The following is the recommended framework for the Habitat Plan. The Management Board should task the Technical Committee to review, modify as needed, and approve this framework. This outline is designed to be an inclusive framework for organizing information on habitat, and threats to that habitat. As such, it is likely that data may not yet be available for some items. In those cases, states and jurisdiction should indicate data status (e.g., not available, being collected, being analyzed, under review).

1) **Habitat Assessment –** Assess the habitat (historic and currently available) and impediments to full utilization of the habitat.

a. Spawning Habitat

i. Amount of historical in-river and estuarine spawning habitat (e.g., river kilometers, water surface area (hectares)).

ii. Amount of currently accessible in-river and estuarine spawning habitat (i.e., habitat accessible to adult fish during the upstream spawning migration).

b. Rearing Habitat

i. Amount of historical in-river and estuarine young-of-year rearing habitat (e.g., river kilometers, water surface area (hectares)).

ii. Amount of currently utilized in-river and estuarine young-of-year rearing habitat (i.e., habitat available to larval stage and young-of-year fish through natural spawning or artificial stocking of hatchery reared juvenile fish).

2) **Threats Assessment –** Inventory and assess the critical threats to habitat quality, quantity, access, and utilization (see - *Appendix C* for a detailed habitat description). For those threats deemed by the state or jurisdiction to be of critical importance to restoration or management of an American shad stock, the state or jurisdiction should develop a threats assessment for inclusion in the Habitat Plan. Examples of potential threats to habitat quality, quantity, and access for American shad stocks include:

a. Barriers to migration inventory and assessment

i. Inventory of dams, as feasible, that impact migration and utilization of historic stock (river) specific habitat. Attribute data for each dam should be captured in an electronic database (e.g., spreadsheet) and include: name of dam, purpose of the dam, owner, height, width, length, impoundment size, water storage capacity, location (i.e., river name, state, town, distance from river mouth, geo-reference coordinates), fish passage facilities and measures implemented (i.e., fish passage type, capacity, effectiveness, and operational measure such as directed spill to facilitate downstream passage), and information source (e.g., state dam inventory).

ii. Inventory of other human–induced physical structures (e.g., stream crossing/culverts), as feasible, that impact migration and utilization of historic habitat (data on each structural impediment should include: type, source, and location).

iii. Inventory of altered water quality (e.g., low oxygen zones) and quantity (e.g., regulated minimum flows that impact migration corridors and/or migration cues), as feasible, impediments that impact migration and utilization of historic habitat (data on each water quality and quantity impediment should include: type, source, location, and extent).

iv. Assess barriers to migration in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

b. Water withdrawals inventory and assessment

i. Inventory of water withdrawals (both permitted and known unpermitted), as feasible, that impact or have the potential to impact (e.g., fish entrainment and impingement, instream habitat alteration, and/or alteration of instream flow) migration and utilization of historic habitat.

ii. Assess water withdrawals in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

c. Toxic and thermal discharge inventory and assessment

i. Inventory of toxic and thermal discharge of water, where applicable, that impact or have the potential to impact (e.g., create a barrier, lethal concentration, and/or reduce fitness) migration and utilization of historic habitat.

ii. Assess toxic and thermal discharge in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

d. Channelization and dredging inventory and assessment

i. Inventory of channelization and dredging projects, as feasible, that impact or have the potential to impact (e.g., create a barrier, degrade substrate, and/or reduce water quality) migration and utilization of historic habitat.

ii. Assess stream channelization and dredging in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

e. Land use inventory and assessment

i. Inventory of land use in the watershed that impact or have the potential to impact (e.g., alter run-off regimes, degrade riparian habitat, increase siltation, reduce water quality and/or diminish riparian buffers) migration and utilization of historic habitat.

ii. Assess land use in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

f. Atmospheric deposition assessment

i. Assess atmospheric deposition in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

g. Climate change assessment

i. Assess potential climate change impacts in the watershed and characterize

their impact on American shad migration and utilization of historic habitat.

h. Competition and predation by invasive and managed species assessment

i. Assess competition and predation by invasive and managed species in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.

Habitat Restoration Program – For threats deemed to be of critical importance to the restoration and management of American shad stocks within its jurisdiction, each state or jurisdiction should develop a program of actions to improve, enhance and/or restore habitat quality and quantity, habitat access, habitat utilization and migration pathways. These programs may include plans to take direct corrective actions within the state or jurisdictions' authority, or to consult with agencies that have management authority over the threat, inform them of the impacts the threat is having on American shad stocks, and recommend potential alternatives or corrective actions to alleviate that threat. Section 5.5 Habitat Restoration, Enhancement, Utilization, and Protection Recommendations should be consulted for potential actions that could be included in the Habitat Restoration Program. While this amendment proposes the development of such programs, the implementation of these programs is not required. Programs could include:

a. Barrier removal and fish passage program – Develop a program to eliminate, minimize, or mitigate impacts from barriers identified in 2 (a) above.
b. Hatchery product supplementation program – Consider the stocking of hatchery reared larvae or juveniles to spawning or rearing habitat that is underutilized due to migration barriers or to new habitat following barrier removal.
c. Water quality improvement program - A program should be developed to address identified impacts of poor water quality to spawning success and juvenile recruitment in 2 (b) and (c) above.
d. Habitat improvement program - A program should be developed to address identified impacts to habitat in 2 (d) and (e) above and to protect quality habitat.
e. Project permit/licensing review program for water withdrawals, toxic and thermal discharge, channelization and dredging, and land use and development, that includes development of recommendations and conditions to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat - A program should be developed to identify, review, assess, and comment or condition permitted/licensed development projects that could impact aquatic habitat or restoration efforts
f. Programs to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat from atmospheric deposition and climate change – Atmospheric deposition and climate change may impact restoration efforts and will need to be addressed through cooperative engagement with the public and regulatory bodies that can influence positive change, or eliminate/diminish the identified impacts. It is recommended that a program be developed to engage in the public debate and/or regulatory actions in order to attain full consideration of impacts of atmospheric deposition and climate change on American shad habitat and restoration efforts. It is also recommended that the ASMFC should consider developing a plan to engage as a unified body in the atmospheric deposition and climate change debate, and formulate a position statement on future action by regulatory agencies that address the identified impacts.

Maine Department of Marine Resources

American Shad Habitat Plan

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Submitted to the Atlantic States Marine Fisheries Commission as a requirement of the Amendment 3 to the Interstate Management Plan for Shad and River Herring

Report Overview

This report will provide river-specific information for the major known American shad spawning and young-of-year rivers: the Saco, Androscoggin, Kennebec (and Sebasticook), and Penobscot rivers. Information about general threats, data availability, current work and recommended actions are summarized in the first section.

State-Wide Information

Amount of Habitat

State-wide, there are twenty-three identified American shad rivers with over 2545 river kilometers of potential habitat. Currently only 1611 river kilometers are known to be open to American shad passage, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1, Table 1). Of the habitat that is accessible, a large portion on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat represents both adult and juvenile use. American shad are documented as regular catches in recreational fishing reports from the Sheepscot, Mousam, Presumpscot, Saco and Kennebec rivers and Scarborough Marsh, but there are few reports from other rivers. The population sizes are unknown.

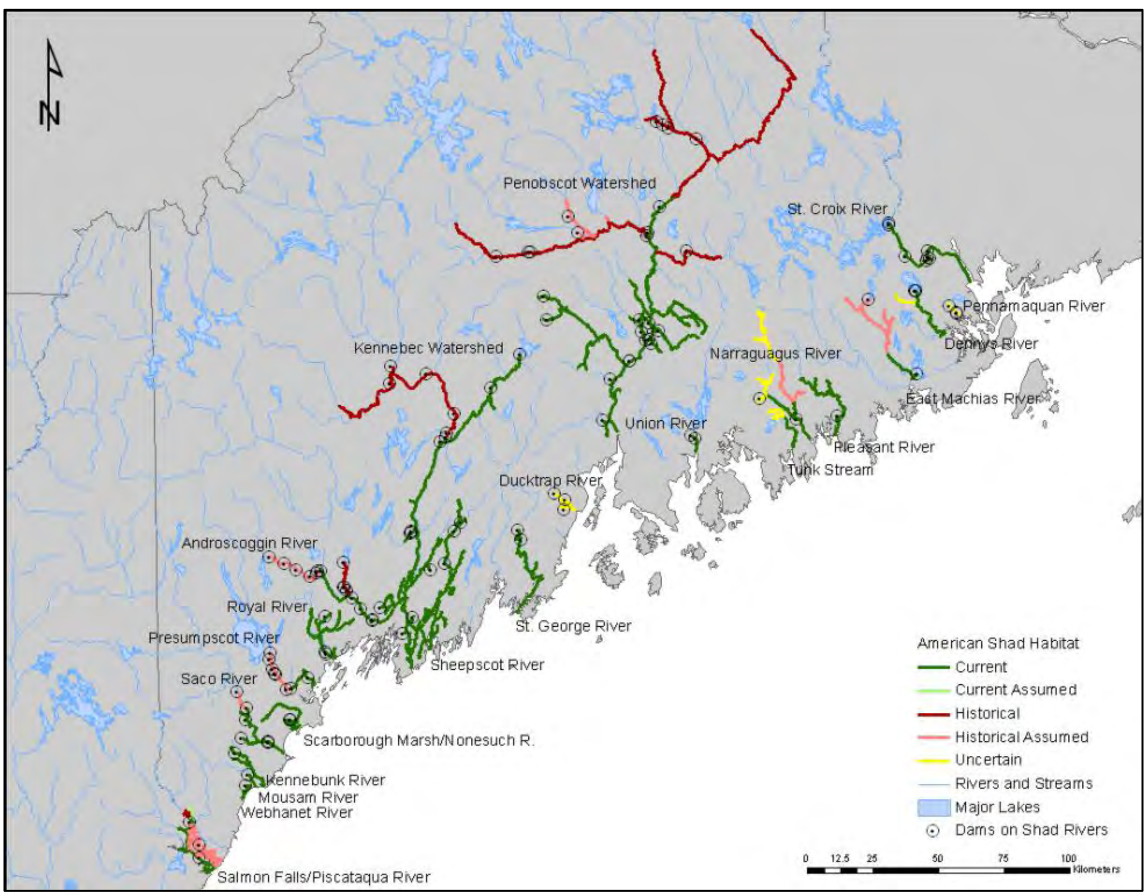

Figure 1. American shad habitat in Maine waters as identified by a USFWS mapping effort (USFWS 1983). Dams and impoundments on shad rivers are also shown.

Major Threats

<u>Barriers to migration</u> are the primary impediments to American shad habitat and successful spawning within Maine state waters. Out of 24 shad rivers in Maine, 18 have a mainstem dam that likely limits shad passage upstream. Of these, five have no capacity for fish passage (Table 2).

Even when fish passage is installed at these dams, the use of habitat upstream of dams is thought to be much lower than the use of areas below the dam. In 2011, video monitoring below Brunswick Fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Fish passage efficiency for American shad has not been documented at the other sites in Maine, however other studies have described the potential for shad passage.

