U.S. Army Corps of Engineers
Charleston District

APPENDIX K

CHARLESTON HARBOR POST 45
CHARLESTON, SOUTH CAROLINA

Fish Habitat Assessment

03 October 2014

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1.0 INTRODUCTION

The Charleston Harbor Post 45 feasibility study analyzed and evaluated improvements to Charleston Harbor. Objectives of the study were to:

1) Reduce navigation transportation costs of import and export trade through Charleston Harbor and contribute to increases in national economic development (NED) over the period of analysis;
2) Reduce navigation constraints facing harbor pilots and their operating practices including limited one-way traffic in certain reaches; and
3) Develop an alternative that is environmentally sustainable for the period of analysis.

The third objective above takes into consideration both the short-term (i.e., resulting directly from construction itself) and long-term effects of the selected alternative on project area wetlands, water quality, air quality, noise, land development, and environmental justice. To inform users of environmental impacts, a careful analysis of potential harbor improvements was conducted. Analyses included determining environmental effects of the Federal project (1) in its existing (45-foot channel depth) condition, (2) in a future-without-project (FWOP) condition, and (3) in the future condition given that the selected alternative is constructed. The USACE feasibility study analyzed, inventoried, and quantified environmental impacts related to construction incrementally based on potential dredge depths for the Entrance Channel, Lower Harbor, and Upper Harbor, in addition to combinations of deepening in certain areas of the Federal project and widening measures. The construction alternatives that were examined were determined based on anticipated vessel sizes/drafts and traffic/utilization over the expected "life of the project." Future-with-project (FWP) evaluations were performed for proposed depths up to and including -54 feet MLLW (Entrance Channel); -52 feet (Lower Harbor) and -48 feet (Upper Harbor). The array of alternatives that were examined in the feasibility study included navigational improvements to some or all of the channels in Charleston Harbor, including (1) deepening channel(s), (2) widening channel(s), (3) adjusting existing channel alignments/bend easing, and (4) widening and/or lengthening turning basins. A detailed description of the alternatives can be found in the main report. Environmental impacts of the project were compared to environmental attributes that would be present in the FWOP condition.

Environmental assessments must be conducted to determine if the navigation improvements, including deepening and widening channel reaches, would adversely impact fish species.

2.0 TECHNICAL APPROACH

2.1 Habitat Suitability Modeling

In order to better understand the implications of deepening the harbor on fisheries and the ecosystem, the US Army Corps of Engineers (USACE) has applied US Fish and Wildlife Service Habitat Suitability Index (HSI) models for representative species in order to evaluate effects of project alternatives. HSI models are approved for use by the USACE Ecosystem Planning Center of Expertise. This series of models was developed to provide habitat information for evaluating impacts on fish and wildlife habitat from water or land use changes (Schamberger et al., 1982). The models reference numerous literature sources in order to consolidate scientific information on species habitat relationships. All models are based on a numerical index of habitat suitability on a 0.0 to 1.0 scale (1.0 being the best habitat) (Schamberger et al., 1982). Their purpose is to serve as a basis for improved decision making and increased understanding of habitat relationships (Schamberger et al., 1982).

2.2 Environmental Fluid Dynamics Code

The hydrodynamic model (Environmental Fluid Dynamics Code, or “EFDC”) was used to predict pre- and post- project salinity, temperature, currents, and dissolved oxygen conditions within each geographic “cell” of the project area to support impact evaluation (Figure 1). Each cell was analyzed for the existing condition, the future-without-project (FWOP) condition (year 2071 / with sea level rise), as well as each feasible alternative, and displayed using Geographic Information System (GIS). National Marine Fisheries Service (NMFS) (1998) indicated that essential habitat can easily be portrayed in GIS format. Putting the data into a GIS database to share with the natural resource agencies and other interest groups will be helpful for visualizing various predicted habitat changes. This approach is meant to guide decision making and evaluation of impacts, and has been demonstrated as acceptable by the Savannah Harbor Expansion Project as well as the Jacksonville Harbor Navigation Study.

2.3 Post-Processing EFDC Data

Charleston Harbor Deepening Study (Post 45) hydrodynamic and water quality models were developed and finalized by USACE based on EFDC. A Charleston Harbor specific post-processor was developed by Tetra Tech Inc. to analyze the model results of various deepening scenarios as well as the existing and future without project condition. This processor is a standalone program that can read EFDC output files (BMD files) and generate required output in specific formats in accordance with requirements developed by USACE and the ICT. The hydrodynamic and water quality models identified changes in salinity, dissolved oxygen, temperature, and velocity that would be expected to occur throughout the harbor and its rivers.

Within the HSI’s, each of the variables for the species has a suitability graph that gives the relationship between the variable and the suitability index. These relationships were taken from the HSI model and the functions for the curves were created in the post-processor of the EFDC model in order to facilitate faster generation of outputs. For example, the below documentation shows an example of the suitability index for mean water temperature for shortnose sturgeon foraging adults (Figure 2). In this case, the post-processor uses the below function to define this curve:

```
Function SS1(x)
Real a1,b1,a2,b2,x,SS1
A1=1./3.;b1=-8./3.;a2=-1./13.;b2=35./13.
IF(x.LT.8.)SS1=0
IF((x.GE.8.).AND.(x.LT.11))SS1=a1*x+b1
IF((x.GE.11.).AND.(x.LT.22.))SS1=1
IF((.GE.22.).AND.(x.LT.35.))SS1=a2*x+b2
IF(x.GE.35.)SS1=0.
RETURN
End !SS1
```

where GE = greater than; LT = less than

All functions in the HSI models were built in a similar fashion to the above example.

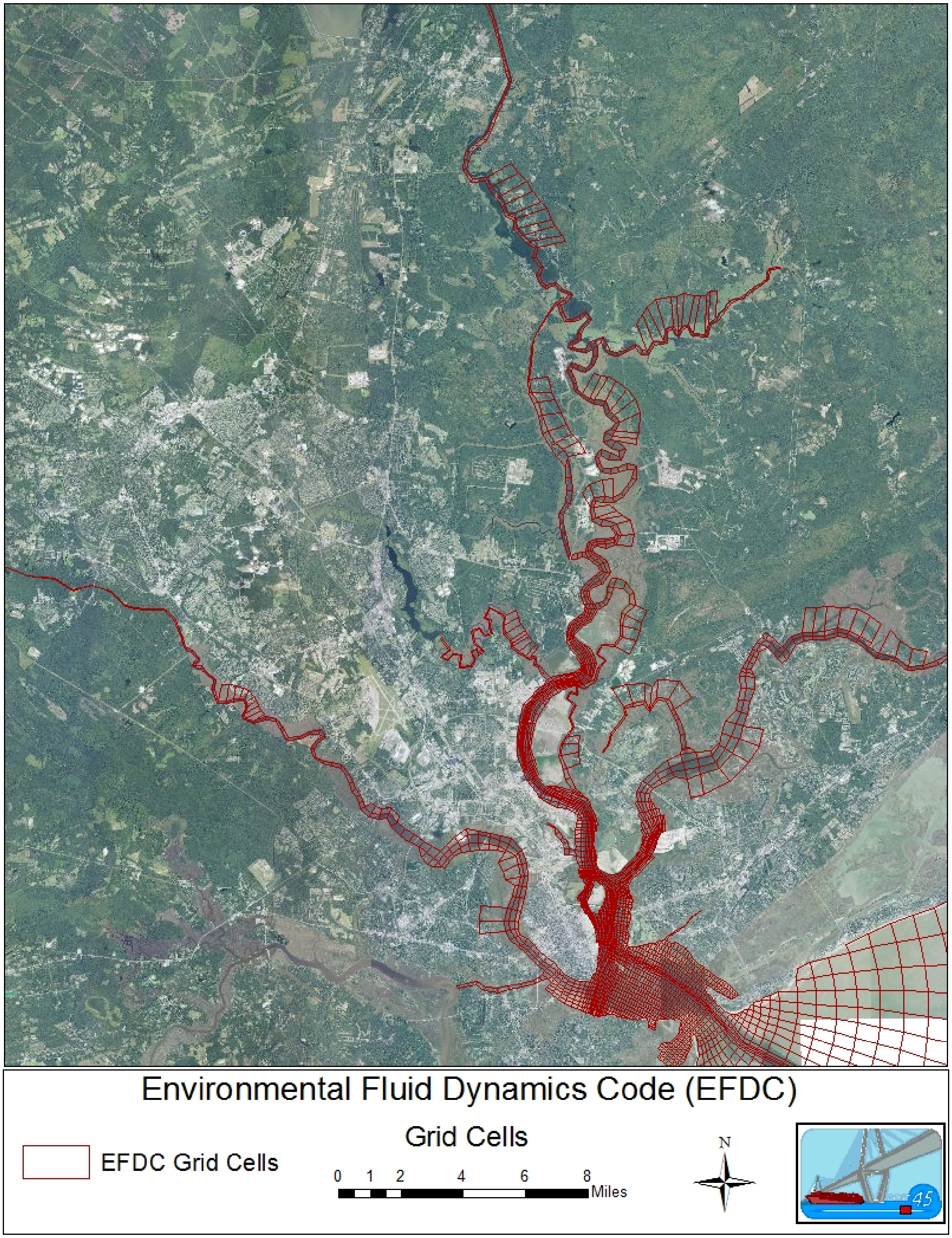

Figure 1 Model cells that were used to represent potential change in fish habitat as a result of navigation improvements at Charleston Harbor

Variable		Coordinates x	y
V_1	Mean water temperature during summer. Foraging site, adults	°C	SI
		8	0.0
		11	1.0
		22	1.0
		35	0.0

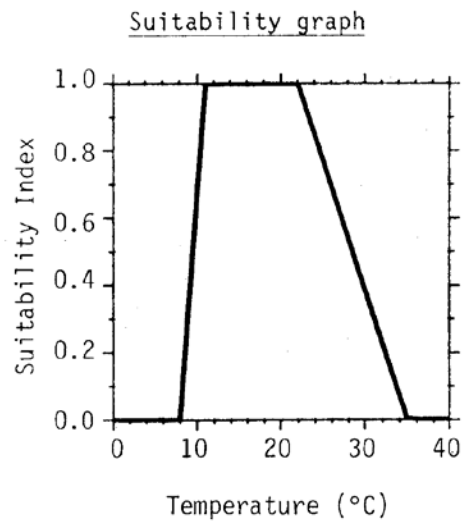

Figure 2 Typical habitat suitable index model

2.4 Selection of Species

Based on the environmental setting of Charleston Harbor and fish community composition, the following USFWS HSI's were available for use for the Post 45 Study:

- Alewife and Blueback Herring (*Alosa pseudoharengus and A. aestivalis*)
- American Shad (*Alosa sapidissima*)
- Shortnose Sturgeon (*Acipenser brevirostrum*)*
- Southern Flounder (*Paralichthys lethostigma*)
- Southern Kingfish (*Menticirrhus americanus*)
- Spot (*Leiostomus xanthurus*)
- Spotted Seatrout (*Cynoscion nebulosus*)
- Striped Bass (*Morone saxatilis*)

**Federally listed species*

It was not feasible or practicable to study all potentially affected species. Therefore, USACE supported the assessment of certain populations having habitats that were most likely to be impacted and those that could represent broader fish guilds. USACE tentatively narrowed down the potential study list to the following species:

- Shortnose sturgeon, an anadromous, demersal, endangered species
- Southern flounder, a benthic, non-migratory, recreationally fished species
- Spotted seatrout, a pelagic, non-migratory, recreationally fished species
- American shad, an anadromous, pelagic, recreationally and commercially fished species

USACE considered the inclusion of a commercially important species and an invertebrate (either white shrimp or oysters). However, the only HSI models for these species are specifically for the Gulf of Mexico coast. During consultations with other agencies, NMFS suggested adding white shrimp, blue crabs, gray snapper, sciaenids, summer flounder, and SCDNR suggested adding striped bass, Atlantic sturgeon, and blueback herring.

On April 5, 2012 USACE convened an ICT meeting to discuss the inclusion of HSI models and the tentative list of species selected. At the conclusion of the meeting, the ICT agreed to the following:

1. Removal of American shad in exchange for blueback herring;
2. Removal of spotted sea trout in exchange for red drum (juvenile and larval stage);
3. Assessing southern flounder;
4. Assessing striped bass;
5. Assessing shortnose sturgeon only if the model can be modified to include salinity;
6. Assessing Atlantic sturgeon (identified as a species of concern to the ICT due to their being recently listed as endangered); at the recommendation from an ICT member, a series of thresholds will be used (Greene et al, 2009), and will result in a "pass/fail" determination;
7. Removal of hard clam from consideration;
8. Removal of gray snapper from consideration;
9. Assessing oyster habitat on the basis of surface salinity change.

The above adjustments resulted in this final array of HSI's and other species:

- Shortnose sturgeon (*Acipenser brevirostrum*), an anadromous, demersal, endangered species
- Atlantic sturgeon* (*Acipenser oxyrinchus*), an anadromous, demersal, endangered species
- Southern flounder (*Paralichthys lethostigma*), a benthic, non-migratory (but for inshore/offshore movements), recreationally fished species
- Red Drum (*Sciaenops ocellatus*), a demersal, non-migratory, recreationally fished species
- Blueback Herring (*Alosa aestivalis*) , an anadromous, pelagic, recreationally and commercially fished, schooling species
- Striped Bass (*Morone saxatilis*) – Anadromous, Pelagic, Recreational Fishery

Agency consensus on the HSI models was not reached. However, the ICT did reach agreement on the variables that are of concern that needed to be obtained from the EFDC post-processor. These variables include DO, temperature, salinity, and velocity. The ICT also recommended that the project evaluate six vertical layers in the EFDC model instead of four. The Charleston District modified the EFDC grid to include this ICT recommendation.

2.5 Definitions

2.5.1 Riverine/ Estuarine /Ocean Boundaries

Many of the HSI's have different functions for riverine or estuarine habitats for the fishes. In order to define the "breakpoint" or grid cell in the EFDC model where this transition occurs, a definition query had to be created. USACE coordinated with SCDNR in order to ascertain where the state designated the boundary between riverine and estuarine habitats in the Ashley, Cooper, and Wando Rivers. SCDNR indicated that the saltwater/freshwater dividing line for Charleston Harbor is defined in law (50-5-80) but does not conform exactly to the current, *in situ* saltwater-freshwater dividing lines. The Wando River is saltwater for its entire length and SCDNR indicated this description is still valid. The Ashley River boundary is at the confluence of Popper Dam Creek across from Magnolia Gardens; SCDNR indicated that this is probably very close to the actual *in situ* position in non-drought years. The Cooper River boundary is at the seaward shoreline of the Old Back River downstream from the Bushy Park Reservoir; SCDNR indicated that this is probably not accurate due to the diversion and rediversion associated with the Santee Cooper lakes, which altered freshwater inputs to the river. For modeling purposes, SCDNR concurred with USACE that the cut points should occur at the saltwater-freshwater dividing lines, and not what is defined in law. For this reason, USACE determined that the lines should occur based on the modeled outputs of the existing condition in the EFDC model. The cells would be split so that all cells >0.5 ppt salinity would be classified as estuarine and all cells <=0.5 ppt salinity would be classified as riverine. The ocean boundary was determined based on the river segments that SCDHEC used in the Total Maximum Daily Load (TMDL) model for the Charleston Harbor System.

2.5.2 Substrate Composition

The suitability index (in various HSIs) for substrate provided some difficulties in interpretation of classes. In order to determine the overall sediment composition within the harbor, sediment data from years of sampling (principally from SCDNR's Estuarine and Coastal Assessment Program (SCECAP) and from other SCDNR investigations for the Post-45 project) were obtained (Sanger et al., 2013). SCDNR had collected sediment composition as part of SCECAP since 1999, and the full sediment dataset was provided to USACE for the project area (unpublished data from George Reikerk, SCDNR). USACE used the SCDNR data that was collected as part of this project (Sanger et al., 2013) in addition to the SCECAP data. The latitude/longitude data within the excel tables were used to generate a shapefile of all the sampling locations and the percent sand/silt/clay associated with those sites. The data were interpolated using a kriging methodology (a statistical method using interpolation based on regression and weighted according to spatial covariance values) to determine these distributions between points (see Attachment D). Using GIS, the EFDC grid was overlaid with information from this interpolated dataset and each cell was populated with the average percent sand, silt and clay.

Four of the HSIs incorporated "substrate composition" as a variable (herring, shortnose sturgeon, red drum, and southern flounder). All of these variables had different classes of substrate that resulted in varying interpretations of classification of substrates. Since USACE accessed only substrate composition data that accurately distinguished between only sand, silt, and clay, these were the factors that had to be used; it was not possible to accurately classify such HSI descriptors as gravel, cobble, rock, shell, or coral.

The HSI's use "mud" as a category but it is never really defined. Because of this, USACE determined to generally classify "mud" as the combination of silt and clay. An additional challenge that the data presented was that in many of the samples in the upper portions of the Cooper River, the stainless steel 0.04 m^2 Young grab that SCDNR used for the sample collection was only able to scrape the surface of the sediment. This was because these samples were predominantly Cooper Marl. The Cooper Group is named for exposures of phosphatic clayey limestone that outcrop along the Cooper River in Berkeley County, South Carolina. The unit was extensively studied and served as a source for agricultural lime production between 1867 and 1920. Locally, the unit is commonly referred to as the "Cooper marl". The Cooper Group is described as a thick, soft, impenetrable, sandy to clayey, phosphatic limestone, with uniform color and texture, with no obvious bedding (Park, 1985; Weems and Lemon, 1993). Field descriptions by SCDNR geologists indicated that the formation resembles a stiff, partially consolidated, calcareous, silty-clay (SCDNR, Will Doars, personal communication, 2012). Because Cooper marl is not a predominant substrate type in the HSIs, it had to be represented in an alternative manner for use in the models. The SCDNR analysis resulted in differentiating the marl into its geological components (% sand/silt/clay). Using these geological components for marl that were familiar from the HSI schemes, marl was therefore represented as substrates in the relevant parts of the Cooper River. The classification of substrate will be further discussed below for each species.

2.6 Habitat Requirements and Input Variables

2.6.1 Shortnose Sturgeon

The shortnose sturgeon (*Acipenser brevirostrum*) was federally listed as an endangered species in 1967. This smallest of sturgeons is long-lived, and reaches sexual maturity at three (for males) and six years of age (for females) in southern populations. Its populations have dwindled due to habitat loss, pollution, fishing mortality from by-catch (especially in shad gill nets), and poaching for its valuable roe. Unlike other anadromous species (such as American shad), shortnose sturgeon do not spend much time in the ocean (Collins and Smith, 1997; Crance, 1986). After fertilization, eggs adhere to the river substrate. Once hatched the larvae emerge and migrate downstream with the river flow (Duncan et al., 2011). They spend most of their lives near the bottom of fresh and brackish rivers and estuaries, habitats that are vulnerable to water quality degradation and other impacts.

