount of spawning habitat within the river even if proper substrates are present. Of the 153 transects throughout the study area, there were 55 transects that had observed velocities less than 0.3 m/s at/near the bottom of the water column, and of those 55, there were 42 transects in which unsuitable or marginally suitable velocities were observed in an area known to comprise a suitable or marginally suitable substrate class.

Habitat assessment. The HSI reports (Crance 1986 and NOAA 2007) state, respectively, “the variable with the lowest HSI defines the upper potential limit for shortnose sturgeon populations in the habitat being evaluated,” and, “the overall habitat suitability value expressed in this model is simply the lowest of the four individual Suitability Index (SI) values.” Given that, the individual model elements were not intended to be “combined” per se, but only compared to find which value is the lowest. That value is then considered the “overall suitability.” Implicit in this evaluation procedure is that (1) all four types of data (substrate, temperature, depth, and velocity) are available and (2) all types of data are formatted to portray to a distinct geographic area.

For the approximately 2,600-acre section of the river from NSBLD to Highway 301, suitable and marginally suitable benthic coverage combined was approximately 127.7 acres, or 4.9% of this study area. Water temperature data were not collected, though reservoir discharges and precipitation could significantly affect stream temperature. Certainly, deeper parts of the channel would comprise a thermocline with cooler temperatures at depth. For our purposes in attempting to qualitatively determine suitable habitat, we assumed that during spawning season, temperatures are adequate. Depth and current velocity data were collected, but it could be represented in only a linear dimension, due to the transect method employed for the study. Sometimes a single transect was the only one planned for depth and velocity data collection, even if the substrate polygon which it bisects covered up to 10 acres. Extrapolating data collected along a single line in such as case would not meet statistical rigor. For example, we cannot state that “50% of the transect is sub-optimal for depth. Therefore, 50% of the substrate polygon (delineated area on a map) is sub-optimal for depth.” Furthermore, because both depth and current data were collected on slightly different positions (due to river currents and vessel positioning; it was nearly impossible to have two vessels over the exact, same locations during consecutive data collection), even if vessels followed the same planned transects.

Given these constraints above, the reported data/maps can reasonably inform resource managers of the likely suitability of an area, but not definitively provide absolute acreages pertaining to suitability, marginal suitability, or unsuitability. That said, a stepwise approach may be useful for interpreting collected data. Given the available coverage of suitable and marginally suitable benthic substrates, it may be most convenient to consider depth next, because, based on the observed data, there are very few points on the sample transects (see Figure Series B) where depth would be considered unsuitable according to NOAA (2007) criteria. In fact, based on a visual appraisal of mapped data, it appears that very few (if any) of the soundings indicating unsuitable depths are located within the areas comprising suitable or marginally suitable benthic substrates. Given that, it appears that the overall suitability of the 127.7 acres of benthic habitat would not be diminished by depth. Depth appears not to limit potential habitat, but in many locations, it appears that current velocity may. Among all 153 transects, 42 involved observations of river-bottom current velocities that were unsuitable or only marginally suitable (i.e., less than

0.3 m/s) within areas where conducive benthic substrate was observed. However, for the majority of these occasions, the current was not completely unsuitable (less than 0.2 m/s). It was estimated that only approximately 15% of the 42 transects (or 6 out of the total 153) had benthic current velocities considered unsuitable. Therefore, although marginally suitable velocities were fairly common in areas with conducive benthic coverage, and may decrease the suitability of these areas to some degree, unsuitable velocities were more uncommon among transects, as they occurred in only about 4% of all transects. Given that, it appears that where suitable or marginal benthic substrates were present, depths and currents proved to be fairly inconsequential. Hence, the amount of suitable or marginal spawning habitat in this study area comprises approximately 120 to 125 acres, i.e., only slightly less than the 127.7 acres identified above as suitable or marginal habitat based on only benthic substrate characterization. his estimate does not address any influence that temperature may have on SNS spawning habitat (see p. 31 of NMFS 1998), and further assumes that dissolved oxygen levels are appropriate in spawning and developmental habitats.

3.2 Study Area: Augusta Shoals

The shoals area of the study was dominated by consolidated substrates (Table 5). Boulders and bedrock were most commonly observed, and there was considerable difficulty in determining which was present if they were in deeper water. Dragging the aluminum probe along the bottom provided some indication of which was at hand; boulders tended to be more round, and bedrock flatter. The probe method was able to also somewhat helpful in detecting gravel, sand, or cobble between rocks or sections of bedrock. Of the 57 sites where substrate data were observed/collected in Augusta Shoals/Savannah Rapids (see Figure Series C in Appendix A), the combined frequency of sites associated with substrate types considered suitable by NOAA (2007) was 40% and the combined frequency of marginally suitable sites was 37%. Approximately 33% of sites appeared to have unsuitable substrates.

Table 5: Benthic substrate frequency in Augusta Shoals study area

Class	Benthic substrate	SI[1]	Number of Sites	Frequency (%)
1	Mud, soft clay/fines	0.0	0	0
2	Silt, sand (diameter < 2.0 mm)	0.0	7	12
3	Sand, gravel (diameter > 2.0 mm to < 64 mm)	0.5	0	0
4	Cobble/gravel (diameter > 64 mm to < 250 mm)	1.0	3	5
5	Boulder (diameter 250 mm to 4,000 mm)	0.8	20	35
6	Bedrock w/ fissures w/ gravel/cobble mixtures	0.6	21	37
7	Bedrock smooth w/ few fissures or gravel	0.2	6	11

[1]1.0 indicates highest suitability; 0.0 the lowest.

Quantitative current velocity and bathymetric data were not assessed for the Augusta Shoals area. Many portions of this reach are very shallow (or emergent), especially during low-water conditions, and may not be suitable for spawning sturgeon. Also, many areas have very high current velocities, again, especially during low-water conditions, and may not be suitable for that reason. However, it appears that even with those considerations, the Augusta Shoals area possesses some reasonable potential as spawning grounds.

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APPENDIX A:
FIGURES

APPENDIX B
DATA
(DVD Enclosed)