Table 1. Amount of American shad habitat (river kilometers) in Maine waters (USFWS 1983). Rivers are listed in order of descending habitat kilometers.

River/Watershed	Current (though may be limited)	Current Assumed	Historical	Historical Assumed	Uncertain	Total
Penobscot Watershed	399.6		354.0	32.7		786.3
Kennebec Watershed	300.4		107.2			407.6
Salmon Falls/Piscataqua River	59.8	8.1	8.9	108.1		184.9
Sheepscot River	178.8					178.8
Narraguagus River	38.9			35.6	60.4	134.9
Royal River	106.2					106.2
Androscoggin River	48.3		17.4	34.8		100.5
Saco River	49.1			50.6		99.7
East Machias River	18.8			67.0		85.7
Pleasant River	72.1					72.1
Scarborough Marsh/Nonesuch R.	70.4					70.4
St. George River	65.5					65.5
St. Croix River	61.8					61.8
Kennebunk River	47.0					47.0
Dennys River	34.8				10.7	45.5
Presumpscot River	22.0			22.2		44.2
Tunk Stream	20.2				16.8	37.1
Ducktrap River					22.8	22.8
Webhanet River	8.9					8.9
Union River	7.9					7.9
Pennamaquan River					7.6	7.6
Mousam River	6.3					6.3
Little River	5.5					5.5
Grand Total	**1622.3**	**8.1**	**487.5**	**351.0**	**118.2**	**2587.2**

The majority of the dams with fish passage on shad rivers in Maine have Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway opening in a large mainstem dam may be low, especially when there is a large spillway. Thus, the potential for shad passage above a mainstem dam with a Denil fishway is generally moderate.

Other mainstem dams in Maine have fishlifts. The potential for these locations to pass American shad is thought to be low to moderate. As discussed above, the ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, in all Maine dams with fishlifts there is evidence that shad remain in holding areas above the fishlift but do not exit the headpond, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report).

Table 2. The first mainstem dams on American shad rivers in Maine with fish passage and dam ownership information listed.

River/Watershed	Distance to first mainstem dam (km)	First Mainstem Dam Name	Fish Passage Type	Shad Passage Potential	Dam Ownership	FERC License	FERC License Renewal
Salmon Falls/ Piscataqua River	26.8	South Berwick Dam	Denil	Moderate	Consolidated Hydro New Hampshire, Inc	Yes	11/30/2037
Salmon Falls/ Piscataqua River	26.6	Great Works Pond Dam	None	None	Great Works Hyrdo Co.	No	
Webhanet River	None						
Little River	3.3	Skinners Mill Dam	None	None	Not listed	No	
Mousam River	6.8	Kessler Dam	None	None	Kennebunk Light and Power District	Yes (3 dams)	3/31/22
Kennebunk River	27.9	Days Mill	None	None	Private	No	
Saco River	9.3	Cataract Project	Fish Lift, Denil, 2 fish locks	Low to Moderate	Brookfield Renewable Energy	Yes (4 dams)	11/30/29
Scarborough Marsh/ Nonesuch R.	None						
Presumpscot River	12.6	Cumberland Mills	Denil Fishway	Moderate	S. D. Warren	No	
Royal River	4.9	Bridge Street Dam	Denil Fishway	Low	Town of Falmouth	No	
Androscoggin River	48.2	Brunswick Project	Vertical slot	Low (Documented)	Brookfield Renewable Energy	Yes	2/28/29
Kennebec River	140.8	Lockwood Project	Fish Lift	Low	Brookfield Renewable Energy	Yes	10/31/36
Sebasticook River	173.6	Benton Falls	Fish Lift	Moderate	Essex Hydro Associates	Yes	2/28/34
Sheepscot River	44.0	Head Tide Dam	Slots	Moderate	Town of Alna	No	
St. George River	48.3	Sennebec Pond Dam	Rock Ramp	High	Sennebec Lake Assoc.	No	
Ducktrap River	17.9	Dickey Mill Dam	None	None	Not listed	No	
Penobscot Watershed	68.5	Milford Dam	Fish Lift	Low to Moderate	Bangor Hydro Electric Co.	Yes	4/1/38
Union River	7.3	Ellsworth Dam	Denil,Trap and Truck	Not Passed Upstream	Black Bear Hydro	Yes	12/31/18 (consulting)
Tunk Stream	None						
Narraguagus River	10.6	Cherryfield Dam	Denil Fishway	Moderate	Town of Cherryfield	No	
Pleasant River	None						
East Machias River	None						
Dennys River	None						
Pennamaquan River	2.9	Pembroke Cottage Dam	Denil Fishway	Moderate	Private	No	
St. Croix River	30.8	Milltown Power Station Dam	Denil Fishway	Moderate	New Brunswick Electric Co.	No	

Water quality. While poor water quality due to point source pollution from tanneries, paper mill companies, and other manufacturing may have negatively impacted adult spawners, developing embryos, and young-of-year in the early to mid-twentieth century, improvements were made as a result of the Clean Water Act after 1970. As a result, it is not thought that poor water quality remains a threat in most known spawning/rearing locations. Basic water quality parameters (temperature, dissolved oxygen, turbidity, pH) are well above the tolerances for American shad, *when they are taken*. It should be noted that only temperature is taken on a daily basis at most fishways in Maine whether DMR or power-company operated,. Moreover, there are no current studies in Maine to determine whether existing levels of toxic contaminants (heavy metals, PCBs) may be negatively affecting shad populations.

The Maine Department of Environmental Protection (DEP) administers regular water quality testing of Maine's waters. The State has four classes for freshwater rivers, three classes for marine and estuarine waters, and one class for lakes and ponds. A close comparison of the standards will show that there are few differences between the uses or the qualities of the various classes. All classifications attain the minimum fishable-swimmable standards established in the federal Clean Water Act, and most support the same set of designated uses with some modest variations in their description. More information about the classification schema can be found at: http://www.maine.gov/dep/water/monitoring/classification/

The Maine DEP determines the water quality classification of freshwater areas through the Biological Monitoring Program. This program assesses the health of rivers, streams, and wetlands by evaluating the composition of resident aquatic benthic macroinvertebrate and algal communities. The DEP develops standards for each river, stream and wetland using these methods, testing important sites on a rotating basis. Smaller waterways may be tested infrequently. More information can be found at:
http://www.maine.gov/dep/water/monitoring/biomonitoring/index.html

Marine water quality is assessed by multiple organizations and the information compiled by the Maine DEP for Clean Water Act reports that are due every other year to the EPA. The DEP utilizes data for assessments in marine waters from its own environmental and toxics monitoring programs including the Surface Water Ambient Toxics and the Gulf of Maine Council on the Marine Environment's Gulfwatch project, and to a large extent from a variety of governmental agencies, academic institutions, non-profit organizations and municipalities, such as the Maine Healthy Beaches program, Maine Department of Marine Resources, New Hampshire Department of Environmental Services, University of Maine, BioDiversity Research Institute, Casco Bay Estuary Partnership, Kennebec Estuary Land Trust, Marine Environmental Research Institute, Mount Desert Island Biological Laboratory, Town of Rockport Conservation Commission, and the Wells National Estuarine Research Reserve. Additionally, a number of volunteer monitoring groups monitor Maine's estuarine and coastal waters. The DEP currently accepts data from organizations with approved Quality Assurance Project Plans (QAPPs) whose monitoring programs and analytical labs enable collection and processing of quality data, and from selected organization with DEP-approved sampling plans. Biannual reports can be found at:
http://www.maine.gov/dep/water/monitoring/305b/index.htm

Channelization and dredging occur in Maine waters, though are not thought to be a significant threat to American shad habitat. Channelization and dredging typically occur beyond the mouths of rivers in association with beach restoration (southern Maine) or shipping lanes (Kennebec River, Bath Iron Works). Before any channelization or dredging project commences, it must first be reviewed by all relevant agencies (including Maine DMR, Maine DEP, USFWS, and NOAA) which provide comments concerning species interaction.

Invasive species. Concerning the threat from competition and predation, a growing number of invasive white catfish, carp (*Cyprinus carpio*), and Northern pike have been documented in Maine. These species are found in American shad spawning areas, but the impact on shad populations has not been documented.

Statewide Available Data

In 1982, the US Fish and Wildlife Service (USFWS) compiled habitat information for many diadromous species to create a snapshot of the current and historic distribution in Maine that is available from the USFWS Northeast Regional Office's data website (USFWS 2013). The purpose of this project was to identify, based on the best available information, the current and historic geographic distribution of 12 diadromous (sea-run) fish species in Maine (alewife, American eel, American shad, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, sea run brook trout, shortnose sturgeon, striped bass).

To begin this process, available digital data depicting current and historic extent of each species was presented on a series of paper maps. These maps were distributed throughout the state and reviewed by fisheries biologists, including representatives from government agencies, non-government organizations and private individuals. Reviewers edited the maps on the basis of their personal knowledge, institutional knowledge and review of existing data and documents, both published and unpublished. These maps were then collated and coded in a networked hydrography dataset (the most detailed available National Hydrography Dataset[NHD]) resulting in one GIS layer (a line Feature Class) for each fish species. Each Feature Class shows the user the current and historic extent of the species and the sources used to delineate that extent. The Feature Class can be used alone but is most useful when joined back to the NHD as an event table, thus making additional data available (e.g. feature names, flow, etc.). The 'AmericanShad' feature class specifically identifies the current and historic distribution of American shad in Maine (USFWS 1982).

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, FERC

Other Organizations

Dam ownership for first mainstem dams is listed in Table 2.

Current Action and Progress

During all Federal Energy Regulatory Commission (FERC) relicensing processes, the Maine DMR in collaboration with federal agencies advocates for fish passage that will allow the best accommodation for all diadromous fish passage, including American shad passage. In addition to FERC processes, the Maine DMR also provides comments on most fish passage projects in the state – where there is a project on identified shad river, we provide comments and work with public and private landowners to install fish passage, or upgrade existing passage, to allow for all maximum passage potential for all diadromous species, including American shad.

Regarding monitoring projects, other than three on-going activities (fishway monitoring on the major rivers, juvenile beach seine and in-river trawl surveys, recreational fishing surveys), there are few efforts focused on American shad in Maine waters. There are a few river-specific projects that are discussed in the sections below, including video monitoring at Brunswick fishway. There are, however, no efforts to ground-truth the assumed current spawning habitat, and currently no fishway efficiency studies that focus on shad passage.

Larval stocking. American shad fry were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook Rivers. The program ended in 2008 due to a lack of funding. Larval American shad that were reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin, Kennebec, and Sebasticook Rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding and current management of American shad along the East Coast.

Adult American shad otoliths are collected from mortalities at fish passage facilities, from juveniles collected during the beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a sub-sample of American shad in fall 2012. We are currently fine-tuning our instrumentation and methods to correctly identify OTC marked otoliths. While we have not directly measured the success of the stocking program, juvenile abundance in the Kennebec/Androscoggin complex does seem to have increased concurrent to larval stocking (Figure 2).