While dredging has been implicated as negatively impacting sturgeon in several ways, most of the contributing factors would occur if dredging took place within the spawning grounds. This study examined any changes to salinity regimes as a result of deepening beyond the authorized depth of 45' plus 2' (advanced maintenance) plus 2' (allowable overdepth). ASMFC (1990) noted that deepened channels can allow saltwater to intrude further inland, and changes in salinity regimens can dramatically impact prey distribution.

The shortnose sturgeon's status as an endangered species requires compliance with the ESA and specific consultation procedures with USFWS. The Post 45 Project raised concerns about this fish because it is endangered and because it spends much of its life in the interface between fresh and saltwater, where potential project impacts to salinity and dissolved oxygen may occur. Since there is relatively little freshwater habitat for this species in the Ashley and Wando rivers, the Cooper River is the major area of concern. Collins and Smith (1997) recorded zero shortnose or Atlantic sturgeon caught in the Ashley and Wando Rivers.

The Shortnose Sturgeon Recovery Team (NMFS 1998) notes that sturgeon essential habitat can be geographically portrayed in a GIS format. Putting the data into a GIS database to share with the natural resource agencies and other interest groups may be helpful for visualizing the sturgeon's migrations and habitat needs. Hall et al, (1991 in Duncan et al., 2011) found that shortnose sturgeon (SNS) in the Savannah River used sharp river bends near hard-packed clay areas where no sediment would accumulate. The substrate in Pinopolis Dam tailrace does not consist of material typically preferred by SNS (Duncan et al., 2011).

HSI variables for this species are the following (Figure 3):

- Mean water temperature
- Mean water column velocity
- Predominant substrate type

Two life stages are used in the HSI: 1. Reproduction (Spawning Adults) and 2. Foraging Adults. The below table shows the relationship of habitat variables and life requisites for the shortnose sturgeon. In the case of summer foraging adults, the time period was defined as April 1 – Oct 31 (as defined in the HSI). In the case of spawning adults the time period was defined as Feb 15 – April 30.

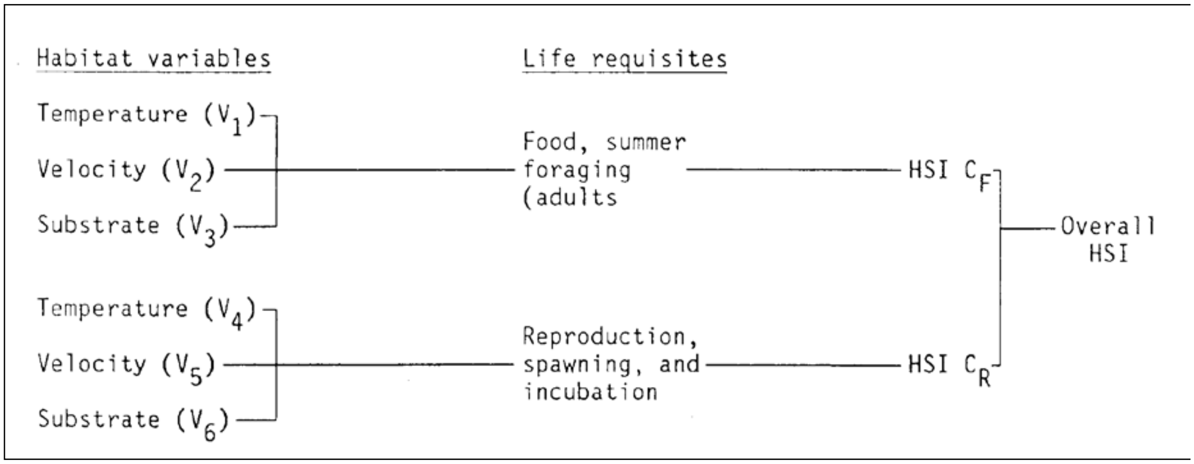

Figure 3 Components of shortnose sturgeon overall HSI

For the EFDC post-processor, substrate classes for <u>spawning</u> adults (see Figure 4) were defined by the following representation from the interpolated SCDNR data:

Class 1: no cells were given this classification
Class 2: if <=50% sand and %clay > %silt
Class 3: if <=50% sand and %silt >%clay
Class 4: >50% sand
Class 5: no cells were given this classification
Class 6: no cells were given this classification
Class 7: no cells were given this classification
Class 8: no cells were given this classification

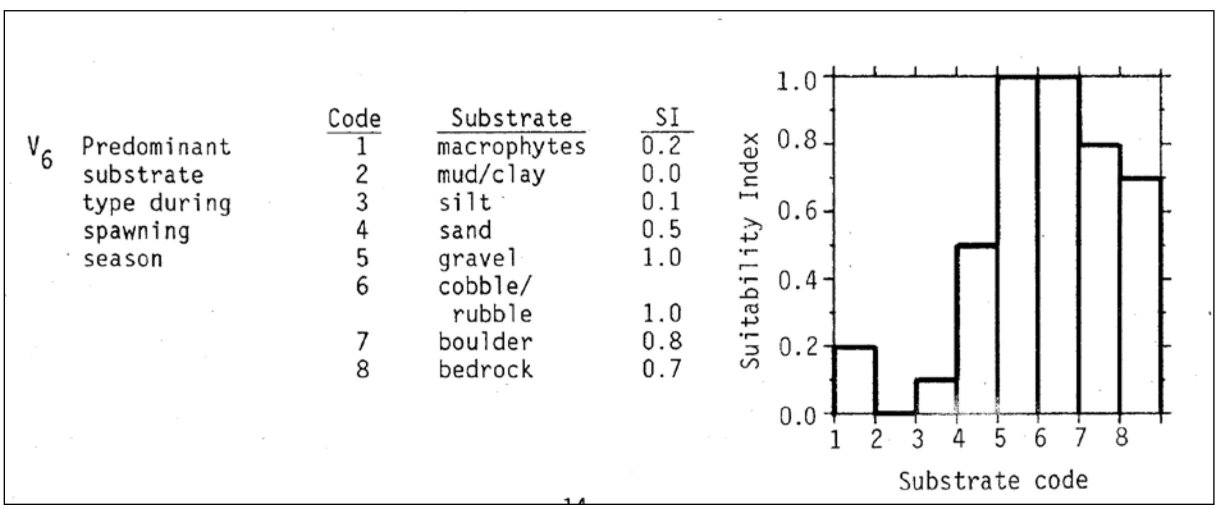

Figure 4 Substrate classification for spawning shortnose sturgeon HSI

For the EFDC post-processor, substrate classes for <u>foraging</u> adults (see Figure 5) were defined by the following representation from the interpolated SCDNR data:

Class 1: no cells were given this classification
Class 2: if <=50% sand and %clay > %silt
Class 3: if <=50% sand and %silt >%clay
Class 4: >50% sand
Class 5: no cells were given this classification
Class 6: no cells were given this classification
Class 7: no cells were given this classification
Class 8: no cells were given this classification

In this case all cells in the grid were assigned a “1” for the substrate index because all classes that could be distinguished had an SI of 1.

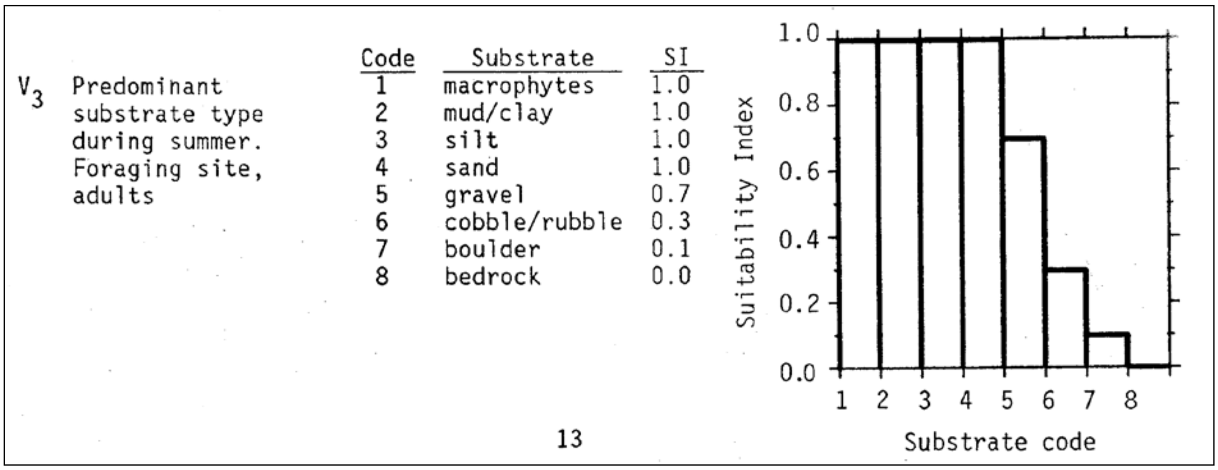

Figure 5 Substrate classification for foraging shortnose sturgeon HSI

2.6.2 Atlantic Sturgeon

The Atlantic sturgeon was listed as endangered on February 6, 2012. Collins and Smith (1997) noted that juvenile Atlantic sturgeon may ascend rivers, but primarily inhabit estuarine areas and move into higher salinity waters during late fall and winter. They were not noted to spawn in the Cooper River. However, the presence of small juveniles (only slightly larger than 44 cm) suggests that spawning may take place in the Cooper River. The Code of Federal Regulations (CFR) notice on the listing of the Atlantic sturgeon does not mention that spawning occurs within the Cooper River (pg 16, CFR ruling). The report does mention that the proximity of spawning areas to saltwater may result in “very high mortality to any larvae spawned in those systems”. However, no evidence is provided, and there are approximately 18 river miles from the Pinopolis Dam to the northern extent of saltwater influence (the “tee”). NMFS indicated that they used the “best available commercial and scientific information to evaluate the status of the Carolina and South Atlantic DPSs”. In the CFR, NMFS states that impacts from dredging include the disturbance of benthic fauna, elimination of deep holes, and alteration of rock substrate, as well as the creation of turbidity/siltation, contaminant resuspension, noise/disturbance, and alterations to hydrodynamic regime and physical habitat. Additionally, NMFS states that the most significant potential threat to Atlantic sturgeon from dredging is associated with effects to their habitat (pg 120, CFR ruling). If the Atlantic sturgeon does not use the Cooper River to spawn, then the only impact would be from an impact to their juvenile/adult stage estuarine habitat within Charleston Harbor.

As stated at the beginning of this document, a series of thresholds will be used for Atlantic sturgeon. These thresholds are derived from the ASFMC (2009) (Greene et al., 2009) and are shown below in Table 1. Use of these thresholds will result in a pass/fail for each cell in the EFDC grid.

Table 1: Atlantic sturgeon habitat criteria

Atlantic Sturgeon Physical Parameters			**FROM ASMFC 2009 (except as noted)**	
Pass or Fail			NIF - No Information Found by ASMFC 2009	
Fails if not in range for any parameter				
				Month
	MIN	**MAX**	Use average bottom layer for all parameters	**Range**
Temperature (°C)	13	23.4	Adult Spawning (reported, female spawning)	Late Feb - Late April
		33.1	adult estuarine (reported in SC)	June - August (summer)
	15	24.5	egg/larval	Late Feb - Late April
	3	28	(juvenile estuarine tolerable. Temps >28 are sub-lethal	Entire year
DO (mg/L)	NIF	NIF	Adult Spawning	Late Feb - Late April
	NIF	NIF	Adult Estuarine	June - August (summer)
	NIF	NIF	Egg and Larval	Late Feb - Late April
	3.3		Juvenile estuarine in summer (26°C)	Entire year
Salinity (ppt)	0	0.5	Adult Spawning (above salt wedge in freshwater)	Late Feb - Late April
	0	28.6	Adult Estuarine	June - August (summer)
	0	10	Egg and Larval (upstream of salt wedge - low tolerance to salinity	Late Feb - Late April
	0	27.5	Juveniles (optimal ~10)	Entire year
Velocity (m/sec)	0.06	1.07	Adult Spawning Feb	Late Feb - Late April
	NIF	NIF	Adult Estuarine	June - August (summer)
	NIF	NIF	Egg and Larval	Late Feb - Late April
	NIF	NIF	Juvenile Estuarine	Entire year
South Carolina spawning migration begins in February (Smith 1985b)				
Potential "Fall Migration" suggested from August - September - unknown if fall movement is accompanied by spawning (many authors)				
Spawning occurs in freshwater (eggs cannot tolerate salinity)				
Mature females spawn every 3-5 years, males 1-5 years (Smitn 1985b)				

2.6.3 Southern Flounder

The southern flounder is found along the shores of bays, sounds, estuaries, and lagoons in shallow waters. The eggs of the southern flounder are buoyant and pelagic, and take 40 to 46 days to metamorphosize into juveniles. Juveniles migrate from estuarine to marine water in fall or early winter. While some flounders have been collected in hypersaline waters around 60 ppt, the majority of southern flounder prefer salinities between 5 and 20 ppt (Enge and Mulholland, 1985).

HSI variables for this species are the following:

- V1: Temperature (average temperature 10 to 15 cm above the bottom, May to August)
- V2: Salinity (average annual salinity 10 to 15 cm above the bottom)
- V3: Dissolved oxygen (average daily minimum 10 to 15 cm above the bottom, May to August)
- V4: Substrate (composition of mud, silt, sand, and shell; see Figure 6)

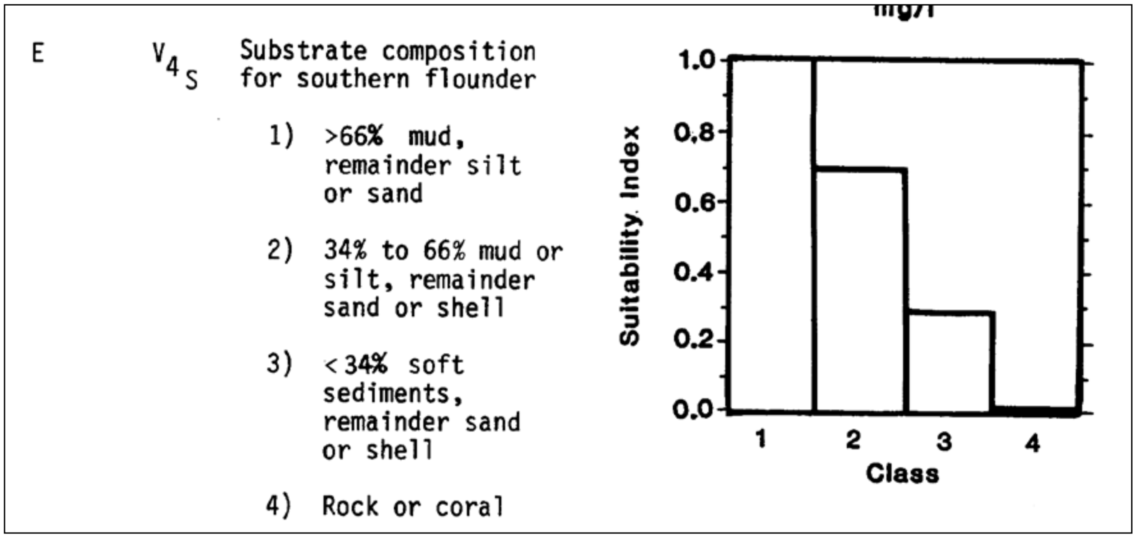

Figure 6 Substrate classification for southern flounder HSI

For the EFDC post-processor, these classes were defined by the following representation from the interpolated SCDNR data:

Class 1: >=66% clay and silt
Class 2: 34-66% clay and silt
Class 3: <=34% clay and silt
Class 4: no cells were given this classification

2.6.4 Red Drum

Red drum are an extremely important recreationally fished species. SCDNR, the principal agency responsible for management of the species, provided the following life-history description:

> "As red drum develop, they utilize different habitats. Juvenile red drum are abundant in the shallow creeks that meander through cordgrass (*Spartina alterniflora*) marshes. As juveniles mature, their habitat preferences change. Sub-adult red drum can usually be found in larger creeks and rivers, although they have been observed in waters off barrier islands and sandbars. Young red drum, between the ages of one and three, show a pattern of movement and feeding that is related to the tide. During the warm months, as the incoming tide begins to reach the marshgrass, fish move into the grass. Here, they feed on fiddler crabs (80% of their diet), mud crabs, grass shrimp, and fishes that are associated with this structured habitat. As the tide ebbs, the young red drum move off the marsh surface to the shallow water of tidal mudflats adjacent to the marsh. Most red drum prefer mud flats with structure, such as oyster reefs. This pattern of movement reduces their exposure to bottlenose dolphin, which is a major predator.
>
> "Males of the species mature at age three (27-30 inches long), and females mature at age four (32-36 inches)…Male red drum produce characteristic 'drumming' sounds by contracting muscles attached to the swim bladder, in an effort to attract females to spawning sites…Adult red drum in South Carolina spawn in August and September. Spawning activity is believed to be sparked with the cooling water temperatures and shorter days in August. Spawning in South Carolina is thought to occur in coastal

inlets, including St. Helena Sound, although some nearshore spawning activity is believed to take place as well.

"Fertilized eggs float in the water column, and hatching occurs in 28-29 hours, depending on water temperature. Eggs hatch more quickly in warmer waters, and more slowly as water temperature declines. Upon hatching, larval red drum face the difficult task of reaching nursery grounds inside the estuary. Using currents generated by winds and tides, larvae make their way to shallow tidal creeks. By swimming towards the surface when currents are rising (flood tide), and staying close to the bottom when the tide is ebbing, these larvae eventually reach their destination. Once they reach the shallow water of estuarine creeks, the larvae settle out of the plankton community.

"Larval red drum feed on crustaceans and small fishes. The smallest feed on copepods, and as they grow, they eat ghost shrimp known as mysids, and eventually consume grass shrimp and penaeid shrimps" (SCDNR 2013d).

Habitat variables for this species are the following:

- V1: Mean water temperature during larval development (August and September)
- V2: Mean salinity during larval development (August and September)
- V3: Percentage of open water fringed with emergent vegetation
- V5: Substrate composition
- V6: Mean depth of estuarine water at low tide

**As per HSI, V4 (Percentage submerged vegetation) not included because Charleston Harbor does not support submerged aquatic vegetation.*

SCDNR (2013d) indicates that spawning and growth occurs in August and September. Therefore, this was the time frame used for the water quality variables.

The suitability graph for potential habitat substrates (V_5) is shown below in Figure 7:

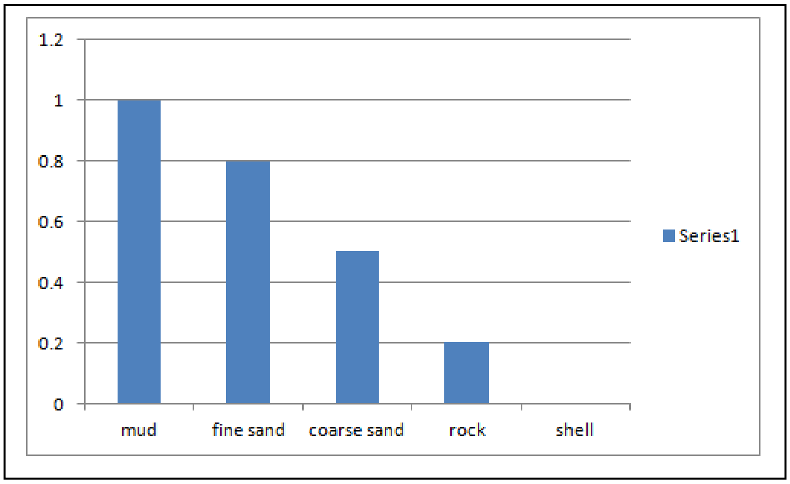

Figure 7 Substrate classification for red drum HSI

For the EFDC post-processor, these classes were defined by the following representation from the interpolated SCDNR data:

Class 1: <=50% sand
Class 2: >50% sand
Class 3: no cells were given this classification
Class 4: no cells were given this classification
Class 5: no cells were given this classification

The SCDNR data do not distinguish between fine sand and coarse sand, and since: a) this is the only variable that requires the information, b) there is not a lot of coarse sand in Charleston Harbor (as per ASTM and Wentworth classification systems), and c) the project will not change the composition of substrate outside of the navigation channel, it was determined to leave these classifications as just the dominance of mud (silt and clay) or sand.

One of the variables for "cover" is "percentage of open water fringed with persistent emergent vegetation". In order to determine the values for this variable in the post-processor a detailed GIS analysis was used. A shoreline layer from NOAA was overlaid on 2011 NAIP imagery to categorize the shoreline as either "yes" or "no" (1 or 0) for containing emergent vegetation or not, respectively. This new shoreline shapefile was then used to perform an interpolation analysis of the percentage of fringing emergent vegetation using the SCDHEC TMDL segments; each segment was classified as one consistent percentage. Then each grid cell within the segment was assigned that percentage.

Another variable for red drum that factored into the analysis was the percentage of area covered by submerged vegetation (V4). The HSI model has different equations for estuaries with submerged vegetation and estuaries with little or no submerged vegetation. Charleston Harbor, in fact, most of South Carolina estuarine waters, does not contain submerged aquatic vegetation. Because of this, USACE determined that the equations for "estuaries with little or no submerged vegetation" would be used and therefore, V4 was not a factor in the analysis.

2.6.5 Blueback Herring

The blueback herring is a diadromous fish that migrates between freshwater (spawning habitat) and saltwater. The species is an important species for commercial and sport fisherman of South Carolina (SCDNR 2013a). SCDNR indicates that large numbers of this species congregate near the Pinopolis lock and dam along the upper portion of the west branch of the Cooper River. The species migrates to freshwater rivers from March through July (mainly March and April) to spawn (from Pardue 1983 and SCDNR 2013a). Eggs are demersal and adhesive at first and then become pelagic after water-hardening occurs (Pardue, 1983). Juveniles remain in the rivers where spawning occurred (Street et al., 1975) and emigrate from freshwater-estuarine nursery areas between June and November of their first year (from Pardue, 1983).

Habitat variables for this species were the following:

- V1: Dominant substrate type for spawning
- V2: Mean daily water temperature during spawning season (March – June) *HSI says "spring to early summer
- V3: Mean number of zooplankton per liter
- V4: Mean salinity during spring or summer (March – August)
- V5: Mean surface water temperature (June – October)

All time periods were based on HSI information.

For the EFDC post-processor, the substrate classes (see Figure 8) were defined by the following representation from the interpolated SCDNR data:

Class 1: >=75% clay and silt
Class 2: >=50% < 75% clay and silt
Class 3: <50% clay and silt

Since there was a gap in the percentages between class 2 and class 3, some sites would have had a “null” value which would not work for the HSI. It was determined to bridge the gap by applying a <50% clay and silt definition (Mark Caldwell, USFWS, personal communication, 4/24/213).

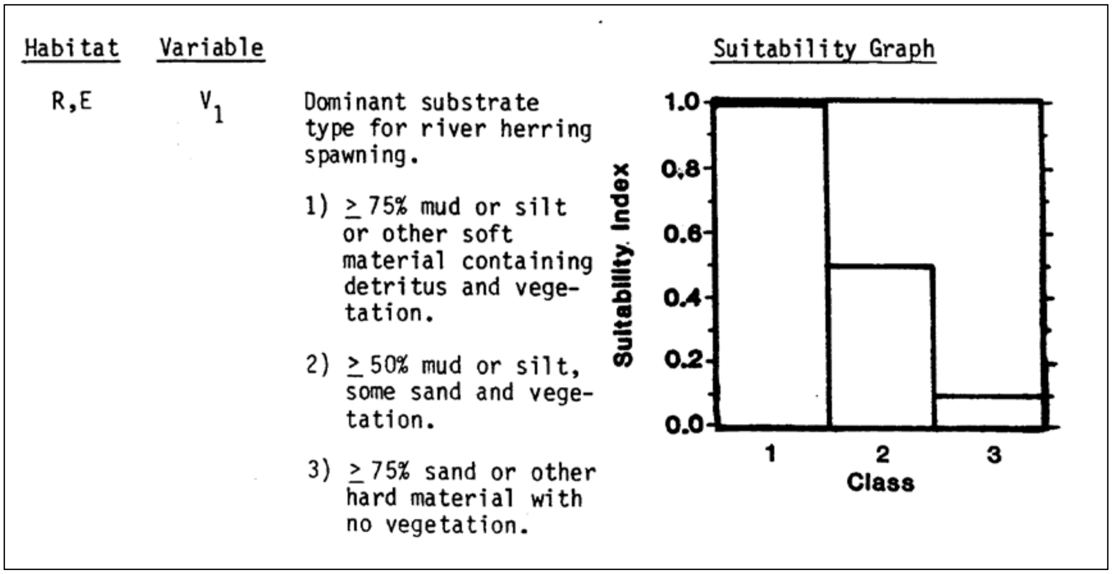

Figure 8 Substrate classification for blueback herring HSI

Zooplankton are an important food variable for herring in the HSI model (V3). Estuarine zooplanktons are of considerable trophic importance. Studies of the zooplankton of freshwater habitats in coastal regions of the southeast are limited (NOAA 2014). In lakes and rivers, zooplankton is dominated by free-living non-photosynthetic protists, rotifers and microcrustaceans (Sandifer et al. 1980). The following text is from the NOAA-NERRS ACE Basin Website:

> “Dames and Moore Associates (1975) sampled freshwater creeks and portions of the Cooper River, collecting 12 taxa of rotifers, 4 taxa of copepods, and 2 taxa of cladocerans. Rotifers and copepods together comprised nearly 90 percent or more of the total number of zooplankters at all six sample sites. The most abundant rotifers were *Polyarthra* sp. and *Keratella cochlearis*, while the only genus of copepod identified was *Diaptomus*. The cladocerans *Bosmia longirostris* and *Alonella sp*. were dominant within that taxon.”

For estuarine mesozooplankton, Knott (1980) found that in the North Edisto River monthly mean densities (Figure 9) were greater than 10,000 individuals/m^3 from April through June, although zooplankton abundances in the river remained above 6,000 indiv./m^3 year round. The total zooplankton abundance reported by Knott (1980) within the North Edisto River was similar to abundances described by Lonsdale and Coull (1977) at North Inlet, SC. In addition, a qualitative description by Burrell (1975) from the Wando River, SC suggests that estuarine waters support comparable communities. In a study by Davis and VanDolah (1986) they stated that one report

(Enwright Laboratories, Inc. 1977) described zooplankton communities in the Charleston Harbor Estuary. The study involved a short-term assessment of zooplankton populations in the upper portions of the Cooper River between the Back River and the "tee" during 1976. The only seasonal trend observed by the researchers was an increase in the densities of amphipods during August and September. Another study (Bears Bluff Inc., 1964) studied zooplankton in the Cooper River over a one-year period and determined that zooplankton abundance was lowest among the rivers studied in SC. Zooplankton abundance fluctuated seasonally, with peaks in June and July and lowest abundance in December. DNR (personal communication, Sanger and Knott, 4/12/2013) indicated that they were unaware of any recent studies documenting the abundances of zooplankton in the Charleston Harbor system. For this reason and due to the noted similarities between river systems and the documentation of the Cooper River zooplankton abundance being lower than other systems, the following chart will be used to represent zooplankton in this Habitat Suitability Index. The use of this should provide for a more conservative SI number. The average over the course of one-year was 10,008 individuals/m^3 and this number was supplied to the HSI post-processor.

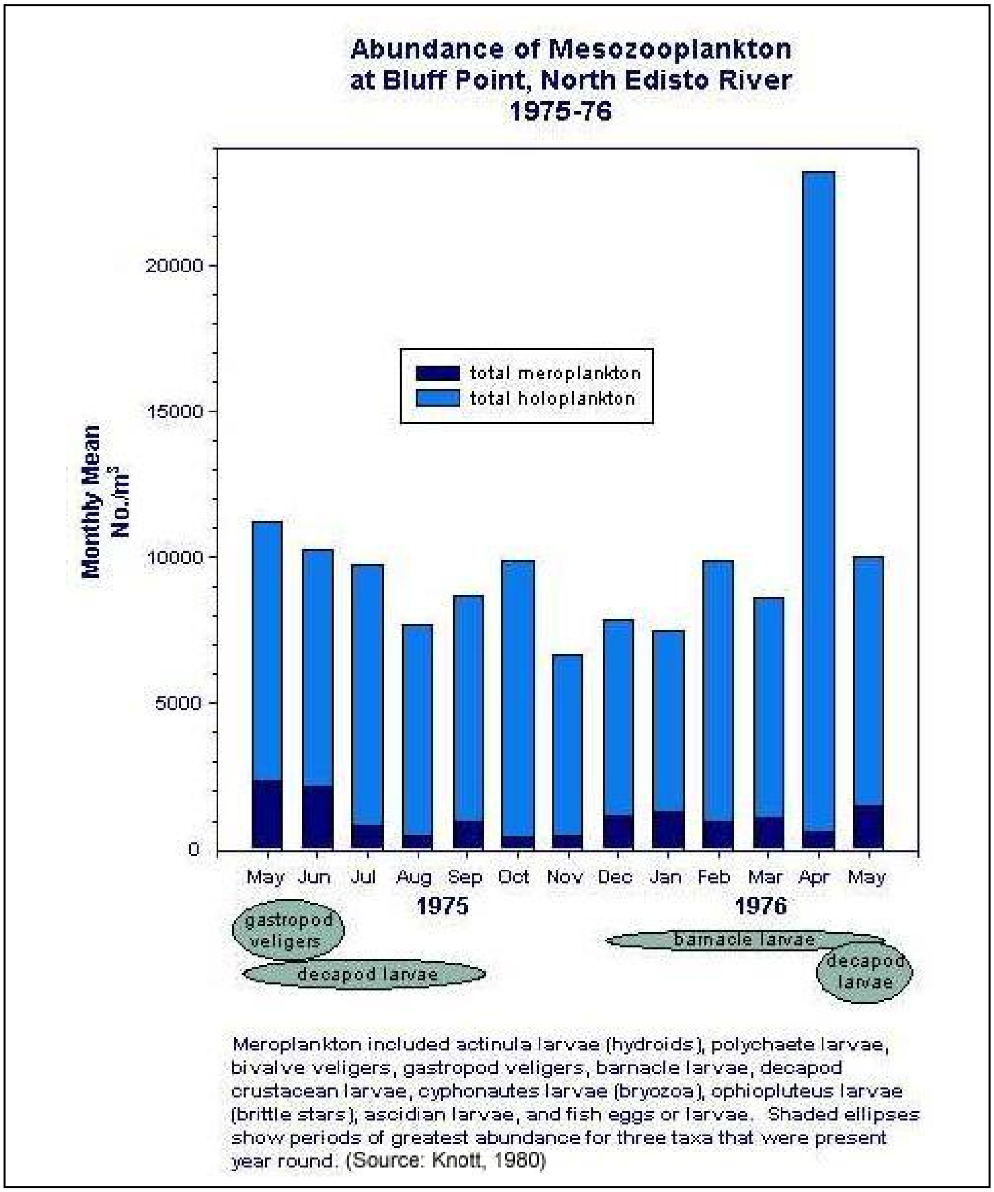

Figure 9 Monthly zooplankton abundance in a South Carolina estuary

2.6.6 Striped Bass

Striped bass are commonly found in major rivers and large reservoirs in South Carolina. The striped bass is an anadromous fish that spawns in early spring after migrating up river systems. The semi-bouyant eggs are released in moving water and fertilized by several males. Females can release as many as 3 million eggs at a time. During the first few days of life, larval fish are sustained by a yolk while they develop, after which they begin to feed on zooplankton. These fish prey mostly on fish including shad and herring (http://www.dnr.sc.gov/fish/species/stripedbass.html).

The HSI for striped bass uses total dissolved solids (TDS) as a variable. The text of the HSI (Bain and Bain, 1982, page 3) discusses this parameter in the context of salinity. Since the EFDC model does not factor in TDS, the closest proxy would be salinity. This situation was discussed with USFWS (personal communication, M. Caldwell, SCDNR, email 3/6/2013) and it was agreed that salinity provided an appropriate proxy.

Habitat variables for this species were the following:

- V1: Percent natural river discharge during spawning season (March – May)
- V2: Maximum total dissolved solids (salinity) during spawning season (March – May)
- V3: Average water temperature during spawning season and period of egg development (March – May)
- V4: Minimum dissolved oxygen during egg and larval development (March – May)
- V5: Average current velocity in water column during egg development (March – May)
- V6: Percent original salt marsh in estuary
- V7: Percent original freshwater input (average volume) to estuary during late winter and spring high flow period (February – May)
- V8: Average water temp during larval development (April – Sept)
- V9: Average salinity during larval development (April – Sept)
- V10: Average dissolved oxygen during growing season (March – June) (Sept – Nov)**
- V11: Average water temperature during growing season (March – June) (Sept – Nov)**

***these time periods were determined by personal communication with SCDNR Biologist Chad Holbrook and Scott Lamprecht on July 26, 2013.*

Percent natural river flow (V1), was determined by using historic inflows from the Cooper River, which were determined to be 72 cfs (Teeter, 1989).

2.7 Modeled Habitat Effects

For the future-without-project (FWOP) condition and each project alternative (i.e., dredge depth) and species/life-history phase or habitat element, the predicted change in HSI was determined per EFDC cell. Each cell's HSIs per the FWOP condition and each alternative were multiplied by the acreage of the respective cell to yield a value indicating "habitat units." Comparison of the summation of all habitat units of FWOP cells with those of each of the project alternatives yielded "deltas," or the difference (i.e., relative effect) of each project alternative. Comparing the alternative outputs to the FWOP gives a percent change in the amount of available habitat (see Attachment A for results). Low flow was used for the purposes of evaluating impacts. This is because four of the six species used in analyses were anadromous and their migratory and spawning behaviors require minimal levels of flow.

Results were graphically represented in plots found in Section 3 below. The legend of the figures indicates seven arbitrary degrees/levels of change in HSI, each represented by a color reflected in model cells in the grid. HSI scores may range from 0 to 1. Therefore changes in HSI per model cell could likewise increase by 1 or decrease by 1 unit. Future-with-project *decreases* in HSI from the

FWOP per model cell were indicated where values were negative and future-with-project *increases* from the FWOP were indicated where values were positive. Cells where relatively "no change" was predicted to occur, i.e., change in HSI from -0.0099 to (+)0.0100, were left uncolored in the figures. Improvements in "deltas" were shown as either light green (increases in HSI by 0.0100 to 0.0200) or dark green (increases in HSI by more than 0.0200 units). Decreases in habitat quality were shown with cells colored yellow (HSI *decreases* between 0.0100 and.02499 units), tan (HSI decreases between 0.0250 and 0.2069), orange (HSI decreases between 0.2070 and 0.3959), or red (HSI decreases from the FWOP HSI between 0.3960 and 1.0). Note that these increments are not evenly spaced.

2.8 Project Area Fishery Data

In order to provide another perspective for modeled changes in habitat units, based on HSI outputs (as discussed in the above paragraph), USACE compared areas of anticipated habitat change (future with vs. future without project) to fishery data collected by the South Carolina Department of Natural Resources (SCDNR). The objective was to determine if areas with confirmed presence of fishery study target species would be adversely affected by the proposed project. However, reasonably conclusive results in that regard were not possible due to various limitations of utilized datasets and the overall study approach. Notably, assumptions regarding potential effects in areas where no fishery samples were attempted or where the target species were not captured were not possible. Other limitations are discussed in the study conclusions section (Section 4.0). Notwithstanding various limitations, the use of the SCDNR datasets was informative in certain instances and provided various anecdotal materials for consideration of impacts.

SCDNR manages several programs, many in collaboration with federal sponsors/partners such as NMFS, that routinely collect fishery data for a variety of purposes. Programs with data relevant to this fishery analysis included the South Carolina Estuarine and Coastal Assessment Program, ongoing diadromous fish telemetry studies, and trammel-netting and electrofishing operations.

SCECAP Trawls. The South Carolina Estuarine and Coastal Assessment Program (SCECAP) is a multi-agency program designed to assess the condition of South Carolina's coastal zone. SCDNR and the South Carolina Department of Health and Environmental Control (SCDHEC) are the primary agencies responsible for the program. The National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (USEPA), and the U.S. Fish and Wildlife Service (USFWS) are cooperating federal agencies. The program collects data related to multiple measures of water quality, sediment quality, and biological condition at a large number of sites throughout the state's coastal zone each year and integrates those measures into an overall assessment of estuarine habitat condition at each site and the entire state. Data were collected from 1999 through 2010, in coastal areas including Charleston Harbor and its associated estuaries. According to SCDNR 2013c, fish sampling was conducted in the following manner:

> "Fish and large crustaceans…are collected at each site... Two replicate tows are made at each site using a 4-seam trawl…Trawl tow lengths will be standardized to 0.5 km for open-water sites and 0.25 km for creek sites. Tows are made only during daylight hours with the current and speeds standardized as much as possible. Tows made in tidal creeks are limited to periods when the marsh is not flooded (approx. 3 hrs + mean low water)…Catches are sorted to lowest practical taxonomic level, counted, and checked for gross pathologies, deformities or external parasites. All organisms are measured to the nearest 1.0 cm. When more than 25 individuals of a species are collected, the species is subsampled. Species targeted for tissue contaminant analyses are wrapped and labeled (separately by species) in foil and stored on ice in plastic bags until they can be transferred to the laboratory…"

Approximately 65 sites existing within the federal project (Charleston Harbor) area were visited during the program. G. Riekerk of SCDNR supplied USACE with unpublished, Charleston Harbor and estuary data on 19 October 2012 via email, who indicated that fish data were represented as density per hectare (density for each trawl was generated by dividing the fish abundance by the area of each trawl, where area was estimated by multiplying the length by the estimated width based on a formula in Krebs [1972]).