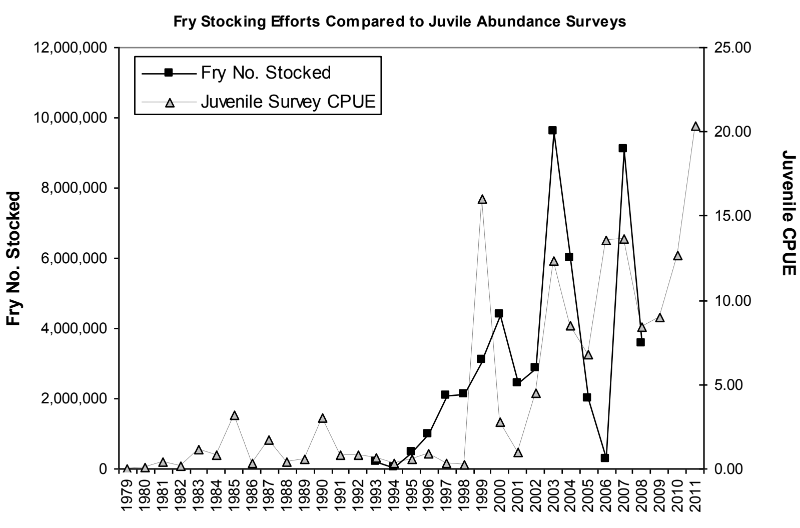

Figure 2. Juvenile abundance compared to fry stocking efforts.

Juvenile Abundance Surveys. In 1979, MDMR established the Juvenile Alosine Survey for the Kennebec/Androscoggin estuary to monitor the abundance of juvenile alosines at 14 permanent sampling sites. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abagadasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, Maine DMR added six additional sites in the lower salinity-stratified portion of the Kennebec River.

Over the entire sampling period (1979-2012), the overall highest average catch per unit effort (CPUE) for juvenile American shad was found in the Abagadasset River (11.46 shad per haul), followed by the upper Kennebec River (9.02). Merrymeeting Bay (4.99), the Cathance (3.83), Eastern (2.87), and the lower Kennebec rivers (2.09) all have lower but consistent CPUE values. The Androscoggin River consistently has low catches of shad or years where no shad are caught (0.51 shad per haul; Table 3). The strength of these data in identifying successful spawning areas is limited because sampling in performed after the spawning event, and juvenile shad may have become dispersed from their natal location by passive larval drift. These data may provide some insight into juvenile shad habitat.

Recommended Action(s)

- Remove mainstem hydropower dams or install effective fish passage
- Ground-truth assumed current spawning habitat state-wide
- Conduct population estimates for Saco, Androscoggin, Kennebec/Sebasticook, and Penobscot rivers
- Map young-of-year habitat based on existing beach seine and in-river trawl surveys in the Kennebec River/Merrymeeting Bay estuary complex and Penobscot River
- Conduct fishway efficiency studies that focus on shad passage at existing fishways
- Determine locations beyond those regularly monitored where American shad passage may be limited by human-made obstructions
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) at known spawning grounds during May-July

Table 3. American shad catch per unit effort in eight survey locations in the Kennebec River/Merrymeeting Bay estuary complex. Survey design was altered in 1994 when 6 stations were added to the survey sites.

Juvenile American Shad Catch per Unit Effort by River Segment								
Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Mid Kennebec River	Lower Kennebec River
1979	0.16	0.00	0.00	0.00		0.00		0.00
1980	0.00	0.36	0.29	0.00		0.00		0.00
1981	1.08	0.85	0.29	0.50		0.00	0.17	0.00
1982	0.00	0.33	0.17	0.00		0.00	0.63	0.00
1983	0.15	0.20	2.18	3.00		0.00		
1984	0.90	0.46	0.00	2.00		0.67		
1985	0.69	1.53	0.40	6.50		7.00		
1986	0.10	0.15	0.08	1.00		0.50		
1987	0.15	8.05	0.17	1.25	0.50	0.00		
1988	0.11	1.36	0.00	0.00	0.33	0.51		
1989	1.25	0.29	1.29	0.48	0.00	0.00		
1990	3.50	2.46	0.83	6.83	0.33	4.20		
1991	1.21	0.00	0.00	0.67	1.67	1.17		
1992	0.10	0.67	0.67	3.67	0.00	0.00		
1993	0.00	0.29	3.63	0.00	0.00	0.00		
1994	0.00	0.35	1.00	0.00	0.17	0.50		
1995	0.21	0.39	1.89	0.17	0.60	0.33		
1996	4.15	0.25	0.00	0.20	0.33	0.50		
1997	0.00	0.88	0.80	0.00	0.40	0.00		
1998	0.00	1.67	0.00	0.00	0.00	0.00		
1999	0.00	20.46	0.00	42.67	33.00	0.00		
2000	15.14	0.33	0.14	0.33	0.33	1.33		1.58
2001	0.57	3.14	2.57	0.43	0.00	0.20		0.05
2002	1.96	2.18	0.18	1.86	22.86	2.43		0.19
2003	74.13	3.63	0.00	2.17	0.67	5.33		0.42
2004	48.21	6.67	0.00	0.67	3.00	0.50		0.39
2005	24.96	3.42	0.06	2.83	10.00	2.40		3.72
2006	38.79	25.30	0.00	0.67	16.50	8.33		5.44
2007	33.38	24.13	0.00	0.67	19.00	16.83		1.40
2008	3.95	12.88	0.00	3.00	34.17	3.67		1.38
2009	4.29	16.38	0.20	4.17	31.67	5.17		1.27
2010	45.63	8.25	0.39	11.00	15.33	7.17		1.03
2011	0.63	11.25	0.00	25.33	94.17	9.17		1.73
2012	1.30	11.17	0.06	8.00	13.00	19.67		16.86
Average	9.02	4.99	0.51	3.83	11.46	2.87	0.40	2.09

Saco River

Amount of Habitat

There are currently 49.1 river kilometers of accessible shad habitat in the Saco River (though accessibility to habitat above dams with fish passage is limited), with another 50.6 river kilometers of assumed historical habitat (Table 1). Spawning and juvenile habitat have not been identified. Although no studies have documented shad spawning areas in the Saco River, it is thought that the majority of spawning occurs below the Cataract Project mainstem dams. Habitat above this area is mapped as accessible habitat because shad passage is possible at the Skelton Dam fishlift and interim trap and truck operations to move shad past the project's fish locks (see discussion below). The river portion listed as inaccessible (historical assumed) is above the Bar Mills, which currently has no fish passage facility (Figure 3).

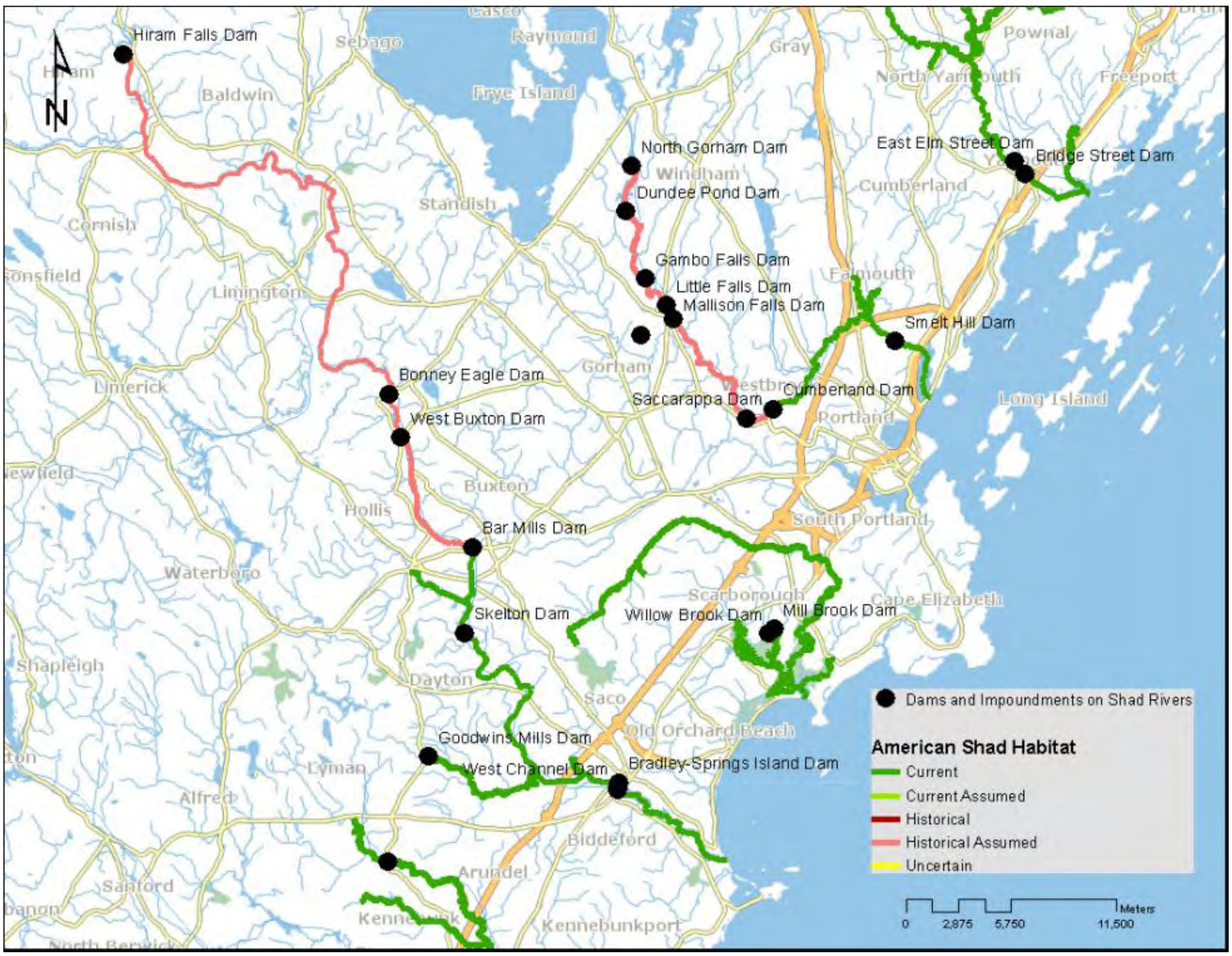

Figure 3. Saco River American shad habitat. Historical habitat is above dams with no fish passage. The Scarborough Marsh and Nonesuch River shad habitat is also shown in full in the middle-right of the figure.

Available Data

- Adult American shad counts, Brookfield Renewable Energy
- Video monitoring of shad behavior downstream on the Cataract Project, Brookfield Renewable Energy
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration

The majority of shad passage on the Saco River occurs at the East Channel fishlift of the Cataract Project. The project is licensed by the Federal Energy Regulatory Commission (FERC No. 2528) and is owned by Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light). The project includes the Cataract (East Channel) Dam and East Channel fishlift and an integral intake powerhouse containing a single turbine generator on the northeastern side of Factory Island in the City of Saco; and the West Channel dam and Denil fishway in the cities of Saco and Biddeford (Figure 3).