Telemetry. Sonic transmitters are inserted into Atlantic and shortnose sturgeon to monitor migration patterns, seasonal habitats, and spawning locations in several coastal systems including the Santee-Cooper basin (Lakes Moultrie and Marion, the Congaree, the Wateree, the Saluda and the Broad Rivers). An array of fixed receivers is deployed throughout the basin to constantly monitor the transmitter (PIT)-tagged fish. This is a critical program because SCDNR has identified (via egg collection) in the Cooper River (as well as in the Congaree River and the Great Pee Dee River) shortnose sturgeon spawning sites (SCDNR 2013b). While new data are continually being generated, the data used in this analysis were provided by S. Arnott, SCDNR, via email during December 2013.

Trammel Net Surveys. Trammel net data were provided by S. Arnott, SCDNR, via email during December 2013. The following description from Arnott et al. (2010) concisely describes the methods used during these surveys:

> “Each month, 10 to 12 sites per stratum were normally chosen for sampling, although this number was not always achieved due to weather, tide or time restrictions. Monthly sites were selected at random (without replacement) from a pool of 22 to 30 possible sites per stratum. Occasionally it was necessary to add new sites to the pool as others were lost due to changing coastal features (e.g. erosion, new docks). Fish were collected using a 183 x 2.1 m trammel net fitted with a polyfoam float line (12.7 mm diameter) and a lead core bottom line (22.7 kg). The netting comprised an inner panel (0.47 mm #177 monofilament; 63.5 mm stretched-mesh; height = 60 diagonal meshes) sandwiched between a pair of outer panels (0.9 mm #9 monofilament; 355.6 mm stretch-mesh; height = 8 diagonal meshes). The trammel net was set along the shoreline (10 to 20 m from an intertidal marsh flat, <2 m depth) during an ebbing tide using a fast-moving boat. Each end was anchored on the shore or in shallow marsh. Once the net was set, the boat made 2 passes along the length of the enclosed water body at idle speed (taking <10 min), during which time the water surface was disturbed with wooden poles to promote fish entrapment. The net was then immediately retrieved and netted fish were placed in a live well.

Electrofishing Surveys. Electrofishing data were provided by S. Arnott, SCDNR, via email during December 2013. The following description from Arnott et al. (2010) concisely describes the methods used during these surveys:

> “The river banks of each stratum were sectioned into 926 m sites, and monthly sets were made at those sites drawn at random (without replacement) from a pool of 35 to 60 possible sites per stratum. In certain months and strata, the pool of possible sites was shifted either up- or downriver (increasing the total number of sites sampled across all years) because of salinity fluctuations brought about by droughts or floods. This was necessary because the electrofishing gear is only effective at salinities <10 psu. Fish were collected using an electrofishing boat (Smith-Root) operating at ~3000 W pulsed direct current. Stunned fish were placed into a live well using dip nets (4.5 mm square-mesh) over a 15 min period while the boat moved with the current at drift or idle speed along the river bank.

3.0 RESULTS

All impacts below are stated as the incremental impact of the alternative from the future without project condition (aka NEPA No Action). The future without project condition (FWOP) factors in an estimated 50 years of historic sea level rise. In this case, the FWOP condition is the year 2071. Alternative plans are compared to the FWOP condition. The below analysis focuses on the changes (deltas), either positive or negative, resulting from these alternatives. A detailed description of the alternatives can be found in the main report/EIS. The ICT also suggested documenting the impacts of the project at the time of construction (anticipated to be 2022). These impacts are summarized in Attachment B. Attachment C includes maps of the existing condition (Year 2022) habitat suitable based on the HSI models and EFDC outputs.

3.1 Atlantic Sturgeon

3.1.1 Spawning Habitat

The Atlantic sturgeon spawning life stage is most impacted by salinity in the habitat models. The only salinity changes occurred in cells approximately three miles south of “The Tee” (Figure 10). Anticipated impacts for the 52’/48’ project alternative are for three cells to change from “suitable” to “non-suitable.” These cells represent a loss of 2.70% from the FWOP condition suitable habitat. SCDNR has determined that spawning does occur in the Cooper River in the tailrace canal near the Pinopolis Dam. The success of this spawning is unknown (Bill Post, SCDNR, personal communication, 10/29/13). Because the impact of the project, as described above, occurs over 20 river-miles downstream of where spawning is known to occur, this change is unlikely to impact this species. Moreover, Figure 10 shows that no sturgeon have been detected in areas where habitat suitability impacts are anticipated for spawning sturgeon. Of course, that does not in itself indicate that those habitats are never used by sturgeon.

3.1.2 Adult Habitat

The various dredging alternative resulted in relatively small changes in suitable habitat for adult Atlantic Sturgeon habitat ranging from -1.66% to -3.97%. The model output for this life stage is driven by two parameters, salinity and temperature. None of the project alternatives cause temperature to go above the identified threshold. Salinity appears to be the ultimate driver in the impacts. With only a few exceptions at the mouth of the Ashley River, the north shore of James Island and near Patriots Point heading east past Shem Creek, changes occur in the navigation channel or along the margins. This is because depths of these areas would increase and would result in subsequent increase in salinity. These impacts are very small and essentially only take cells that had a salinity of just under the 28.6 ppt threshold to just over that threshold. SCDNR has documented the occurrence of Atlantic and shortnose sturgeon within the harbor, and it’s unlikely that the small changes to temperature that occur in and along the navigation channel will impact this species life stage. Since the analysis is based on the future without project condition which factors in sea level rise, the increase in salinity from the alternatives is on top of the expected salinity increase resulting from sea level rise and therefore will be indistinguishable from the sea level rise affects. Because of this and the modeled results which indicate the majority of changes being within the channel where it is unlikely that sturgeon spend much time foraging it is unlikely that this life stage will be impacted by a change of less than 4% modeled suitable habitat. Figure 11 shows where Atlantic sturgeon have been detected in the Charleston Harbor area; these could have been adult or juveniles. The figure also shows that several dozen HSI cells will exhibit (0.4 to 1.0) decreases (on a scale from 0.0 to 1.0) in quality of habitats associated with adult sturgeon. At or within a few hundred meters of approximately three sites where sturgeon were observed, HSI decreases in adult habitat are predicted if the proposed project is constructed (Figure 11).

3.1.3 Egg and Larval Habitat

Ten model-grid cells exhibited decreases in habitat suitability for Atlantic sturgeon egg and larvae habitat (Figure 12). The locations of these are not in proximity to spawning locations. Therefore it is not likely that these potential changes would adversely affect these life-history stages.

3.1.4 Juvenile Habitat

Several dozen model-grid cells exhibited substantial decreases in future-with-project habitat suitability for juvenile Atlantic sturgeon habitat (Figure 13). Large areas in the Wando River are anticipated to decrease in juvenile habitat quality. Other areas of decreased quality are scattered throughout the project area.

3.2 Shortnose Sturgeon

3.2.1 Spawning Habitat

For the 52'/48' dredging alternative, the spawning SNS HSIs of four cells below The Tee decrease to "0" when compared to the FWOP (Figure 14). These cells switch automatically to 0's because salinity goes above 0.5 ppt. This results in a decrease in the HSI for these cells from 0.5 to 0. Other than these four cells the only other changes are very small (thousandths of a change in HSI), and are sometimes positive, and sometimes negative. The negative deltas are located in the upper portions of the Cooper River. These small changes are a result of the velocity variable (V5) and represented only minor changes on the suitability curve. SCDNR has determined that spawning does occur in the Cooper River in the tailrace canal near the Pinopolis Dam. The success of this spawning is unknown (Bill Post, SCDNR, pers com, 10/29/13). Because the impact of the project is over 20 river-miles downstream of where spawning is known to occur, this change is unlikely to impact this species. Figure 14 also shows that tagged individuals were not detected in or near cells that decrease in spawning habitat suitability.

3.2.2 Foraging Habitat

Project-area SNS foraging habitat experiences a net 0.19% increase in habitat units from the 52'/48' dredging alternative when compared to the FWOP condition. HSI numbers for all cells range from 0.715 to 0.85, and the deltas are very small, ranging from -0.004 to 0.007. Figure 15 shows that these changes do not result in substantial changes in modeled cells. Foraging habitat is affected by substrate, velocity, and temperature in the HSI. Since substrate stays constant, velocity, and temperature become the influencing variables. Since the bottom temperatures are slightly lower in the alternative conditions compared to the FWOP, temperature positively benefits shortnose sturgeon foraging in the HSI within many cells, and negatively in fewer cells. Results of HSI modeling indicate that SNS foraging will not be adversely affected by the proposed project. Figure 15 also shows where shortnose sturgeon (adult or juvenile) have been detected in the Charleston Harbor area.

Figure 10   Sites known for presence of Atlantic sturgeon and locations of spawning habitat cells affected by proposed project

Figure 11 Sites known for presence of Atlantic sturgeon and locations of adult habitat cells affected by proposed project

Figure 12 Sites known for presence of Atlantic sturgeon and locations of egg and larval habitat cells affected by proposed project

Figure 13 Sites known for presence of Atlantic sturgeon and locations of juvenile habitat cells affected by proposed project

Figure 14 Sites known for presence of shortnose sturgeon and locations of spawning habitat cells affected by proposed project

Figure 15 Sites known for presence of shortnose sturgeon and locations of foraging habitat cells affected by proposed project

3.3 Southern Flounder

This species only experiences a 0.95% reduction in habitat from the 52-48 alternative when compared to the FWOP condition. Substrate is a strong influencing parameter in the HSI. Many of the areas in the lower harbor that appear to have very different HSI values are only that way because the substrate compositions in those areas are different. The other variables are salinity, temperature, and dissolved oxygen. Since substrate is assumed constant across all scenarios, these three variables drive the changes. The HSI for DO falls to 0 when the minimum bottom DO falls below 3.0 mg/L. Subtle changes in salinity cause some minor HSI decreases in the lower harbor and especially within the navigation channel. Temperature is always a 1.0 on the HSI scale, and never influences a change in HSI. Select locations along the north shore of James Island, Clark Sound, and near the old village in Mt. Pleasant have low DO to begin with and small changes <.2mg/L cause the HSI to drop. Figure 16 shows the deltas for the HSI values across the harbor. Changes that were between -0.01 and 0.01 are shown as hollow because the changes are so small. Also the areas shown in yellow have deltas less than 0.025 and are minimal. Smaller tidal creeks show low DO in the existing and FWOP condition. Beresford Creek is an example where two cells show a reduction in habitat from the FWOP. These cells are affected by minimum bottom DO conditions falling from just barely over 3.0mg/L to just under 3.0mg/L which reduces the HSI from 0.355 to 0. It is evident that the changes are minor when compared to existing conditions, especially when you factor in that smaller tidal creeks are naturally low in DO in summer months and that taking the minimum bottom DO provides for a worst case scenario. This same situation applies in Goose Creek. The minimum bottom DO for the 52-48 scenario averaged across all cells is 4.11 mg/L. This includes marsh and ocean cells which are not calibrated well. Excluding those cells would increase this number. This number is above the DHEC water quality standard for this variable. Since the delta in the HSI value is less than 1%, this change in modeled optimum habitat is unlikely to adversely affect the southern flounder.

Figure 16 shows where southern flounder have been captured during two SCDNR programs and where HSI model results indicate decreases (and increases) in habitat suitability for the species. Approximately a dozen HSI cells demonstrating predicted decreases in habitat quality are located at or near sites where southern flounder were captured. Southern flounder had not been captured at or near cells predicted to have increases in HSI values following project construction.

3.4 Red Drum (Juveniles and Larvae)

This life stage only experiences a 2.46% increase in habitat from the 52-48 alternative when compared to the FWOP condition. A first look at the existing condition map shows a lot of unsuitable habitat in the middle of the harbor and the three rivers. This is because the depth in these areas is too deep to support juveniles and larvae which tend to utilize the marshes and margins of rivers as nursery habitat. Since the marshes are important to the juvenile and larval stage of this species, percent emergent vegetation is an important parameter. This parameter stays constant in the model because no change to this vegetation is anticipated as a result of any of the alternatives. Temperature and salinity become the two variables that influence the HSI the most in the model. Generally speaking, salinities experience a minor increase throughout the harbor, but this increase causes the increase in suitable habitat for this species as they are predicted by the model to have habitat enhanced in areas and slightly move upriver. Red drum have been captured throughout the project area (Figure 17). If the proposed project is implemented, HSI values are anticipated to increase at many locations in the harbor and estuary. Six cells are anticipated to decrease in habitat suitability. However, these are in the middle of the harbor, and no red drum have been captured at or near those locations.

Figure 16 Sites known for presence of southern flounder and locations of habitat cells affected by proposed project

Figure 17 Sites known for presence of red drum and locations of larvae/juvenile habitat cells affected by proposed project

3.5 Blueback Herring (Juveniles)

This life stage experiences a 4.82% decrease in habitat from the 52-48 alternative when compared to the FWOP condition. This life stage is driven by zooplankton abundances, salinity, and temperature in the HSI model. The number of zooplankton stays constant throughout all alternatives and is only given a 0.1 HSI (see methods above for how this number was determined). Water temperature is always given an HSI of 1.0 because it is always demonstrated to be in the optimum range. So this leaves salinity as the cause for HSI reductions for this species and life stage. The optimum range is from 0-5 ppt. It decreases to a 0 HSI at 12 ppt. The red cells in the figure below are where salinity increased from below 12 to just over 12 ppt. Because the number of habitat units was low to begin with because of the number of zooplankton used for this study, the percent change is higher. Because the below map indicates that the only changes occur as a result of salinity in and around the Cooper River between Goose Creek and Bushy Park, it is unlikely that this percent change will adversely impact the blueback herring. Figure 16 shows where blueback herring have been captured in the project area. There are a few locations where project-related effects are anticipated to adversely affect juvenile habitat suitability. However, no blueback herring have been captured at or near those locations. The proposed project is not anticipated to adversely affect habitat suitability for spawning adults, or egg or larval stages of the species in the project area (Figure 18).

3.6 Striped Bass

3.6.1 Adult/Juvenile Habitat

The striped bass HSI has four different life stages: Adult/Juvenile, Egg, Larval, and Spawning. The adult/juvenile life stage is predicted to have an increase of 0.28% suitable habitat with the 52-48 alternative. Dissolved oxygen and temperature drive the changes in this life stage. DO was almost always at 5mg/L in the time periods for this life stage and in instances where it wasn't (upper Ashley River), the model showed very slight, immeasurable, increases in DO that resulted in positive changes from the alternatives. Temperature was commonly the driver of the changes in most cells and the slight decreases in water temperature as a result of various alternatives resulted in very slight positive changes in the suitability index. Figure 19 shows where adult and juvenile striped bass have been captured. The figure also shows a few locations where HSI values were predicted to increase given the implementation of the proposed project, but bass have not been captured at or near those locations.

3.6.2 Spawning Habitat

The spawning stage for striped bass is predicted to have a decrease of 1.76% suitable habitat with the 52-48 alternative. Modeled changes in this life stage are driven by temperature and salinity, with salinity contributing the most. The largest changes are seen near the "tee" of the Cooper River where approximately two dozen cells incurred decreases in spawning habitat suitability (Figure 20), and are a result of a slight increase in salinity in this area. The cell with the largest reduction in habitat is just below the tee and drops by 0.141 on the scale of 0 to 1. These reductions are minor considering error in the instrumentation of the collected data, the EFDC model results, and when considering the inherent generality of the HSI model itself. No adult or juvenile bass were captured in the vicinity of those cells during the two SCDNR programs.

Figure 18 Sites known for presence of blueback herring and locations of juvenile habitat cells affected by proposed project

Figure 19 Sites known for presence of striped bass and locations of juvenile and adult habitat cells affected by proposed project

Figure 20 Sites known for presence of striped bass and locations of spawning habitat cells affected by proposed project

3.6.3 Egg Habitat

Habitat suitable for the egg stage of striped bass is predicted to decrease by 3.30% under the 52-48 alternative. Success for eggs is driven by temperature, minimum DO, and average velocity. While dissolved oxygen is low in the existing condition within the upper portions of the Ashley River (and therefore the model shows existing low habitat suitability in this area), it is not the primary influencing variable of predicted changes in the future. The majority of deltas adverse changes occur in the lower harbor and near the navigation channel and are a result of reductions in water velocity (Figure 21). Because these areas are not prime spawning habitat for striped bass, the modeled reduction is insignificant to the success of striped bass spawning in the Charleston Harbor system. Of more significant concern to this species is the existing low DO in the upper Ashley River even in the absence of the proposed project. None of the proposed alternatives measurably decrease DO in those areas.

3.6.4 Larval Habitat

Habitat suitable for the larval stage of striped bass is predicted to decrease by 2.23% under the 52-48 alternative. Success for larvae is driven by DO, salinity, and temperature in the model. All three variables affect the reductions in habitat suitability for larvae for the affected model cells, which are located sporadically through the harbor (but concentrated upstream of the federal channel in the Cooper River) (Figure 22). Even though there are catch data that indicate that striped bass have been captured in this area, a reduction of 2.23% is insignificant when considering error in the instrumentation of the collected data, the EFDC model results, and when considering the inherent generality of the HSI model itself.

Figure 21 Sites known for presence of striped bass and locations of egg habitat cells affected by proposed project

Figure 22 Sites known for presence of striped bass and locations of larval habitat cells affected by proposed project

4.0 CONCLUSIONS

Fishery (catch) data were not available for all model cells or all reaches, and data used to identify where species were *known* to be present was typically based on a very small number of sample events. Data were not used to indicate "absence," as that would be impossible. Nevertheless, at least some "real" field data were available for each species, and the spatial spread of sample stations throughout the project area was substantial. Data did *not* allow USACE to definitively state that certain areas *are* or *are not* important to/preferred by populations of various species because of the small number of samples per site. However, it indicated areas of *known* presence, and our conclusions below are limited to such areas. In other areas (where no samples exist, or where samples did not show presence), we have only the modeled HSI data on which to base conclusions regarding effect.