The impoundment formed by these dams extends upriver in the cities of Biddeford and Saco about 0.3 mile to another set of dams at Spring Island referred to as Bradbury and Spring Island dams. The impoundment formed by these dams extends upriver approximately 9.3 miles through the cities of Biddeford and Saco and the towns of Dayton and Buxton to Brookfield Renewable Energy's Skelton Project (Figure 3). A 90-foot high fish lift was constructed at the Skelton Project and first became operational in the fall of 2001.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Saco River Salmon Club

Current Action and Progress

Monitoring and Passage. In 2012, the Cataract fishways were operated by personnel from Nextera Energy Resources Hydro Operations division. These fishways were built to pass anadromous target species (Atlantic salmon, American shad, and river herring) as part of resource agency plans to restore these species to the Saco River, and have operated for 19 years. Although fishway construction was completed in the spring of 1993, the fishways were not completely operational until June 2, 1993 (East Channel) and June 25, 1993 (West Channel).

An underwater camera connected to a television monitor and VCR was first used in 1995 to gather information on fish behavior within the lower flume of the East Channel fishlift. The camera documented that shad exhibit a fallback behavior in and around the East Channel lower flume V gate crowder. On occasion, shad would swim upstream through the V gate crowder into the hopper area, then within minutes (and sometimes seconds) swim back downstream through the V gates and out of the lower flume into the tailrace. Also, on many occasions, shad were reluctant to pass through the V gate crowder in the fishing position (see 1995 Cataract fishway study report Sections 3 and 4 for detailed information on camera study and results). Since 1996, the underwater video camera, combined with keeping the V gate crowder wide open, was a very important technique that increased East Channel fishway efficiency. Fishway personnel observed that by keeping the V gate crowder open, shad moved readily into the trapping area. Utilizing the underwater camera, fishway personnel could observe shad as they passed through the wide open V gate crowder, then close the crowder and trap before the shad had a chance to fall back. This technique will continue in 2013.

A 2007 settlement agreement provides a schedule for fish passage at the remaining dams owned by FPL Energy (Table 4), a schedule for effectiveness testing, and a schedule for improvements at the Spring Island or Bradbury dam so American shad can pass.

Table 4. Schedule for fish passage implementation at Saco River dams.

Dam Name	Upstream anadromous passage
Cataract - East Channel, West Channel	fishlift, Denil
Cataract - Springs Island, Bradbury	fishlocks
Skelton	fishlift
Bar Mills	5/1/2016
West Buxton	5/1/2019
Bonny Eagle	5/1/2022
Hiram	5/1/2025

In 2012, NextEra biologists counted a total of 6,404 American shad (6,221 passing the East Channel Dam, and 183 passing the West Channel Dam, Figure 4). In addition to the 6,221 American shad successfully passing through the Cataract East Channel fishway, a total of 68 shad mortalities were noted. This represents a total fishway mortality of 1.2 %, which is similar to past years: 1995 (3.5%), 1996 (4.8%), 1997 (2.7%), 1998 (3.5%), 1999 (2.6%), 2000 (2.7%), 2001 (2.4%), 2002 (2.8%), 2003 (2.5%), 2004 (3.0%), 2005 (2.6%), 2006 (2.8%), 2007 (3.0%), 2008 (2.9%), 2009 (4.8%), 2010(1.9%), 2011 (2.1%). The majority of the American shad captured at the East Channel fishlift were transported to the Diamond Riverside Boat Ramp stocking location (approximately half mile upstream of the fishway), while the remaining shad were allowed to freely swim through the fishway into the Cataract impoundment.

At the Skelton Project during the 2012 season, 47 shad were lifted. It is assumed that many of the American shad that were not lifted at the Skelton fishway spawned below the project, as post-spawned American shad and juvenile American shad are routinely observed at the downstream Cataract Project. Also, the 9.3 miles between the Skelton Project and the Cataract Project provides potential spawning habitat for approximately 25,000 adult American shad.

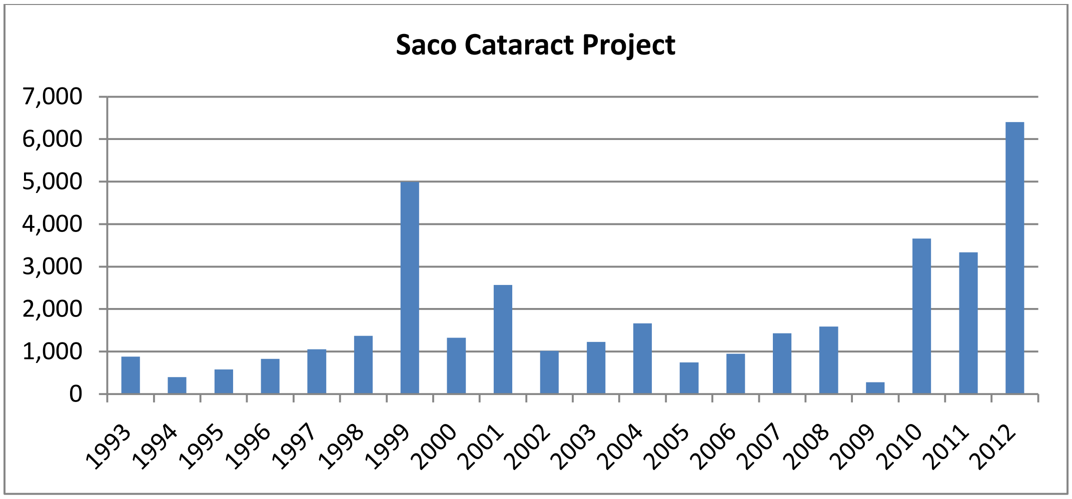

Figure 4. American shad passage at the Cataract Project from 1993 to 2012.

Goals and Recommended Actions

- Continue DMR consultations on proposed operational change to improve shad passage at fish locks
- Ground-truth spawning habitat both below Cataract Project and identify other spawning areas upstream
- Estimate mortality for adult shad passing the Cataract Project
- Conduct downstream efficiency and mortality studies
- In addition to video monitoring at the Cataract Project, document upstream efficiency at this location and at the Skelton Project
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season

The timeline and associated costs of these recommended actions has not been determined.

Androscoggin River

Amount of Habitat

The Androscoggin River contains 100.5 river kilometers of potential American shad habitat. Of this, 48.3 river kilometers are accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining habitat is inaccessible due to obstructed fish passage (Figure 5, Table 1). While passage above the Brunswick Dam is considered possible because the vertical-slot fishway allows some shad passage, actual passage by American shad has been documented to be very low (Figure 6), and the majority of habitat use has been documented in the small portion of river below the dam.

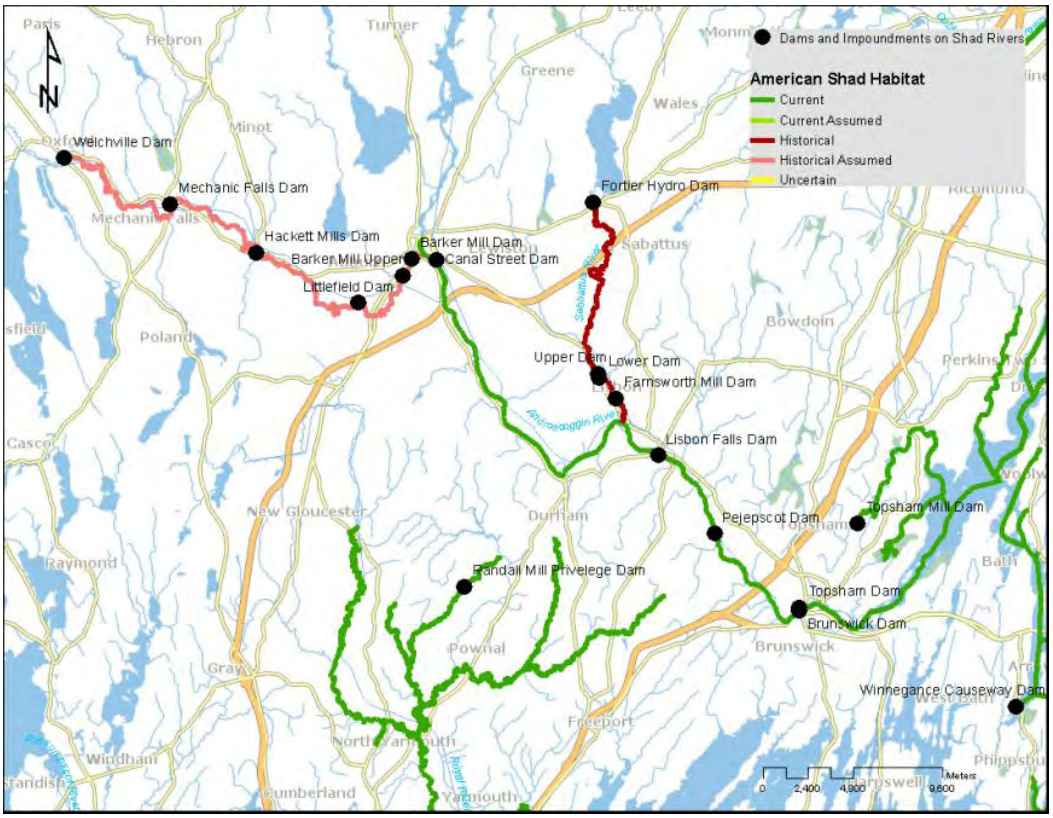

Figure 5. Androscoggin River American shad habitat. Historical habitat is above dams with no fish passage. The upper portion of the Royal River also is shown at the bottom of the figure.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Video monitoring of shad behavior downstream of Brunswick Fishway, Bowdoin College
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

American shad historically spawned in the Androscoggin River from Merrymeeting Bay to Lewiston Falls, and in the Little Androscoggin River from its confluence with the Androscoggin to Biscoe Falls. However, construction in 1807 a low-head dam at the head-of-tide on the Androscoggin River caused the abundant American shad run to decline sharply.

Barriers to migration. In 1980 the U.S. Fish and Wildlife Service developed conceptual drawings for a vertical slot fishway for the Brunswick Project, which is located at the head-of-tide on the Androscoggin River. The fishway was designed to pass 85,000 American shad and 1,000,000 alewives annually. The upstream passage facility was one of the first vertical slot fishways designed to pass American shad on the east coast, and was a scaled-down version of a fishway located on the Columbia River. Redevelopment of the Brunswick Project and construction of the fishway was completed in 1983. The completed fishway was 570 feet long, and consisted of 42 individual pools with a one-foot drop between each. Downstream passage consisted of a 12-inch pipe located between two turbine intakes. When the Federal Energy Regulatory Commission issued a license for the Brunswick Project in 1979, it did not require efficiency studies for the upstream and downstream passage facilities.

Maine DMR initiated an anadromous fish restoration program in the Androscoggin River after fish passage was installed the Brunswick Project dam, and just prior to the installation of passage in 1987 and 1988 at the next two upstream projects. Between 1985 and 2008, a total of 7,882 prespawn American shad from in-state (Cathance and Androscoggin rivers) and out-of-state (Merrimack and Connecticut rivers) sources were stocked into spawning habitat below Lewiston Falls. In addition, approximately 5.6 million shad fry were stocked into these waters between 1999 and 2008.