The following descriptions summarize the potential impacts from the proposed project to these representative species:

1. For larval and juvenile red drum, there are many areas where habitat may *benefit* due to the proposed action. Many of these locations involve sites without species presence data. However, some of these habitats are located at or near locations where the species has been previously captured.

2. Due to the proposed action, habitat suitability was predicted to *increase* for adult and juvenile striped bass at one location (comprising approximately a dozen model cells). The site/area did not correspond to a known capture site. Future-with-project conditions in approximately two-dozen model cells indicated decreases in striped bass spawning habitat suitability. No adult or juvenile bass were captured in the vicinity of those cells during two SCDNR sampling programs.

3. Inconsequential amounts of habitat critical for juvenile blueback herring would be adversely affected by the proposed action.

4. The proposed action may result in extremely slight adverse changes in southern flounder habitat for several areas, including some areas where the species was captured. However, there are no anticipated habitat changes for most/numerous locations where the species was captured.

5. The proposed action may decrease adult Atlantic sturgeon habitat suitability in some areas of the harbor that appear to be affiliated with use by the species. Inconsequential amounts of habitat potentially used by Atlantic sturgeon for spawning would be adversely affected by the proposed action. The proposed action may decrease juvenile Atlantic sturgeon habitat suitability in several dozen model cells. Some of the areas/cells are near stations where the species was detected, but most are not near stations where the tags of individuals were detected. Areas important for Atlantic sturgeon egg and larvae habitat do not appear to be associated with cells predicted to decrease in suitability.

6. Inconsequential amounts of habitat that may be useful for shortnose sturgeon during spawning and foraging behaviors would be adversely affected by the proposed action.

Due to the various project alternatives, future conditions will involve very small changes to various water quality parameters (temperature, salinity, DO, velocity). These minor changes result in positive and/or negative alterations (or no alterations in some cases) in , habitat suitability for various species, their life-history phases, and behaviors, depending on which alternative is modeled. The modeled changes are likely smaller than the year-to-year variation in salinity zones, DO, temperature, etc. No habitats are anticipated to be adversely affected on a widespread basis throughout the project area due to the proposed action. Typically, the proposed action was predicted to affect habitat suitability in isolated model cells or in a small cluster of adjacent cells. The results presented in the section above show the impacts from the “52-48” depth alternative (the deepest alternative dredge depths). Therefore, the changes indicated above are the most different from the future-without-project condition. Hence, none of the project alternatives are anticipated to have a significant impact on fish habitat based on the HSI outputs.

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ATTACHMENT A
Anticipated Habitat Unit Changes for Study Species/Life-history Phases by Project Alternative (Dredge Depths) for the FWOP Condition (year 2071)

Low Flow - Amount of Suitable Habitat (Habitat Units {H S I * Acres})

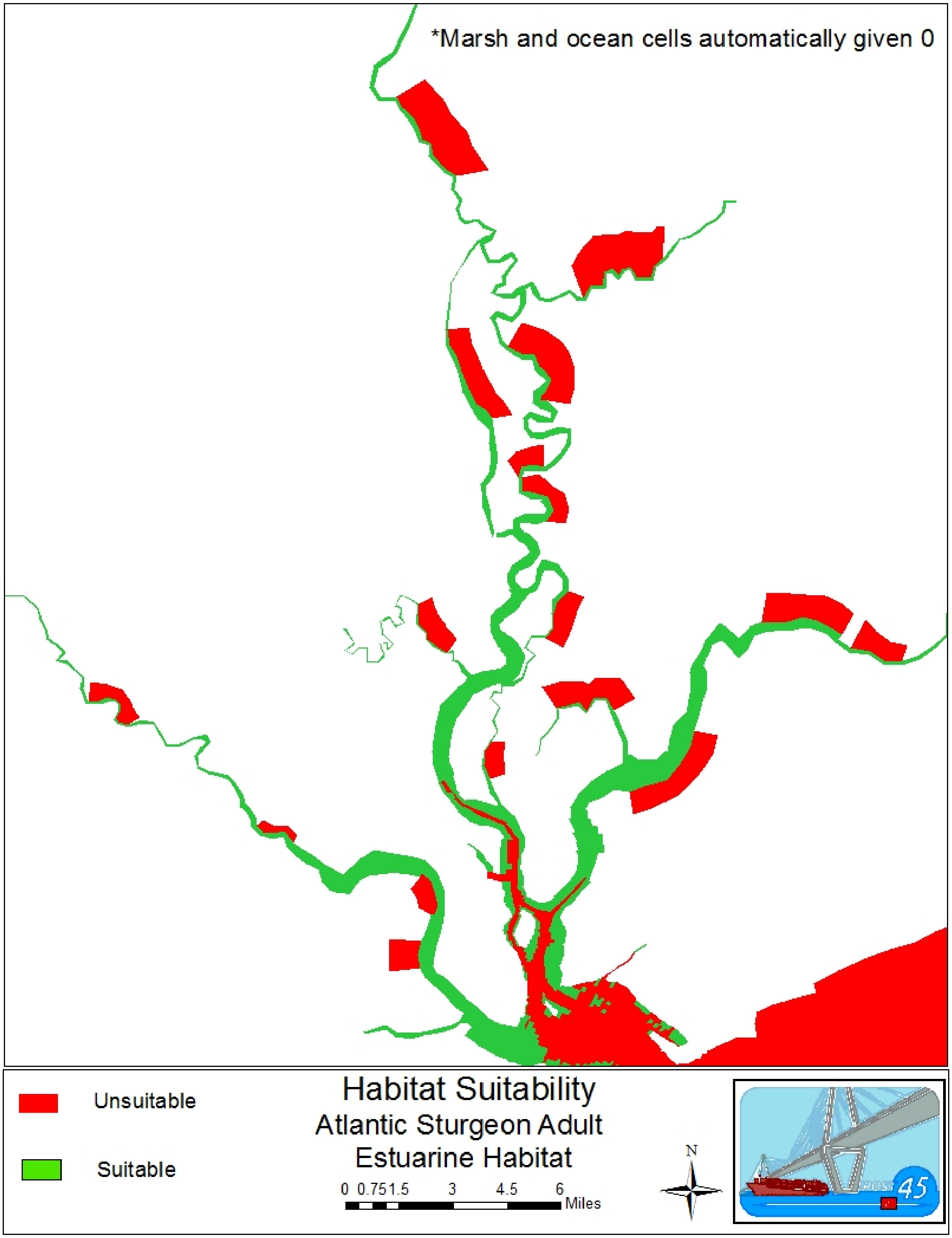
			48-47		48-48		50-47		50-48		52-47		52-48	
	Existing Condition	FWOP	Habitat Units	% Change	48-48	% Change	50-47	% Change	50-48	% Change	52-47	% Change	52-48	% Change
Striped Bass Spawning	2,662.43	2,611.88	2,591.73	-0.77	2,587.66	-0.93	2,582.93	-1.11	2,578.99	-1.26	2,573.24	-1.48	2,565.92	-1.76
Striped Bass Egg	10,680.56	10,753.97	10,507.33	-2.29	10,506.86	-2.30	10,462.91	-2.71	10,461.53	-2.72	10,399.68	-3.29	10,399.45	-3.30
Striped Bass Larval	533.67	444.85	446.29	0.32	451.26	1.44	444.89	0.01	445.84	0.22	435.59	-2.08	434.94	-2.23
Striped Bass Adult and Juvenile	22,002.09	22,004.79	22,035.66	0.14	22,033.80	0.13	22,043.38	0.18	22,044.22	0.18	22,064.45	0.27	22,066.21	0.28
Blueback Herring Juvenile	539.61	523.93	505.69	-3.48	505.69	-3.48	505.69	-3.48	503.02	-3.99	501.08	-4.36	498.69	-4.82
Blueback Herring SAEL	3,747.54	3,747.54	3,747.54	0.00	3,747.54	0.00	3,747.54	0.00	3,747.54	0.00	3,747.54	0.00	3,747.54	0.00
Red Drum	5,805.57	5,530.60	5,585.33	0.99	5,594.39	1.15	5,610.58	1.45	5,619.16	1.60	5,649.35	2.15	5,666.90	2.46
Southern Flounder	15,409.70	15,358.32	15,286.96	-0.46	15,286.62	-0.47	15,245.79	-0.73	15,259.59	-0.64	15,220.59	-0.90	15,212.16	-0.95
Shortnose Sturgeon Foraging	20,977.07	20,992.04	21,009.57	0.08	21,009.30	0.08	21,018.48	0.13	21,015.73	0.11	21,030.96	0.19	21,031.12	0.19
Shortnose Sturgeon Spawning	1,028.38	1,010.44	992.89	-1.74	992.93	-1.73	992.96	-1.73	983.93	-2.62	983.97	-2.62	975.68	-3.44
The below habitat for species life stages are measured in acres														
Atlantic Sturgeon Adult	19,642.59	19,170.39	18,853.03	-1.66	18,848.64	-1.68	18,653.44	-2.70	18,634.50	-2.80	18,436.40	-3.83	18,408.37	-3.97
Atlantic Sturgeon Egg and Larval	3,978.09	3,894.23	3,778.57	-2.97	3,765.29	-3.31	3,735.28	-4.08	3,701.12	-4.96	3,701.12	-4.96	3,701.12	-4.96
Atlantic Sturgeon Juvenile	18,486.46	17,907.54	17,630.31	-1.55	17,590.01	-1.77	17,405.84	-2.80	17,332.02	-3.21	17,090.92	-4.56	17,090.92	-4.56
Atlantic Sturgeon Spawning	2,154.37	1,987.96	1,968.87	-0.96	1,952.39	-1.79	1,952.39	-1.79	1,952.39	-1.79	1,934.26	-2.70	1,934.26	-2.70

ATTACHMENT B
Anticipated Habitat Unit Changes for Study Species/Life-history Phases by Project Alternative (Dredge Depths) for the Construction Year (Year 2022)

Amount of Suitable Habitat (Habitat Units {H S I * Acres})								
			48-48		50-48		52-48	
	Existing Condition	2022 Condition	48-48	Percent Change	50-48	Percent Change	52-48	Percent Change
Striped Bass Spawning	2,662.43	2,658.22	2,646.71	-0.43	2,637.34	-0.79	2,633.40	-0.93
Striped Bass Egg	10,680.56	10,696.47	10,448.05	-2.32	10,386.02	-2.90	10,316.45	-3.55
Striped Bass Larval	533.67	518.523	541.73	4.48	523.09	0.88	515.22	-0.64
Striped Bass Adult and Juvenile	22,002.09	22,003.22	22,034.50	0.14	22,043.72	0.18	22,061.03	0.26
Blueback Herring Juvenile	539.61	538.20	516.57	-4.02	512.49	-4.78	507.69	-5.67
Blueback Herring SAEL	3,747.54	3,747.54	3,747.54	0.00	3,747.54	0.00	3,747.54	0.00
Red Drum	5,805.57	5,765.75	5,822.76	0.99	5,841.03	1.31	5,855.06	1.55
Southern Flounder	15,409.70	15,403.53	15,336.59	-0.43	15,314.45	-0.58	15,297.96	-0.69
Shortnose Sturgeon Foraging	20,977.07	20,981.53	20,999.31	0.08	21,006.65	0.12	21,017.88	0.17
Shortnose Sturgeon Spawning	1,028.38	1,022.06	1,022.30	0.02	1,022.40	0.03	1,022.50	0.04
The below habitat for species life stages are measured in acres								
Atlantic Sturgeon Adult	19,642.59	19,567.39	19132.91	-2.22	18,920.21	-3.31	18,746.49	-4.20
Atlantic Sturgeon Egg and Larval	3,978.09	3,978.09	3,892.46	-2.15	3,892.46	-2.15	3,828.13	-3.77
Atlantic Sturgeon Juvenile	18,486.46	18,426.03	18,020.28	-2.20	17,778.47	-3.51	17,479.37	-5.14
Atlantic Sturgeon Spawning	2,154.37	2129.144	2129.144	0.00	2,103.64	-1.20	2,081.08	-2.26

ATTACHMENT C

Fish Habitat Maps
Existing Condition (Year 2012)
Low Flow
Actual Loads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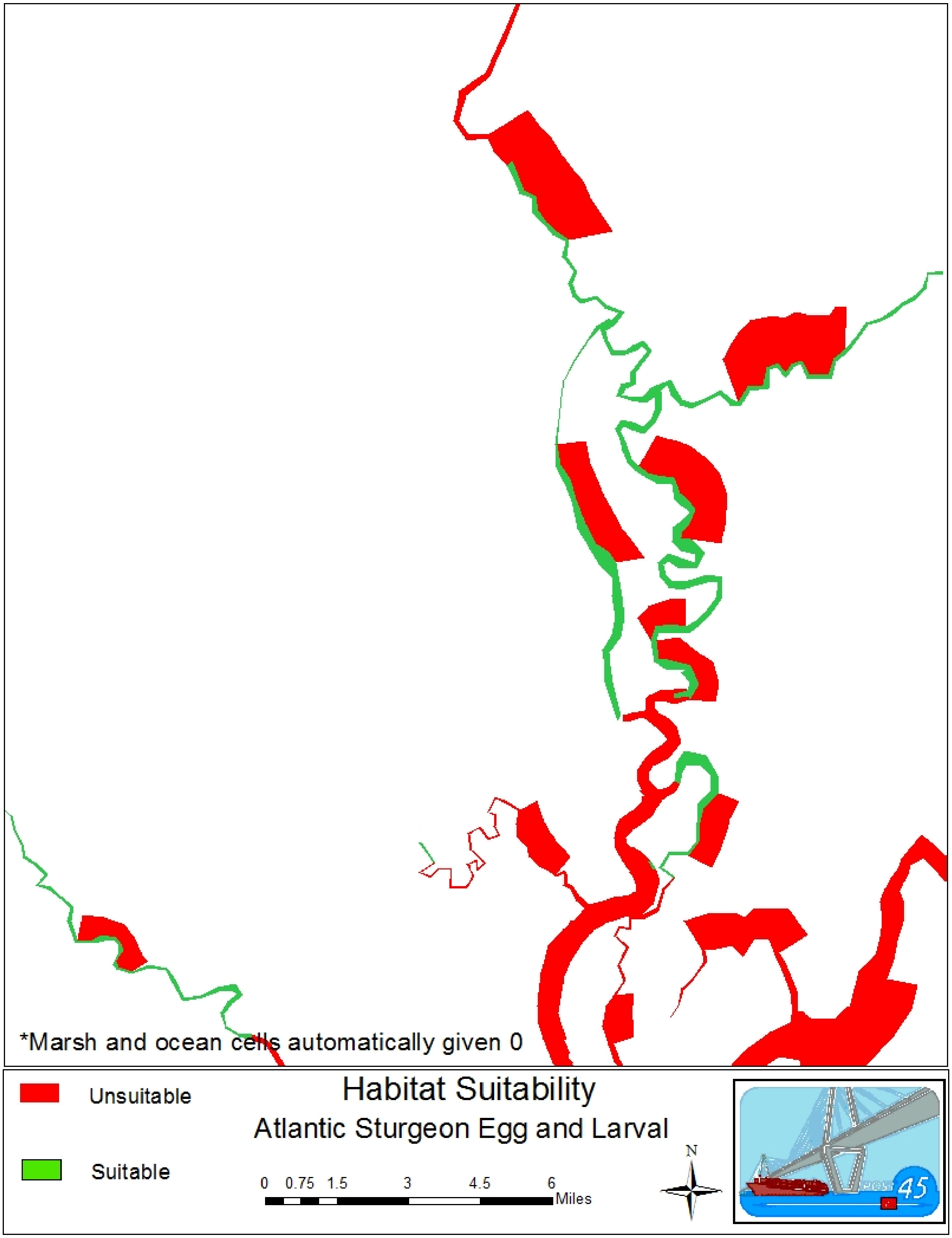
Unsuitable
Suitable
Habitat Suitability
Atlantic Sturgeon Adult
Estuarine Habitat
0 0.751.5 3 4.5 6
Miles
N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Unsuitable
Suitable
Habitat Suitability
Atlantic Sturgeon Egg and Larval
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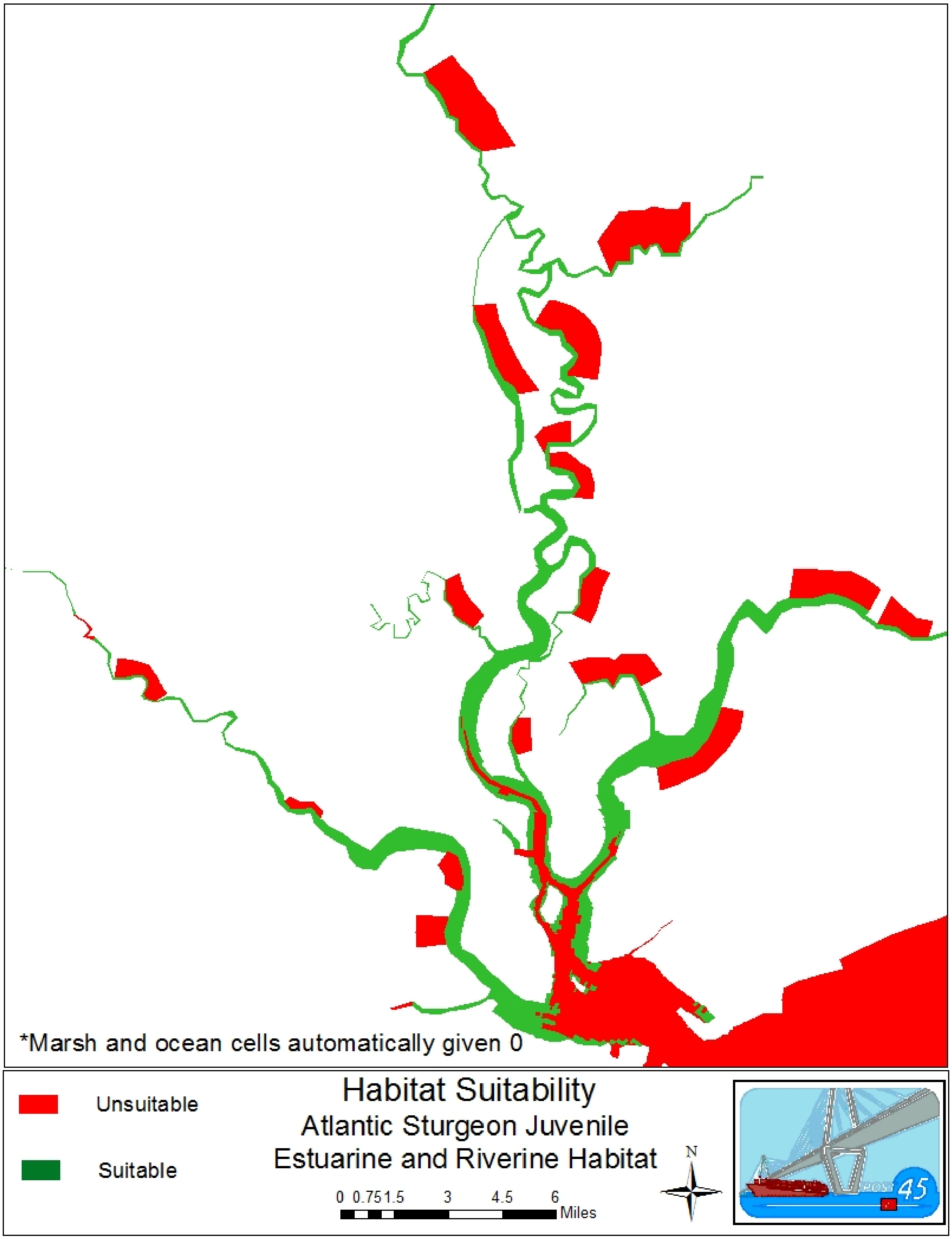
Miles
N
45