Currently the factor limiting successful American shad restoration to the Androscoggin is the lack of effective passage at the Brunswick Project. Neither the Brunswick vertical slot fishway nor a similar one at the Rainbow Dam on the Farmington River, CT, has proven to be successful at passing American shad. Visual observations, underwater videography, and radio telemetry studies conducted at the Brunswick Project by Maine DMR in cooperation with the U.S. Fish and Wildlife Service have shown that American shad swim past the fishway entrance repeatedly, but rarely enter it. The few shad that enter the fishway rarely ascend beyond the corner pool, and in 27 years of operation only 219 American shad have used the fishway.

In February 2011, NextEra Energy, owner of the Brunswick Project, agreed to conduct an experiment to determine whether upstream passage of American shad could be improved by increasing the amount of attraction water at the fishway (see Video Monitoring below).

Past water quality. After dams confined American shad to the tidal portion of the river, severe water pollution virtually eliminated the population. American shad that continued to reproduce in the six-mile stretch of river below Brunswick supported significant commercial fisheries until the late 1920's. By the early 1930s, severe water pollution from upstream industries and municipalities had caused declines in many fish species. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Androscoggin River.

Invasive species. White catfish, carp (*Cyprinus carpio*), and Northern pike populations are known to be increasing in the lower Androscoggin River, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Bowdoin College, University of Maine, Bates College, University of Southern Maine, Androscoggin River Alliance, Friends of Merrymeeting Bay

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Brunswick Fishway on the Androscoggin River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally passed the 42 pools of the fishway. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 11 were passed in 2012, and only 289 total passed in all years of the data series (Figure 6).

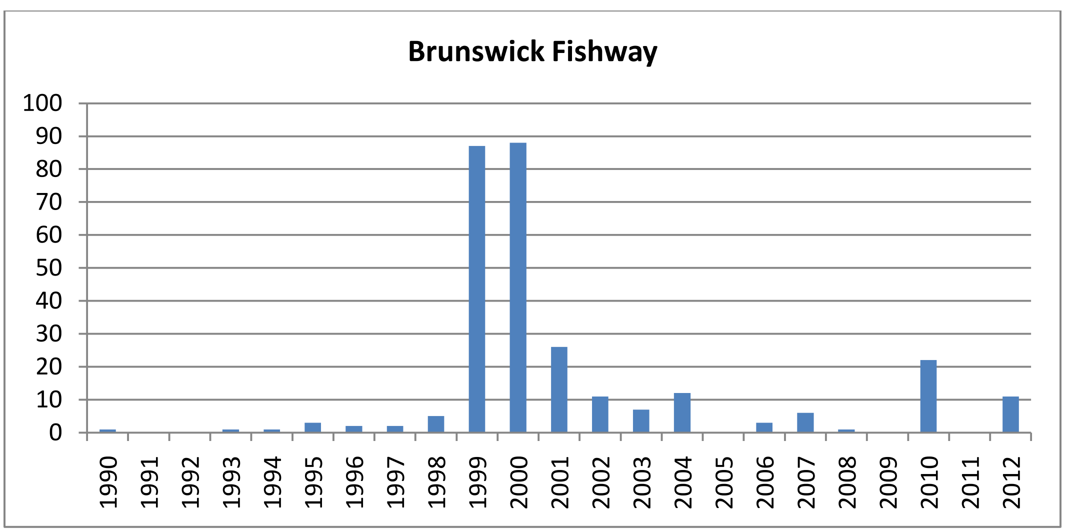

Figure 6. American shad passed above the Brunswick fishway from 1990 to 2012.

Video monitoring. In 2011 and again in 2013, John Lichter of Bowdoin-Bates-USM research group along with his summer research students, Bob Richter of Brookfield Renewable Power, Neil Ward of the Androscoggin River Alliance, and Gail Wippelhauser of the Maine DMR collaborated on an experiment to determine whether upstream passage of spawning American shad at Brunswick Fishway could be improved by increasing the attraction flow at the fishway entrance. Two current inducers were installed adjacent to the fishway entrance. The presence and behavior of American shad was monitored with two underwater cameras, one located in the river about 40 m feet downstream of the fishway entrance to confirm the presence of shad in the river, and a second one placed adjacent to the fishway entrance. Digital video recorders, computers, and software were installed in the fish ladder control room. Salmonsoft@ software was used to record video images when a fish crossed in front of each of the cameras.

In 2011, inducers were turned on and off over alternating two-hour periods. Approximately 16,558 American shad were counted at the lower camera, although previous telemetry studies have shown that an individual may swim past this part of the river multiple times per day. The fish were active primarily during the day for a period of 5-6 h, beginning 1-2 hours before high slack water and continuing for 3-4 hours into the ebb tide. A total of 91 American shad were seen at the entrance of the fishway. More fish were seen at the entrance in the afternoon than in the morning, and more fish were seen when the current inducers were turned on (54) than when the inducers were off (37). However, the current inducers were more effective in the morning than in the afternoon. In 2013, two current inducers were installed adjacent to the fishway entrance and were alternately turned off for 24 hours (attraction water of 100 cfs) then on for 24 hours (attraction water of 180 cfs) with the change occurring at noon every day. Approximately 500 of the nearly 25,000 shad viewed at the lower camera made it to the entrance of the fish ladder. To date, we have only completed roughly 2/3rds of the 2013 video data analysis. Equipment damage related to flooding prevented the study in 2012.

Because it is not clear how many of the 16,000-25,000+ shad viewed at the lower camera circled around the far side of the river after failing to find the fish ladder and were subsequently recounted in the lower camera, we are planning a study that will determine shad movement patterns in the tailrace of the dam for 2014. In any case, there appears to be some number of thousands of shad trying to navigate past the Brunswick Hydroelectric facility each year. Previous work with Michael Brown of the Maine DMR and John Lichter, Bowdoin College, showed that shad will spawn in the tidal waters of the lower Androscoggin if they cannot pass the dam.

Goals and Recommended Actions

- Conduct population estimates for adults spawning in the lower Androscoggin River
- Map young-of-year habitat based on existing beach seine surveys
- Continue fishway efficiency studies at Brunswick Fishway that document poor passage by adult American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Kennebec and Sebasticook Rivers

Amount of Habitat

The Kennebec watershed contains 407.6 river kilometers of potential American shad habitat. Of this, 300.4 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 107.2 river kilometers are inaccessible due to obstructed fish passage (Table 1).

The watershed contains two major spawning areas, the mainstem Kennebec River below Lockwood Dam and the the Sebasticook River below Benton Falls Dam (Figure 7). While passage above these is considered possible because both dams have fishlifts, actual passage by American shad has been documented to be very low (Figure 8), and the majority of spawning is thought to occur below the first mainstem dams.

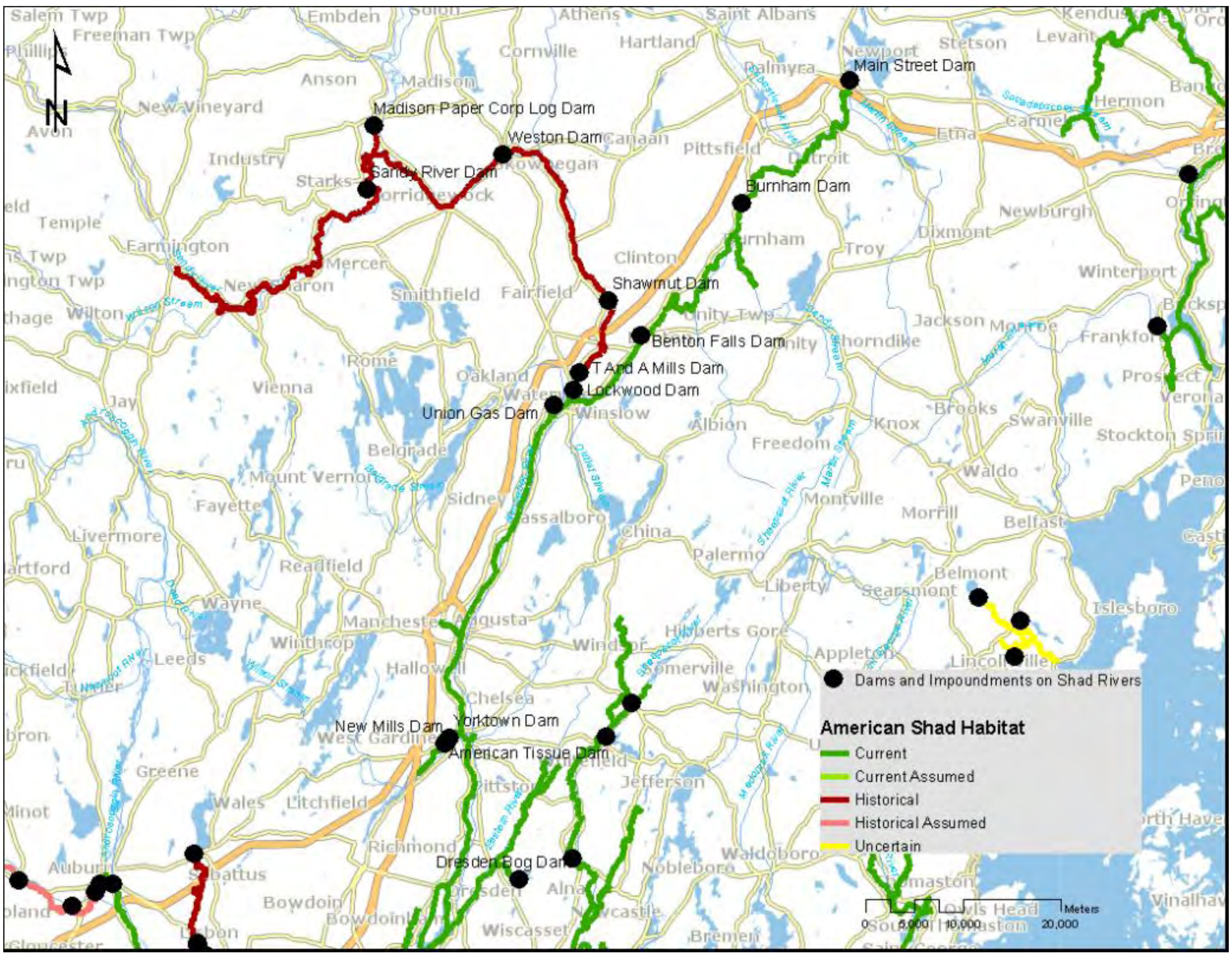

Figure 7. American shad habitat in the Kennebec and Sebasticook rivers. Historical habitat is above dams with no fish passage. The upper portion of the Sheepscot River also is shown at the bottom of the figure, in close proximity to the lower Kennebec River.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

Barriers to migration. The Kennebec River Restoration Program was initiated following the development of a Strategic Plan in 1985, an Operational Plan in 1986, and the signing of an Agreement in 1986 between the Maine DMR and the Kennebec Hydro Developers Group (KHDG). This Agreement provided a delay in fish passage requirements at seven hydropower facilities above Augusta in exchange for funds to initiate the restoration by means of trap-and-truck of river herring and American shad to selected upriver spawning and nursery habitat. In 1998, a new Agreement between state and federal fisheries agencies and the members of the KHDG was signed. The new Agreement provided for the removal of Edwards Dam, included new timetables or triggers for fish passage at the seven hydropower facilities above Augusta, and provided additional funds to continue the restoration by trap-and-truck. In 2006, the Kennebec River Restoration Program entered a new phase when upstream anadromous fish passage became operational at the Benton Falls, Burnham, and Lockwood hydropower projects (Figure 7).

Upstream passage at the Burnham and Benton Falls was required to be operational one year following the installation of permanent or temporary upstream fish passage at Fort Halifax and following installation of permanent upstream fish passage at four upriver non-hydro dams. These projects included the implementation of interim upstream passage measures at Fort Halifax dam and the construction of fishways at the Pleasant Pond dam in Stetson, the Plymouth Pond dam in Plymouth, the Sebasticook Lake outlet dam in Newport and the removal of the Guilford dam in Newport. Passage at the Benton Falls Dam was established in 2006 by way of a fishlift. The top of the lift contains a watered holding area leading to a large fish excluder, a gate with vertical bars spaces 2” apart to prevent larger fish from passing in an effort to minimize invasive species passage. All American shad passing Benton Falls must be manually passed upstream over this excluder grate. A fishlift also provides passage at the Burham Dam, however no upstream excluder panel prevents free passage of shad once they pass the fishlift.

The Lower Kennebec River Comprehensive Hydropower Settlement Accord requires that the Licensee install a trap, lift, and transfer facility at the project’s powerhouses at Lockwood Dam. These facilities were operational in 2006. American shad that reach the top of the fishlift are passed upstream, however the next dam 1.9 river kilometers upstream has no fish passage capabilities.

The potential for these locations to pass American shad is thought to be low to moderate. The ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, at Benton Falls Dam there is evidence that shad remain in holding areas undetected, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report). However, this effect may be a result of flow differentials between the downstream portion of the dam and the headpond. Shad may remain in the portion between the fishlift and the headpond for longer periods of time because the flow is much lower than the tailraces, and use this time for resting.

Past water quality. Water pollution from upstream industries and municipalities in the early to mid-20th century had significant impacts on water quality in the Kennebec watershed and was thought to cause declines in many fish species populations. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Kennebec and Sebasticook rivers. While water quality has drastically improved over the past forty years, high levels of PCBs and some toxic contaminants are still found in many resident fish species.

Invasive species. White catfish and carp (*Cyprinus carpio*) populations are known to be increasing in the Kennebec and Sebasticook rivers, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light), KEI (USA) Power Management Inc., Benton Falls Associates (Essex Hydro Associates), Kennebec Hydro Developers Group

Other Organizations

Friends of Merrymeeting Bay, Kennebec Estuary Land Trust, Sportsman's Alliance of Maine

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Lockwood Dam on the Kennebec River and the Benton Falls Dam on the Sebasticook River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally entered the fishlift. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 5 were passed in 2012 at the Lockwood Dam, and only 39 total since the fishlift at Lockwood was operational. Passage at Benton Falls Dam may be increasing: in 2012 163 shad were passed (Figure 8).

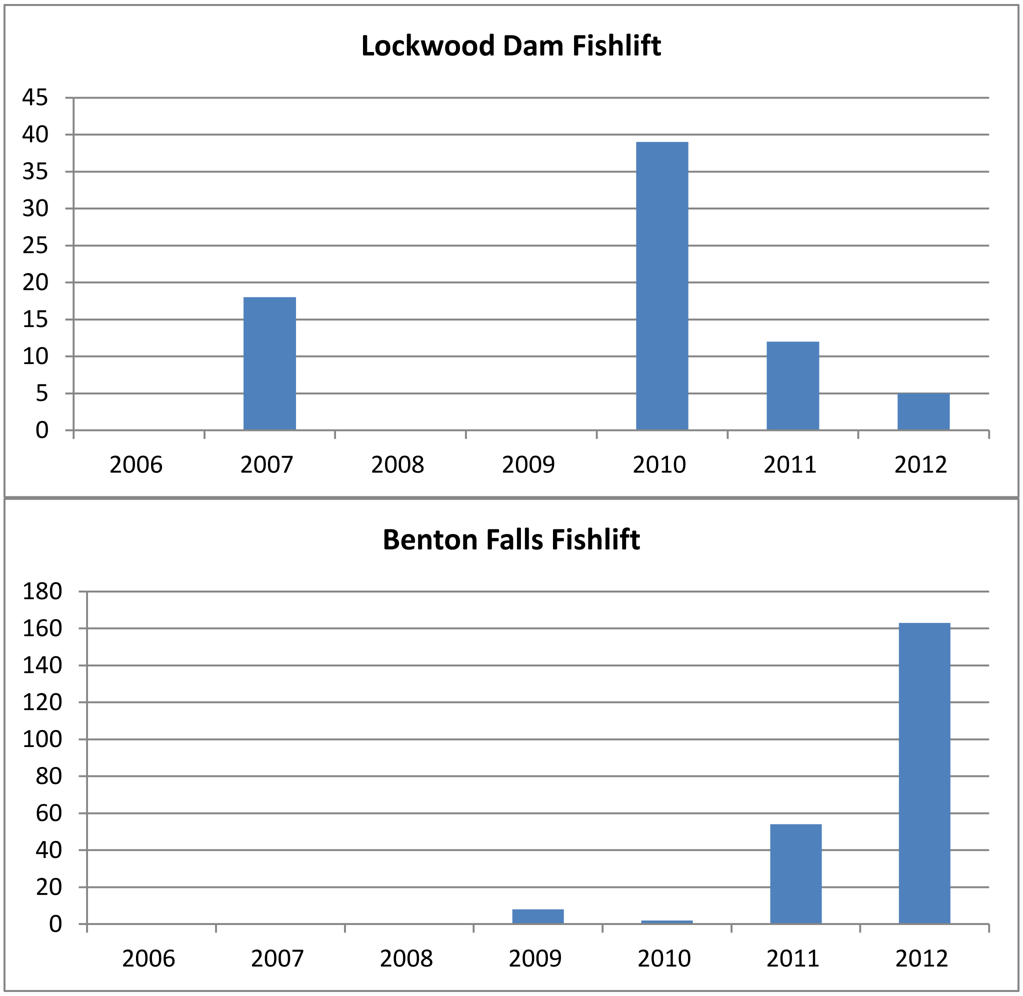

Figure 8. American shad passage at two counting locations in the Kennebec watershed. Fish passage was not operational before 2006.

Goals and Recommended Actions

- Ground-truth spawning habitat in the mainstem Kennebec and Sebasticook rivers
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Benton Falls and Lockwood fishlifts
- Conduct downstream passage studies at Benton Falls for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Penobscot River

Amount of Habitat

The Penobscot watershed contains 786.3 river kilometers of potential American shad habitat. Of this, only 399.6 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 386.7 river kilometers are inaccessible due to obstructed fish passage (Table 1).

Though few adult shad have been captured at the lower mainstem dams as part of fishway operations, recent summer trawl surveys conducted in the lower portion of the river have captured juvenile American shad (Lipsky and Saunders 2013). In 2004, 12 juvenile American shad were electrofished downstream of the Veazie Dam but none were captured during extensive upriver sampling (mainstem Penobscot from Veazie to the confluence of the East and West Branch in East Millinocket, the West Branch Penobscot to the outlet of Seboomook Lake, the East Branch Penobscot to Grindstone Falls, the Piscataquis River, the Stillwater River, Passadumkeag Stream, Pushaw Stream, and Millinocket Stream) (Yoder et al. 2004).

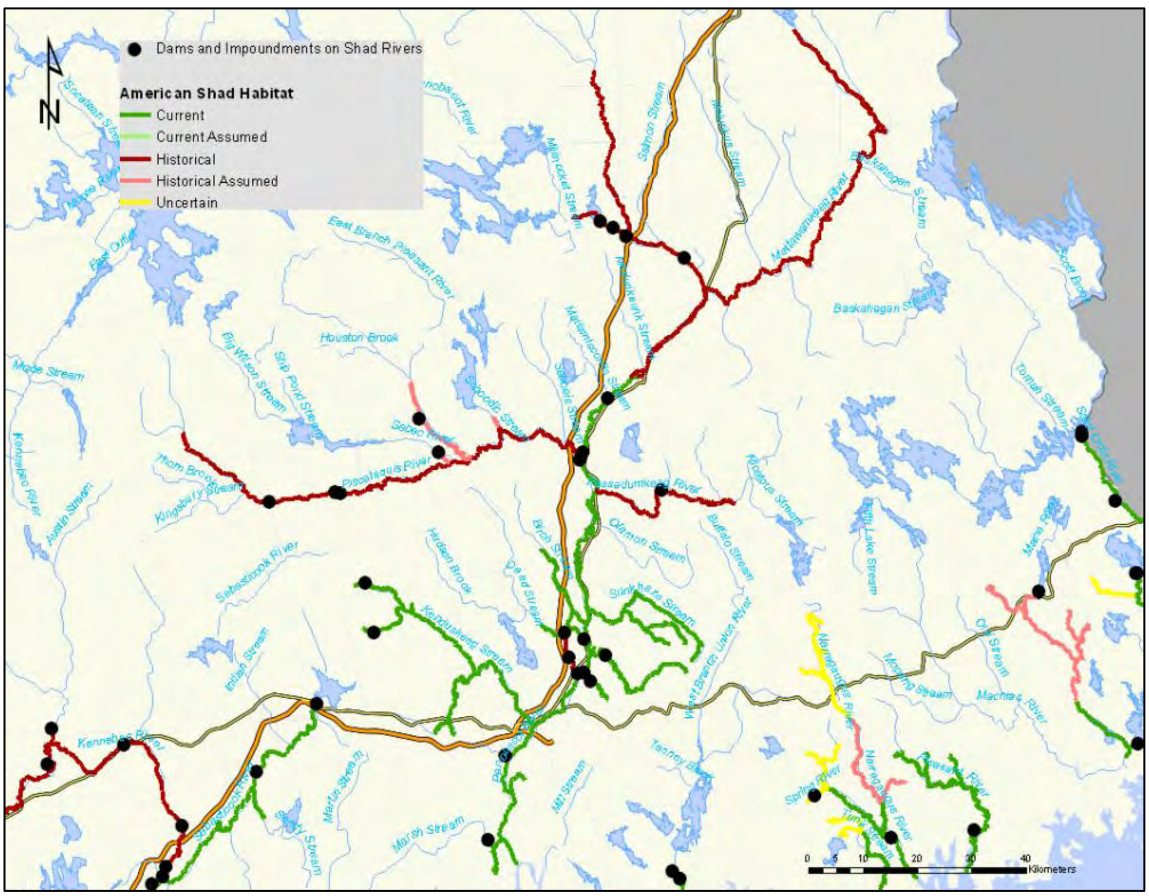

Figure 9. American shad habitat in Penobscot watershed. Historical habitat is above dams with no fish passage. The upper portion of the Kennebec River River also is shown at the bottom left the figure, and the Narraguagus, Pleasant, and East Machias rivers appear in the bottom right.