*Marsh and ocean cells automatically given 0
Unsuitable
Suitable
Habitat Suitability
Atlantic Sturgeon Juvenile
Estuarine and Riverine Habitat
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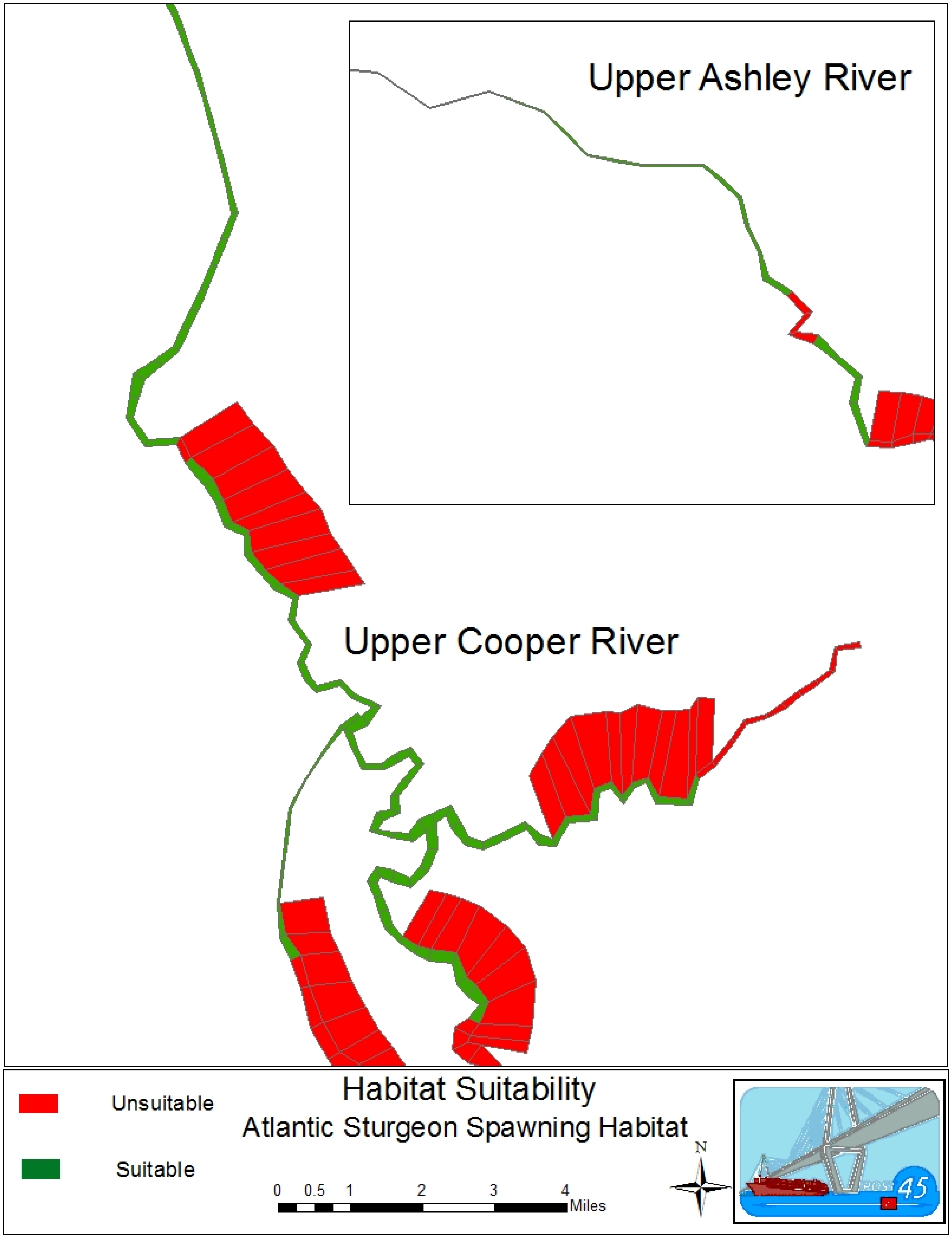
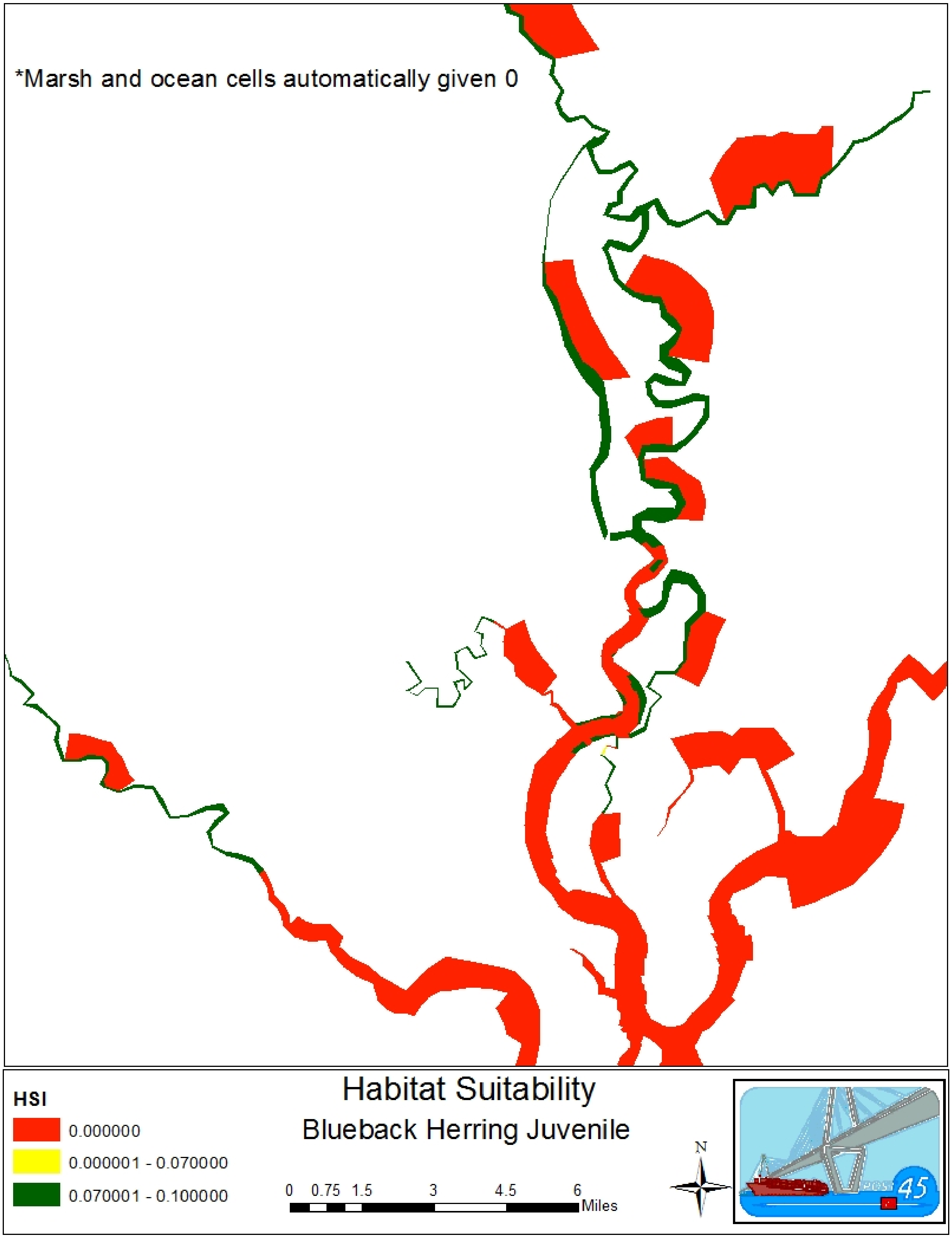
Miles
N
45