Available Data

- Adult American shad counts, Maine DMR
- Fish community survey data, NOAA
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Possible water quality

Barriers to migration. Until recently, mainstem dams in the lower portion of the Penobscot River have limited fish passage by all species, and reduced the amount of spawning habitat for American shad by more than half of the potential area. In 2004, the Lower Penobscot River Settlement Accord was signed, a multi-party agreement which laid the framework for the Penobscot River Restoration Project (PRRP). Through this project, the Penobscot Trust purchased the Veazie, Great Works, and Howland Dams in 2010 with the goal of dam removal or fish passage at each location. Five major projects are part of this effort to improve migratory fish passage and habitat in the lower Penobscot River:

- Removal of Great Works Dam in 2012
- Upgrade of Old Town Fuel & Fiber water intake in 2012 to reduce fish interaction
- Removal of Veazie Dam in 2013
- Installation of a fishlift at Milford Dam in 2013; and
- Decommissioning and construction of a bypass at Howland Dam

Before these projects were completed, limited access was available to American shad by way of upstream passage at the Veazie Dam, and two Denil fishways at the Great Works Dam.

Water quality. In the early 20th century, severe water pollution from upstream industries and municipalities had had a significant impact on fish populations. Water pollution improvement efforts that began in the early 1970s resulted in the dramatic improvement of water quality, however many paper mills and other industry still operate on the river. While the PRRP has addressed some known issues with water intake, others may exist.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Black Bear Hydro Partners, LLC, Penobscot River Restoration Trust, PPL Corporation

Other Organizations

Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, and Trout Unlimited

Current Action and Progress

Barrier removal and passage facilities. Recent work has opened habitat in the lower portion of the Penobscot River through removal of the Great Works and Veazie dams, and upcoming installation of a fishlift at Milford Dam and bypass at the Howland Dam. The result of these projects on American shad will likely not been seen for a few years.

Before the Veazie Dam was removed, few American shad were provided upstream passage at the fish trap installed at that dam – since 1978, fewer than twenty adult spawning shad were passed. It is likely that the majority of shad in the Penobscot River remained below the dam, and any spawning occurred in the mainstem.

Fish community surveys. NOAA Northeast Fishery Science Center (NEFSC) Maine Field Station has conducted fish community monitoring since 2010 in the Penobscot Estuary. The survey has relied on a combination of fixed (seine and fyke) and mobile (trawl) capture gear combined with mobile hydroacoustics to describe relative abundance and species composition in the estuary. Sampling has generally occurred from April through October at weekly to monthly intervals depending on the year, season and gear. Twelve seine sites are distributed from 10 to 40 kilometers downstream of head-tide, four fyke sites at 12 and 25 kilometers downstream of head-tide and trawls from 15 to 55 kilometers downstream of head-tide. A total of 67 species have been identified including 10 diadromous, 27 freshwater and 30 marine life histories. Most dominant in the surveys by number are the clupeids namely *Clupea harengus* with *Alosa* species most common in percent occurrence. The survey has been successful in establishing systematic methods of sampling and has provided a platform for several researchers interested in estuary species such as: *Salmo salar, Fundulus heteroclitus, Osmerus mordax, Microgadus tomcod*, *Alosa pseudoharengus, Alosa aestivalis*, and *Alosa sapidissima*.

One of the objectives of the Penobscot Estuary survey was to describe temporal and spatial distributions of diadromous species including American shad. It is believed the Penobscot has a remnant population of American shad through anecdotal reports from anglers and infrequent occurrence at the Veazie Dam fishway trap operated by the Maine DMR. Seine surveys conducted in collaboration with the Maine DMR in 2010 - 2012, confirmed presence of young-of-year (YOY) American shad in the estuary and 2011-2013 trawl surveys have confirmed presence of age- 1 juveniles. Lipsky and Saunders (2013) summarized YOY distribution in the Penobscot and determined that due to salinity intolerance, the YOY are likely the result of natural reproduction from the Penobscot rather than larval drift from other spawning locations.

Seine and fyke catch data have shown that most (40% of total) YOY shad are captured in September but are present from July through November. Captures were most common (45% of total) in the tidal freshwater reaches of the estuary, 8-15 kilometers below head of tide. However, captures did occur in higher salinity (10-20 ppt) areas over 45 kilometers from head of tide. Trawl data suggests some age- 1 American shad utilize the Penobscot estuary in their second summer for rearing. Trawls in 2011 to 2013 have captured 750 individuals between 9 and 27 cm total length. For the trawl, most captures occur at the high turbidity, salinity mixing zone 20 to 30 kilometers downstream of head tide.

Goals and Recommended Actions

- Ground-truth spawning habitat in the lower Penobscot River once the PRRP current objectives are complete
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Milford fishlift after sufficient time has passed for shad populations that may have spawned below the Great Works Dam have "found" their way upstream (part of current FERC license)
- Conduct downstream passage studies at Milford fishlift for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Continued work to open habitat further upstream

Timeline

Current summer trawl surveys have documents American shad juveniles in the Penobscot River, however, with the large-scale changes occurring under the PRRP, dedicated work towards identifying spawning habitat and performing fish passage efficiency studies may be more productive after sufficient time has passed to allow fish populations to respond. Under the assumption that the PRRP work will be complete by 2016, it is suggested that the above recommendations be implemented in 2020, with the exception of water chemistry sampling which should be implemented at the Milford fishlift when it is operational. Adult shad counts and fish community surveys should continue annually.

Associated Costs

To accomplish the goals of the PRRP, it is estimated that ~$55 million is needed (Penobscot Restoration Trust 2013).

References

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American Shad Habitat Plan for New Hampshire Coastal Rivers

New Hampshire Fish & Game Department
Marine Fisheries Division

September 2013

This habitat plan is submitted by the New Hampshire Fish and Game Department as a requirement of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring. Historically populations of American shad have been present in the coastal waters of New Hampshire including the Merrimack River, Connecticut River, and major tributaries of Great Bay Estuary. However, over the past 30 years of monitoring by the Department the number of returning American shad adults has been highly variable and in significant decline over the past 10 years. This plan outlines the current and historic habitat for American shad within the state. The greatest threat identified to the successful restoration of the species is the presence of dams along the rivers. Dams fragment the habitat and may further reduce the numbers entering fresh water due to the absence of a fish passage structure or poor passage efficacy for American shad of the existing structure.

1) Habitat Assessment

a) Spawning Habitat

Exeter River:

i) Amount of historical in-river and estuarine spawning habitat:

The headwaters of the Exeter River are in Chester, NH and the river flows approximately 75.7 rkm into Great Bay in Newfields, NH. The current surface area of the Exeter River from headwaters to river mouth is approximately 246.6 hectares. The tidal portion of the surface area accounts for half of the total area (123.6 hectares). These surface areas were calculated from current water levels and include impoundments created by existing dams which would reduce total surface area upon their removal.

ii) Amount of currently accessible in-river and estuarine spawning habitat (i.e., habitat accessible to adult fish during the upstream spawning migration).

Anadromous fish, including American shad, currently have access to approximately 32.2 rkm, which includes 10.3 rkm of tidal waters until reaching the Great Dam Fish Ladder in Exeter, NH. The freshwater access for American shad spawning area is the remaining 21.8 rkm and is bounded upriver by the Crawley Falls Dam in Brentwood, NH. Currently access is available to 60.3 hectares of the freshwater portion of the Exeter River, or approximately 49% of the total surface area of the river.

Lamprey River:

i) *Amount of historical in-river and estuarine spawning habitat:*

The headwaters of the Lamprey River are in Northwood, NH and the river flows approximately 80.2 rkm into Great Bay in Newmarket, NH. The current surface area of the Lamprey River from headwaters to river mouth is approximately 255.7 hectares. The tidal portion of the surface area accounts for 15% of the total area (38.1 hectares). These surface areas were calculated from current water levels and include impoundments created by existing dams which would reduce total surface area upon their removal.

ii) Amount of currently accessible in-river and estuarine spawning habitat (i.e., habitat accessible to adult fish during the upstream spawning migration).

Anadromous fish, including American shad, currently have access to approximately 21.4 rkm, which includes 3.0 rkm of tidal waters until reaching the Macallen Dam Fish Ladder in Newmarket, NH. The freshwater access for American shad spawning area is the remaining 18.4 rkm and is bounded upriver by the Wadleigh Falls Dam site (breached) in Lee, NH. Currently access is available to 68 hectares of the freshwater portion of the Lamprey River, or approximately 31% of the total surface area of the river.

b) Rearing Habitat

i) Amount of historical in-river and estuarine young-of-year rearing habitat (e.g., river kilometers, water surface area (hectares)).

In addition to the in-river spawning habitat for each of the rivers, American shad have access to 2,494.4 hectares of possible rearing habitat in Great Bay Estuary. Below the estuary, the Piscataqua River flows an additional 21.14 rkm to the Atlantic Ocean with a surface area of approximately 2,106.3 hectares including Little Harbor.

ii) Amount of currently utilized in-river and estuarine young-of-year rearing habitat (i.e., habitat available to larval stage and young-of-year fish through natural spawning or artificial stocking of hatchery reared juvenile fish).

The amount of rearing habitat that is currently used is unknown, but the amount of available rearing habitat is equal to the accessible spawning habitat (*see* *sections "a)", part "i" above*) within each river plus the estuarine habitat identified (*see sections "b)", part "I" above*).

2) **Threats *Assessment*** *– Inventory and assess the critical threats to habitat quality, quantity, access, and utilization (see - Appendix C for a detailed habitat description). For those threats deemed by the state or jurisdiction to be of critical importance to restoration or management of an American shad stock, the state or jurisdiction should develop a threats assessment for inclusion in the Habitat Plan. Examples of potential threats to habitat quality, quantity, and access for American shad stocks include:*
   a) *Barriers to migration inventory and assessment*
      i) *Inventory of dams, as feasible, that impact migration and utilization of historic stock (river) specific habitat. Attribute data for each dam should be captured in an electronic database (e.g., spreadsheet) and include: name of dam, purpose of the dam, owner, height, width, length, impoundment size, water storage capacity, location (i.e., river name, state, town, distance from river mouth, geo-reference coordinates), fish passage facilities and measures implemented (i.e., fish passage type, capacity, effectiveness, and operational measure such as directed spill to facilitate downstream passage), and information source (e.g., state dam inventory).*

I. Exeter River:

Description:
The Exeter River drains an area of 326 square km in southern NH. The river flows east and north from the Town of Chester to the Town of Exeter. It empties into Great Bay northeast of Exeter. The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River.