Upper Ashley River
Upper Cooper River
Unsuitable
Suitable
Habitat Suitability
Atlantic Sturgeon Spawning Habitat
0 0.5 1 2 3 4
Miles
N
45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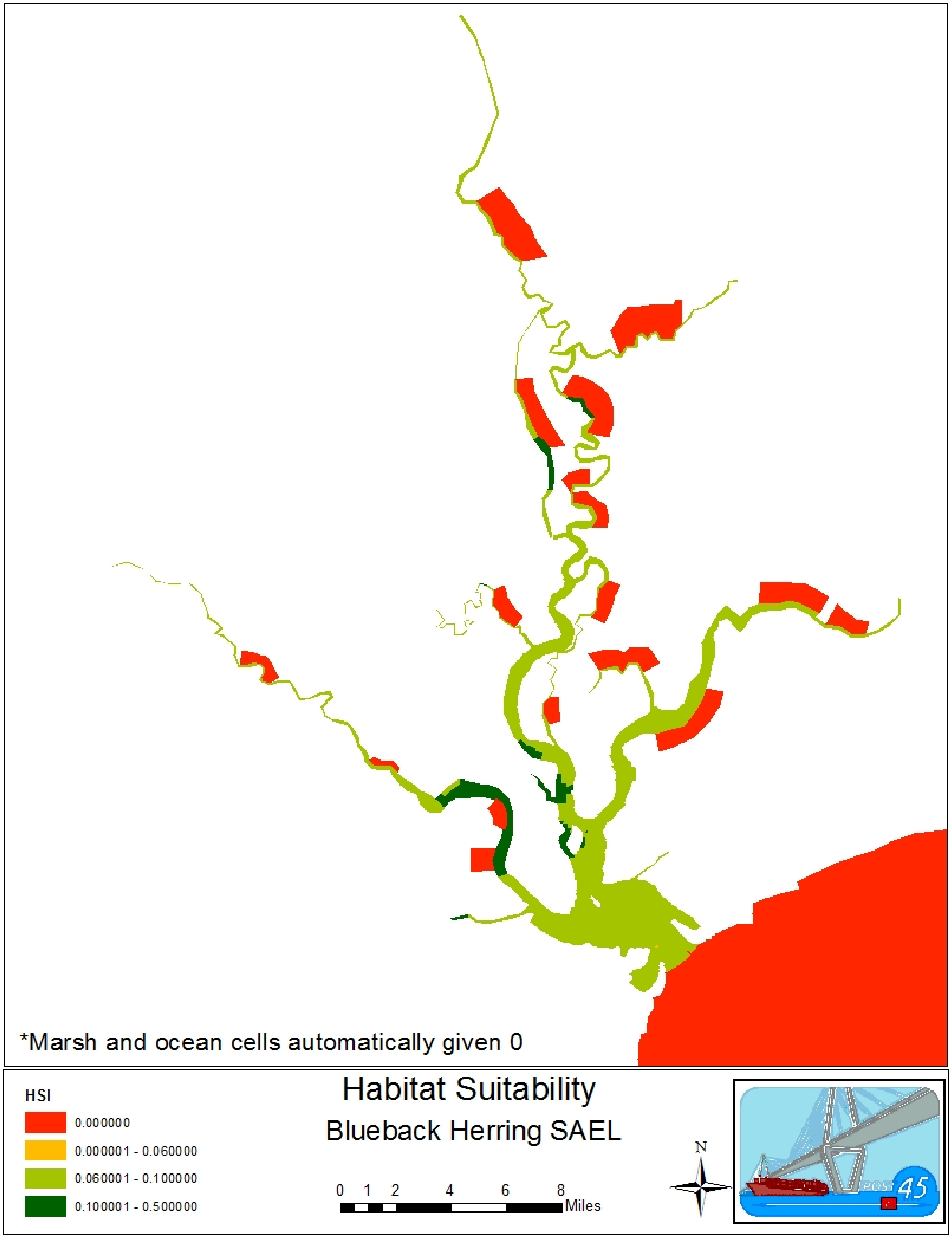
HSI
0.000000
0.000001 - 0.070000
0.070001 - 0.100000
Habitat Suitability
Blueback Herring Juvenile
0 0.75 1.5 3 4.5 6
Miles
N
45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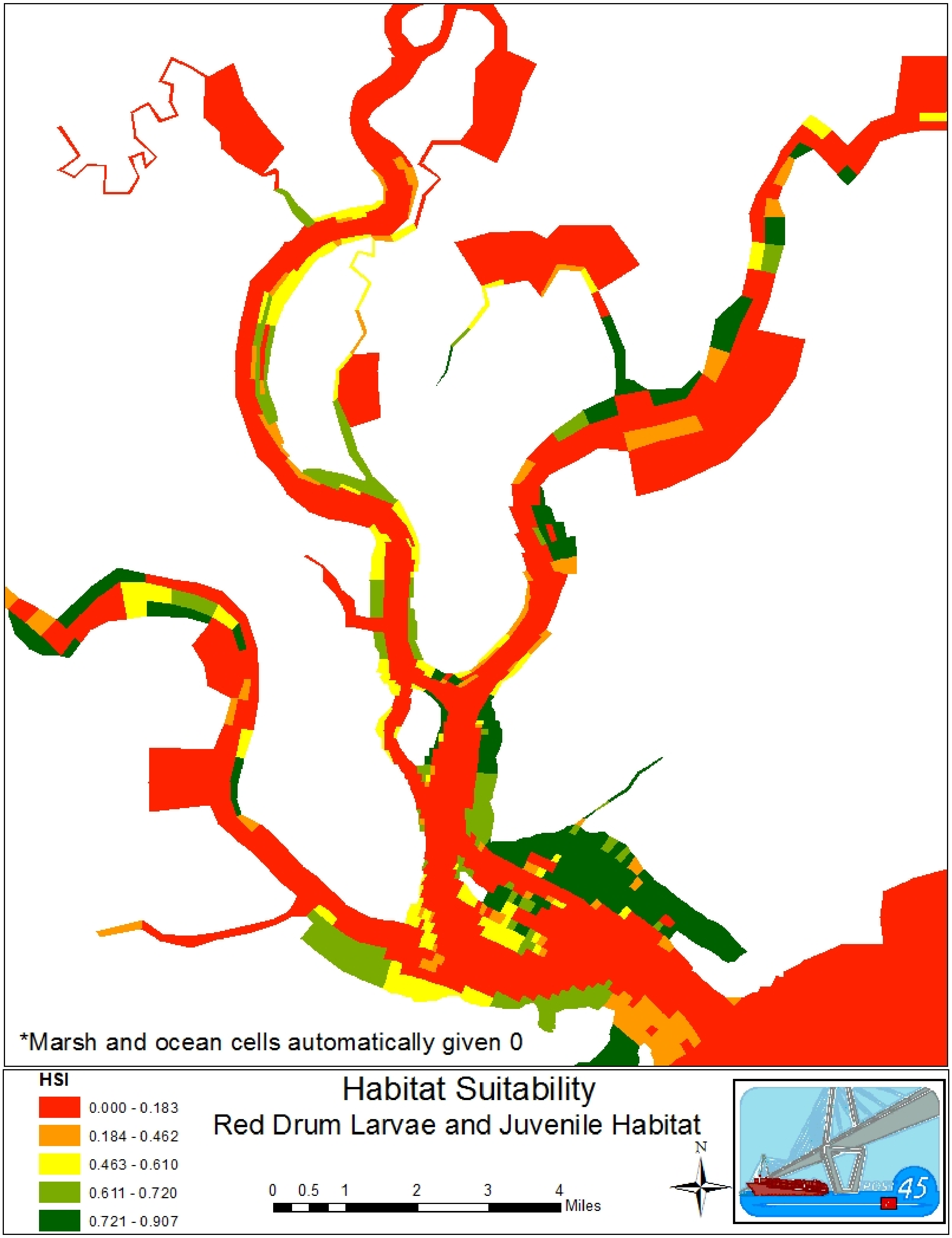
HSI
0.000000
0.000001 - 0.060000
0.060001 - 0.100000
0.100001 - 0.500000
Habitat Suitability
Blueback Herring SAEL
0 1 2 4 6 8
Miles
N
45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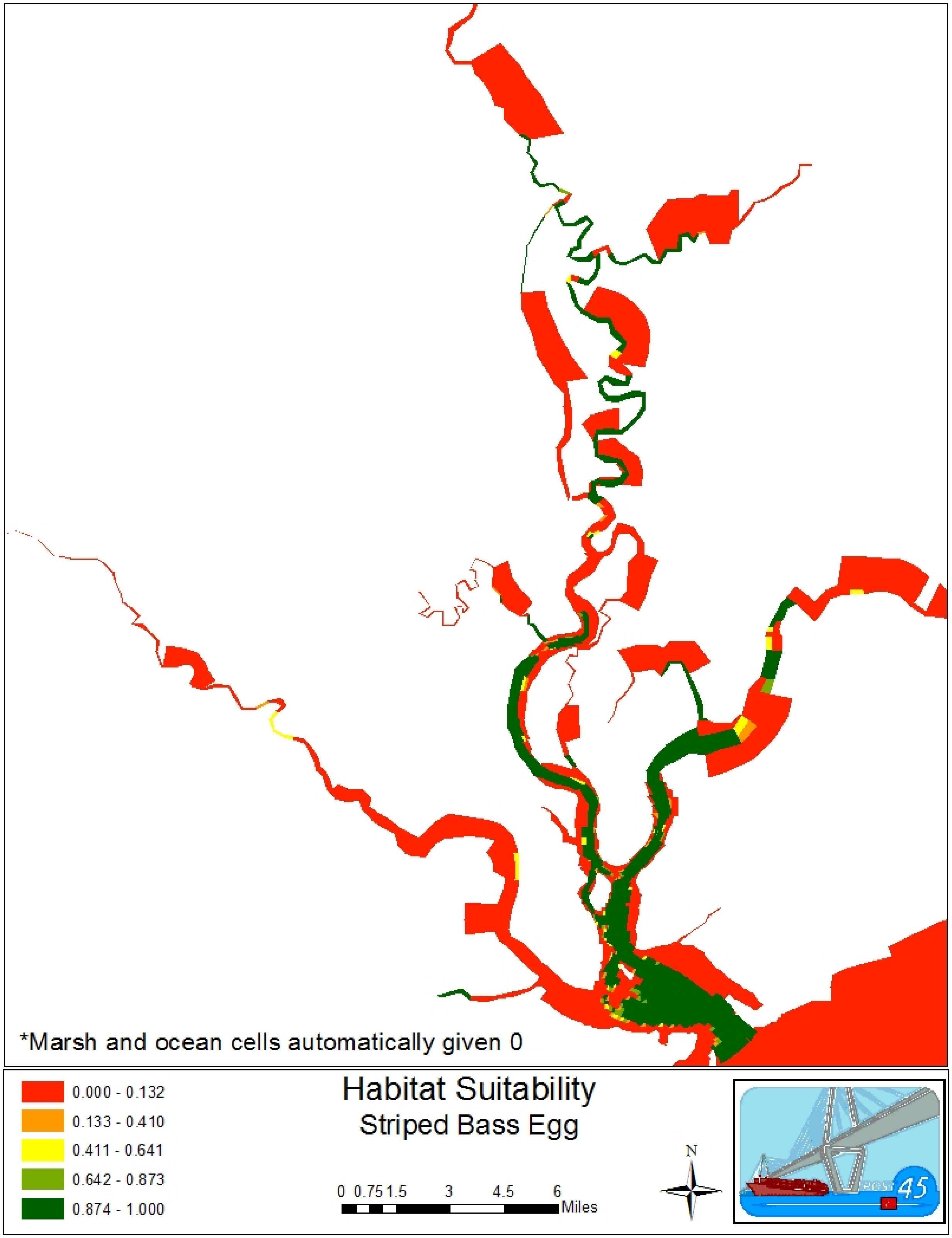
HSI
0.000 - 0.183
0.184 - 0.462
0.463 - 0.610
0.611 - 0.720
0.721 - 0.907
Habitat Suitability
Red Drum Larvae and Juvenile Habitat
0 0.5 1 2 3 4
Miles
N
45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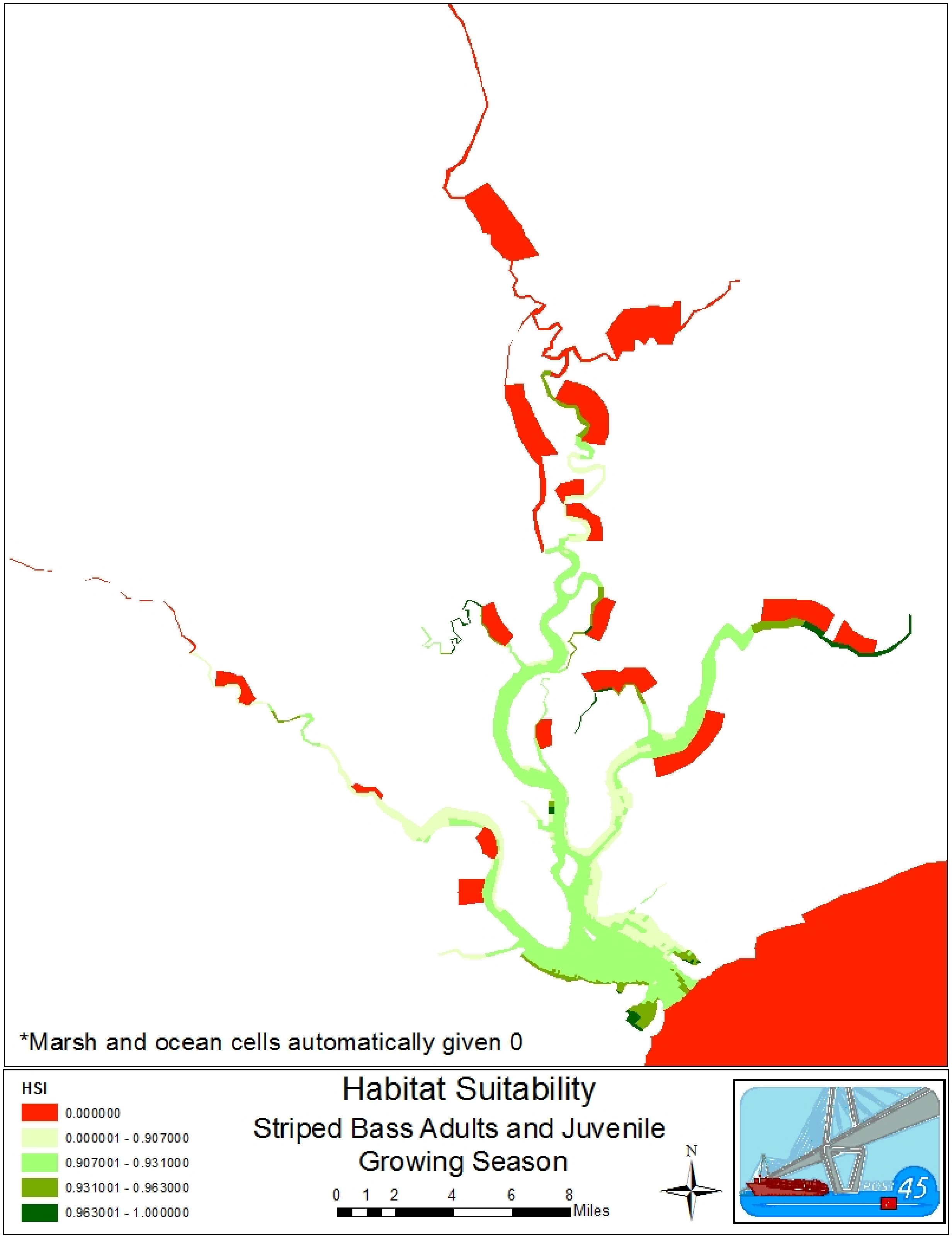
0.000 - 0.132
0.133 - 0.410
0.411 - 0.641
0.642 - 0.873
0.874 - 1.000
Habitat Suitability
Striped Bass Egg
0 0.75 1.5 3 4.5 6
Miles
N
45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HSI
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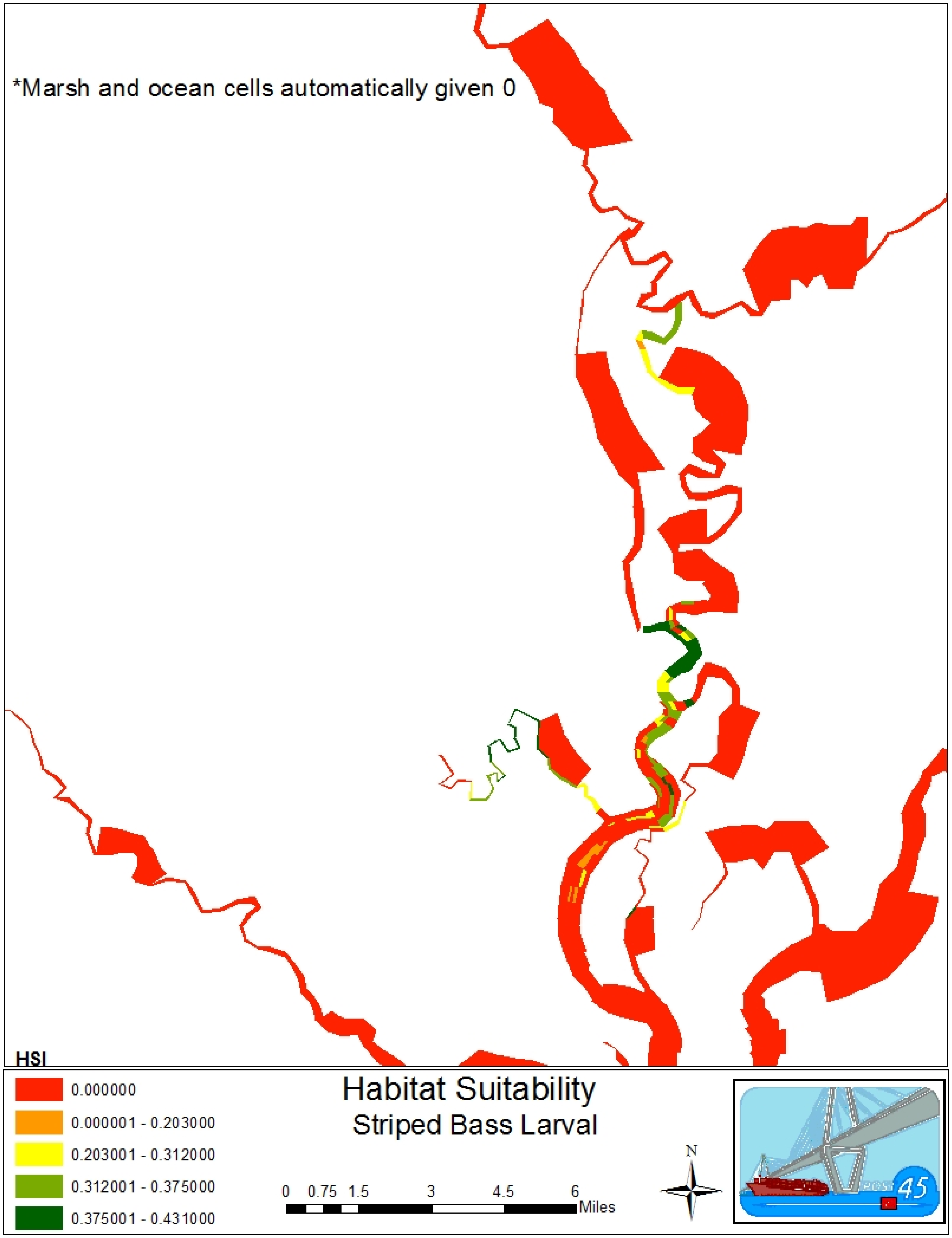
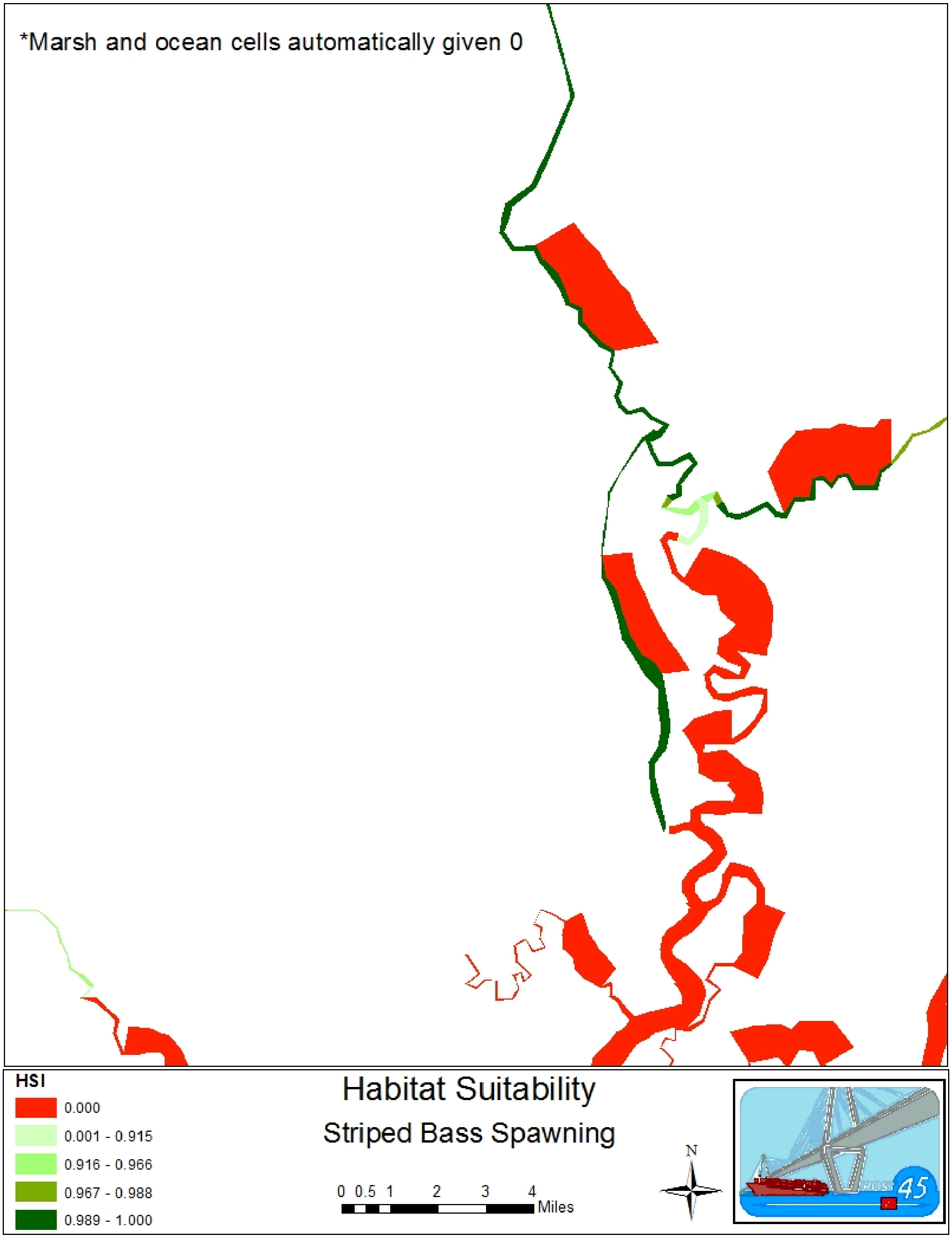
0.000001 - 0.907000
0.907001 - 0.931000
0.931001 - 0.963000
0.963001 - 1.000000
Habitat Suitability
Striped Bass Adults and Juvenile
Growing Season
0 1 2 4 6 8
Miles
N
45



*Marsh and ocean cells automatically given 0
HSI
0.000000
0.000001 - 0.203000
0.203001 - 0.312000
0.312001 - 0.375000
0.375001 - 0.431000
Habitat Suitability
Striped Bass Larval
0 0.75 1.5 3 4.5 6
Miles
N
45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HSI
0.000
0.001 - 0.915
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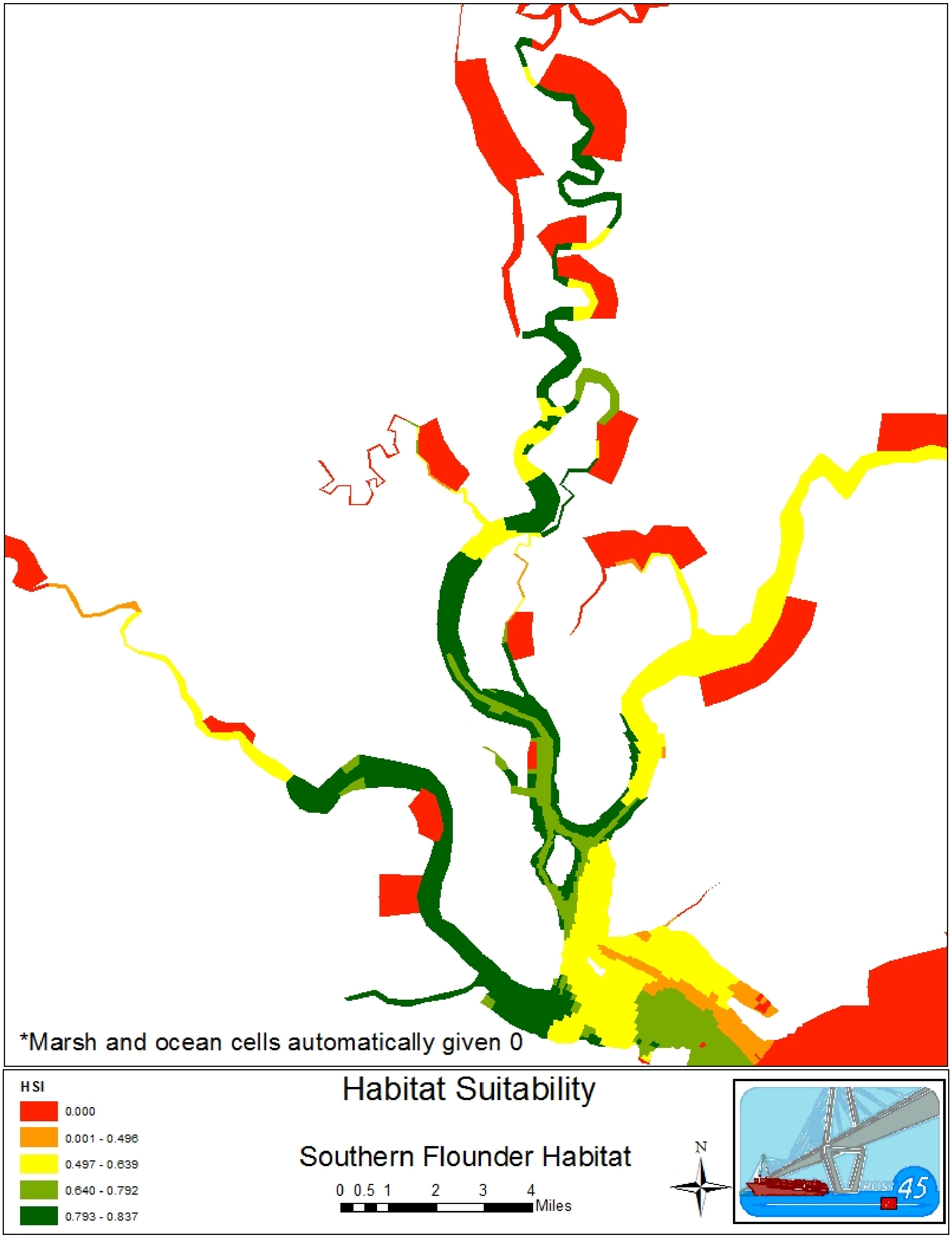
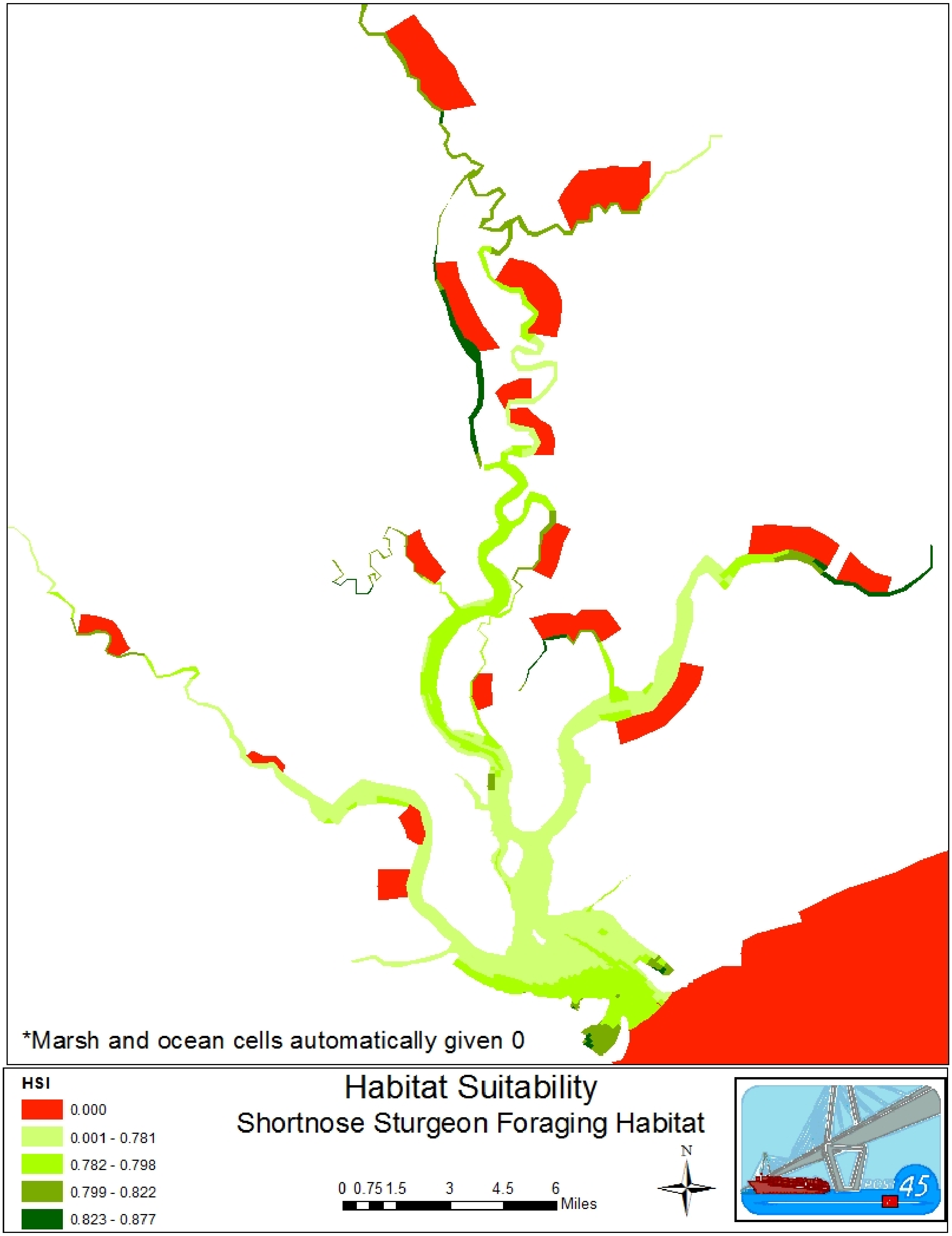
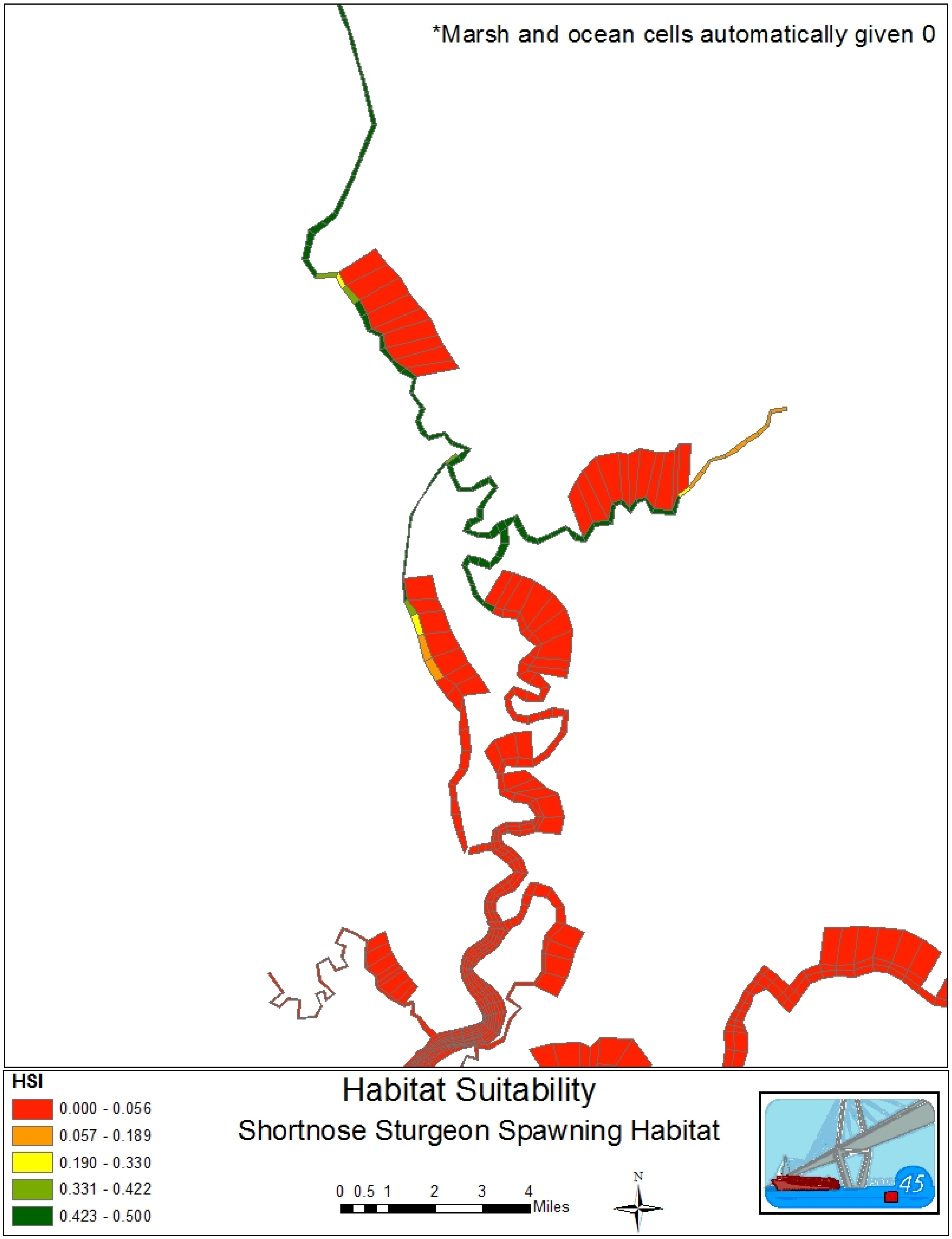
0.967 - 0.988
0.989 - 1.000
Habitat Suitability
Striped Bass Spawning
0 0.5 1 2 3 4
Miles
N


*Marsh and ocean cells automatically given 0
HSI
0.000
0.001 - 0.496
0.497 - 0.639
0.640 - 0.792
0.793 - 0.837
Habitat Suitability
Southern Flounder Habitat
0 0.5 1 2 3 4
Miles
N
45


*Marsh and ocean cells automatically given 0
HSI
0.000
0.001 - 0.781
0.782 - 0.798
0.799 - 0.822
0.823 - 0.877
Habitat Suitability
Shortnose Sturgeon Foraging Habitat
0 0.75 1.5 3 4.5 6
Miles
N
45

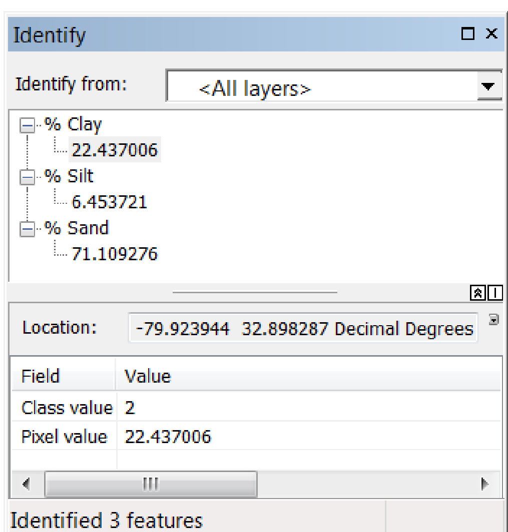

*Marsh and ocean cells automatically given 0
HSI
0.000 - 0.056
0.057 - 0.189
0.190 - 0.330
0.331 - 0.422
0.423 - 0.500
Habitat Suitability
Shortnose Sturgeon Spawning Habitat
0 0.5 1 2 3 4
Miles
N
45

ATTACHMENT D
Data Processing Specifications

Data Correlation Matrix

Incoming data: Mark Messersmith provided the following two spreadsheets on 4/11/2013
Site_Location_all_sediment_data_2.xlsx (**Site_Location_phi tab**)
SCECAP CHD sediment data 20121019 (version 1).xlsx (**CHD SCECAP Stations CT tab**)
The spreadsheets were combined into a single file, named **CHS_SSC.xlsx**. The following attributes are available:
Field Mapping: CHS_SSC.xlsx (Data Import)

Composite Spreadsheet	Supplied Spreadsheet
Year	**CHD SCECAP Stations CT only sites**
StationClass	**CHD SCECAP Stations CT only sites**
StationCode	**CHD SCECAP Stations CT (StationCode); Site_Location_phi (Strata)**
Latitude	Latitude
Longitude	Longitude
Sand	**CHD SCECAP Stations CT (Sand); Site_Location_phi (Sand (%))**
Silt	**CHD SCECAP Stations CT (Silt); Site_Location_phi (Silt (%))**
Clay	**CHD SCECAP Stations CT (Clay); Site_Location_phi (Clay (%))**
Source	*Name of source spreadsheet tab*



Geoprocessing

1. **CHS_SSC.xlsx** was added into an ArcMap session.
2. XY Event layer was created using Latitude/Longitude with WGS84 coordinate system.
3. Shapefile created from Event layer named, **CHS_SSC_Sites.shp**
4. The **CHS_SSC_Sites** layer was used as the input layer for interpolation.
   a. 3 interpolations were performed, using the following attributes respectively: Sand, Silt, and Clay. The final raster represents a **percent** value.
   b. 3 individual floating point raster grids were created: **pertSand**, **perSilt**, and **perClay**.
   c. **Kriging** was the selected interpolation method.
      i. Kriging is most appropriate when a spatially correlated distance or directional bias in the data is known and is often used for applications in soil science and geology.
      ii. http://www.esri.com/news/arcuser/0704/files/interpolating.pdf
      iii. ***Universal*** Kriging method was used. (Figure 1)
      iv. See settings in *Geoprocessing Detail* section
   d. The Grid (which was projected into WGS84) was used as the analysis mask (Figure 2).
      i. Geometry was corrupt in the initial supplied shapefile, **CHSGrid_01_15_2013.shp**. The ***Repair Geometry*** ArcToolbox function was used for the repair.
      ii. The boundary of the grid was honored in the interpolation. A simplified polygon shapefile, **SimplifiedGrid.shp**, was used for the interpolation boundary. This layer was created using the ***Dissolve*** ArcToolbox function.
5. Using the ***Zonal Statistics*** function of ArcToolbox, for each grid cell statistics were generated based off of the floating point grids (Figure 3).
   a. A statistics table was generated for each % Silt, % Sand, and % Clay.
      i. Table names: **siltstat**, **sandstat**, **claystat**
   b. Each statistics table was *joined* to an individual copy of the Grid layer (Figure 4).
   c. Each layer (e.g., % Sand (Mean per Grid Cell)) was symbolized by the Mean % per Grid Cell.
   d. Be aware a large amount of error was introduced when interpolation occurred where no sampling sites intersected a grid cell. Be sure to assess each percentage with the sampling sites layer visible.
6. The percentages of each Sand, Silt, and Clay can be retrieved by using the **Identify** tool.
   a. Click anywhere in the map with the **Identify** tool.
   b. Be sure to select <All Layers> in the Identify From box.
   c. The **pixel** value represents the percentage.

Geoprocessing Detail

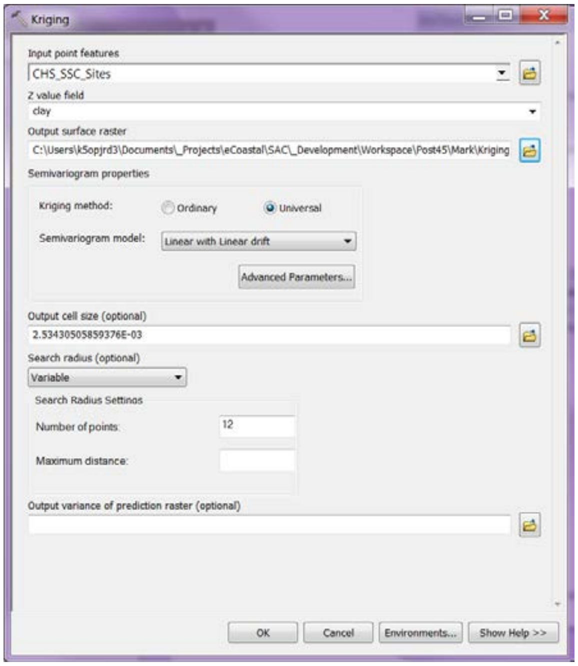


Figure 1: Settings used to create each interpolation.

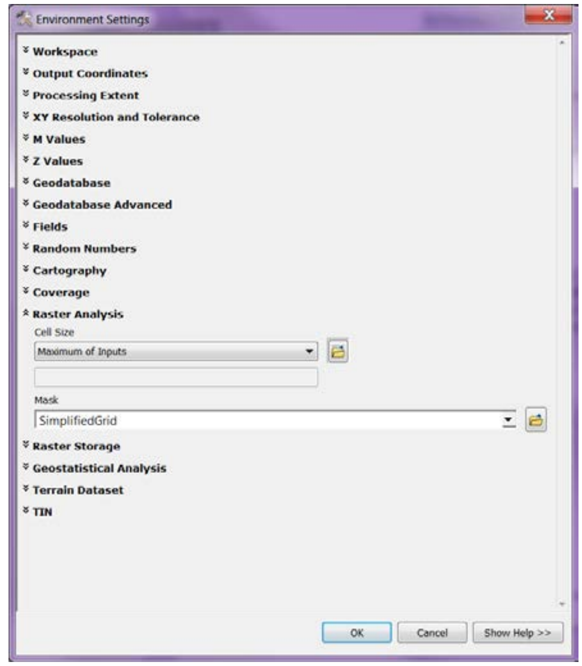


Figure 2: Setting the Analysis Mask.

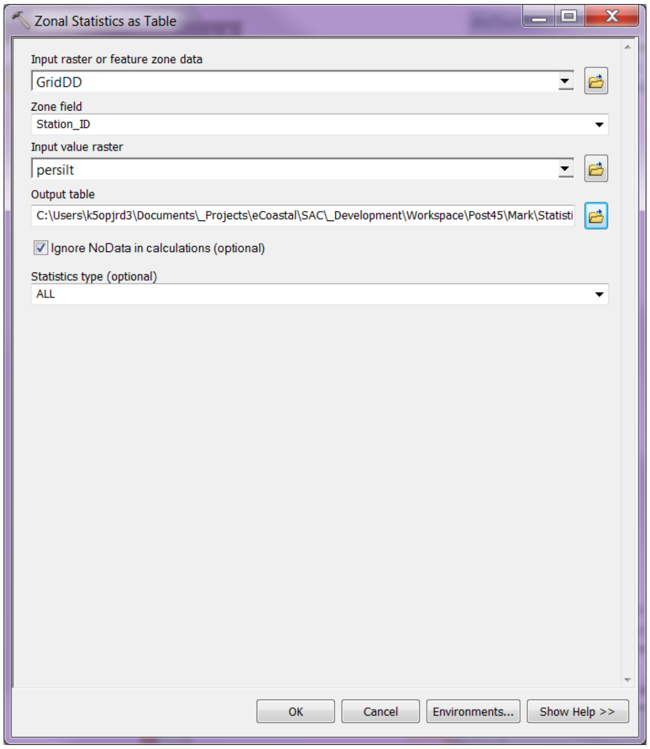


Figure 3: Zonal Statistics for each interpolated raster.

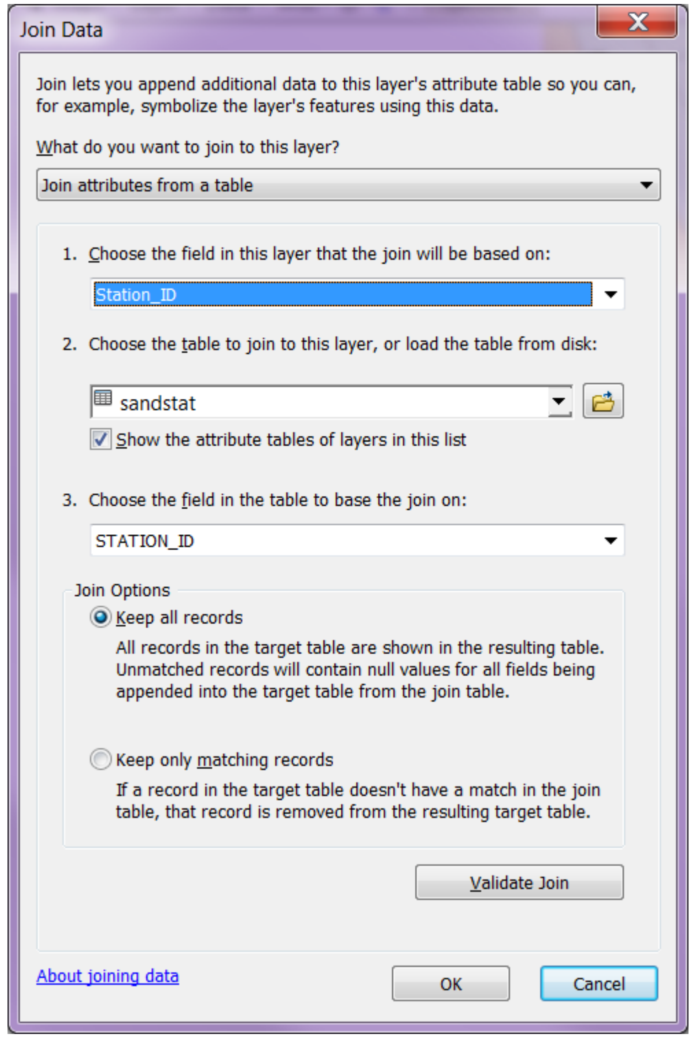


Figure 4: Join properties to display Zonal Statistics results.