There are two man-made barriers to American shad migration on the main stem Exeter River. The Great Dam in Exeter occurs at river kilometer (rkm) 13.5 and the Pickpocket Dam at rkm 26.9 (each at 4.6 meters high). The next barrier above Pickpocket Dam is a natural waterfall at rkm 38.1. The New Hampshire Fish & Game Department (NHFGD) constructed Denil fishways at both dams from 1969-1971 for anadromous fish. Fish ladder improvements occurred in 1994 and 1999, including the addition of a fish trap at the upriver end of the Great Dam fishway. There are no downstream fish passage facilities on either dam so emigrating adult and juvenile shad must pass over the spillway when river flows allow.

Recommended Action:
The fishway at the Great Dam in Exeter has a low efficiency of anadromous fish passage. Each spring thousands of river herring, and potentially many American shad, are observed spawning just several hundred meters below the fishway. Over the last ten years an average of 218 river herring and approximately four American shad are passed through the fishway annually. Fish passage efficiency could improve

by manipulation of the river channel below the fishway, fishway modification, or complete removal of the Great Dam.

Due to low shad passage numbers at the Great Dam fishway, it is unknown how effective the Pickpocket Dam fishway is at shad passage. With higher shad returns to the Pickpocket Dam fishway efficiency could be determined.

Regulatory Agencies/Contacts:
Dam Owners:
Great Dam and Pickpocket Dam:
The Town of Exeter, NH
Public Works Department
Mr. Keith Noyes
10 Front Street, Exeter, NH 03833

The Dam Bureau of the New Hampshire Department of Environmental Services (NHDES) oversees the maintenance, construction, and operation of all dams in the state.

NH Department of Environmental Services, Dam Bureau
Ms. Grace Levergood
29 Hazen Dr, Concord, NH 03301

The NHFGD owns and operates the fishways at both dams and facilitates implementation, monitoring, and oversight of fish passage.

Current Action:
The fishway at the Great Dam is monitored daily from early April to late June each year to allow for the passage of river herring, American shad, and other diadromous fish to historical spawning and nursery areas. All shad passing through the fishway are captured in the trap at the top, enumerated, and passed upstream by hand. Biological samples consisting of length measurement, sex determination, and scale samples used for age determination are attempted to be collected from each shad that returns. The fishway at Pickpocket Dam is also operated from early April through late June. This fishway is operated as a swim through with no trap at the top. Since fish are enumerated and sampled downstream at Great Dam the Pickpocket Dam fishway is monitored weekly to be sure it is operating correctly.

Currently the NHFGD is working with the Town of Exeter on a feasibility study looking at ways to increase the flood capacity of the Great Dam during large rain events. Options in this study include modification of the spillway and total removal of the dam.

Goals/Target:
It is the goal of NHFGD to remove or provide passage around/over as many barriers to the migration of anadromous fish in the Exeter River as possible to provide access to historical spawning habitat. This requires the continued maintenance and operation

of existing fish ladders and efforts to identify barriers further upstream where passage may be provided through modification or restoration. Efforts should be made to increase usage of the Great Dam fishway through river/fishway modifications or complete dam removal which would allow any returning American shad access to habitat upstream and potentially reach the Pickpocket Dam fishway.

Timeline:
Final draft of the Great Dam feasibility study should be released before end of 2013. Town vote on the preferred alternative will be spring of 2014. No timeline has been established for improving the usage of the fishway, but NHFGD will continue monitoring the fishways and identified barriers to fish passage and will work to increase the amount of spawning habitat available to anadromous fish in the Exeter River.

Progress:
Both fishways at Great Dam and Pickpocket Dam have been monitored since the early 1970's. Average annual return of American shad to the Great Dam fishway from 2004-2013 is 3.6 shad/yr.

NHFGD continues to work with the Town of Exeter on development of the Great Dam feasibility study. When a decision is reached on the preferred alternative in 2014, NHFGD will oversee fish passage implementation.

In addition, NHFGD continues to work to identify barriers to anadromous fish passage within the Exeter River and work towards a resolution.

II. Lamprey River

Description:
The Lamprey River flows approximately 80 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay estuary just north of the mouth of the Squamscott River. There are three potential man-made barriers to American shad migration on the main stem of the river. The Macallen Dam, located at rkm 3.8 in Newmarket, is the lowermost head-of-tide dam on the Lamprey River, and has a standard denil fishway constructed by NHFGD between 1969 and 1970. There is no downstream passage facility at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. The Wiswall Dam is located 4.8 rkm above the Macallen Dam at rkm 8.6. A standard denil fishway and downstream notch for emigration of juveniles and adults were constructed in 2012. A third potential manmade barrier, Wadleigh Falls Dam (breached), occurs 12.4 rkm above Wiswall Dam at rkm 21.4 and the ability/inability of passage by anadromous fish at the site is currently undetermined.

Recommended Action(s):
Determine success of American shad passage through the recently constructed standard denil fish ladder at the Wiswall Dam and assess the ability of passage over

the breached Wadleigh Falls Dam If passage of anadromous fish, including American shad, is not possible then efforts should be made to work with landowners and partner agencies to allow fish to pass the barrier.

Due to low returns of American shad to the Lamprey River in recent years, it is unknown if American shad currently reach the Wiswall dam and use the standard denil fish ladder to continue upriver to the third potential barrier, Wadleigh Falls.

Regulatory Agencies/Contacts:
Dam Owners:
Macallen Dam:
The Town of Newmarket, NH
Newmarket Community Development Center
Mr. Leon Filion or Mr.Rick Malasky
186 Main Street, Newmarket, NH 03857

Wiswall Dam:
The Town of Durham, NH
Public Works Department
Mr. Michael Lynch or Mr. David Cedarholm
100 Stone Quarry Drive, Durham, NH 03824

Wadleigh Falls Dam (breached):
Mr. Dodge
RR1, Rte 152, Lee, NH 03824

The Dam Bureau of the New Hampshire Department of Environmental Services (NHDES) oversees the maintenance, construction, and operation of all dams in the state.
NH Department of Environmental Services, Dam Bureau
Ms. Grace Levergood
29 Hazen Dr, Concord, NH 03301

The NHFGD owns and operates the fishway at Macallen Dam and the Town of Durham, NH owns the fishway at Wiswall Dam and NHFGD facilitates implementation, monitoring, and oversight of fish passage.

Current Action:
The fishways at the Macallen and Wiswall Dams are monitored from early April to late June each year to allow for the passage of river herring, American shad, and other diadromous fish to historical spawning and nursery areas. All shad passing through the Macallen fishway are captured in the trap at the top, enumerated, and passed upstream by hand. Biological samples consisting of length measurement, sex determination, and scale samples used for age determination are attempted to be collected from each shad that returns. The fishway at Wiswall Dam is operated as a swim through with no trap at the top.

Currently the Town of Newmarket is conducting a feasibility study looking at ways to increase the flood capacity of Macallen Dam during large rain events. Options in this study include modification of the spillway and total removal of the dam.

Goals/Target:
It is the goal of NHFGD to remove or provide passage around/over as many barriers to the migration of anadromous fish in the Lamprey River as possible to provide access to historical spawning habitat. This requires the continued maintenance and operation of existing fish ladders and efforts to identify barriers further upstream such as Wadleigh Falls Dam (breached) where passage may be provided through modification or restoration.

Timeline:
No timeline has been established, but NHFGD will continue monitoring the fishways and identified barriers to fish passage and will work to increase the amount of spawning habitat available to anadromous fish in the Lamprey River.

Progress:
The fishway at Macallen Dam has been monitored since the early 1970's. Average annual return of American shad to the Macallen Dam fishway from 2004-2013 is less than one shad/yr. The Wiswall Dam fishway has been monitored since construction completed in 2012 through volunteer counting efforts and NHFGD electronic fish counters to estimate passage numbers and maintain ladder conditions conducive to fish passage during the spring.

NHFGD conducted a radio tagging study with river herring in 2013 to determine the passage success of anadromous fish over the Wadleigh Falls Dam location (breached). The study is ongoing and data have not been reviewed at the time of this report.

ii) *Inventory of other human–induced physical structures (e.g., stream crossing/culverts), as feasible, that impact migration and utilization of historic habitat (data on each structural impediment should include: type, source, and location)-***DATA CURRENTLY NOT AVAILABLE**

iii) *Inventory of altered water quality (e.g., low oxygen zones) and quantity (e.g., regulated minimum flows that impact migration corridors and/or migration cues), as feasible, impediments that impact migration and utilization of historic habitat (data on each water quality and quantity impediment should include: type, source, location, and extent).*

In New Hampshire the NH Department of Environmental Services (NHDES) protects the state's inland surface water through its active lakes and rivers monitoring programs and its biological and chemical analyses of rivers and water bodies. During the year, NHDES conducts thousands of water analyses on state waters, including those involving drinking water and industrial and municipal wastewater effluents. The Water Division also oversees lake and river volunteer monitoring programs, a public beach and swimming pool inspection program, and an acid rain monitoring program.

Two factors effecting recruitment and out-migration of adults may be poor water quality and impediments to downstream migration. Floodgate closure issues with the Exeter River dam, water withdrawals from the river by the Town of Exeter, or a combination of both have resulted in prolonged periods of limited or no flow over the Great Dam at various times of the year. The lack of flow over the dam restricts downstream migration of both adult and juvenile American shad and river herring subjecting them to periods of poor water quality. Water quality data collected by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), from 1995, has indicated low levels of dissolved oxygen between two and five mg/L in impoundment reaches of the Exeter River. More recent water quality data collected in 2004 by NHFG in cooperation with the University of New Hampshire during a study of the effects of passage impediments and environmental conditions on out-migrating juvenile American shad have also indicated levels of dissolved oxygen below 5 mg/L. These low levels of dissolved oxygen were recorded even with the Exeter River's 2004 average daily flows being above the eight-year median daily flow between July and September. The decreased spawning returns of American shad and river herring to the Exeter River may be due to poor survival of juvenile out-migrating American shad and river herring as well as adults during periods of low water quality from June through October. Currently, state agencies and the Town of Exeter are working to improve the water quality of impounded reaches of the Exeter River and to allow better passage of emigrating anadromous fish.

Although NHFG has not performed water quality monitoring in other coastal rivers it is likely these conditions are not unique to the Exeter River. Other rivers, especially the Oyster and Taylor Rivers, often experience very low summer flows that result in minimal to no flow out of impoundments. These conditions do not allow adult or juvenile anadromous species to escape periods of low dissolved oxygen caused by low flows.

iv) *Assess barriers to migration in the watershed and characterize potential impact on American shad migration and utilization of historic habitat.*

(See part "I" above)

b) *Water withdrawals inventory and assessment –* **DATA CURRENTLY NOT AVAILABLE**

c) *Toxic and thermal discharge inventory and assessment-* **DATA CURRRENTLY NOT AVAILABLE**

d) *Channelization and dredging inventory and assessment-* **DATA CURRRENTLY NOT AVAILABLE**

e) Land use inventory and assessment- **DATA CURRRENTLY NOT AVAILABLE**

f) *Atmospheric deposition assessment-* **DATA CURRRENTLY NOT AVAILABLE**

g) *Climate change assessment-* **DATA CURRRENTLY NOT AVAILABLE**

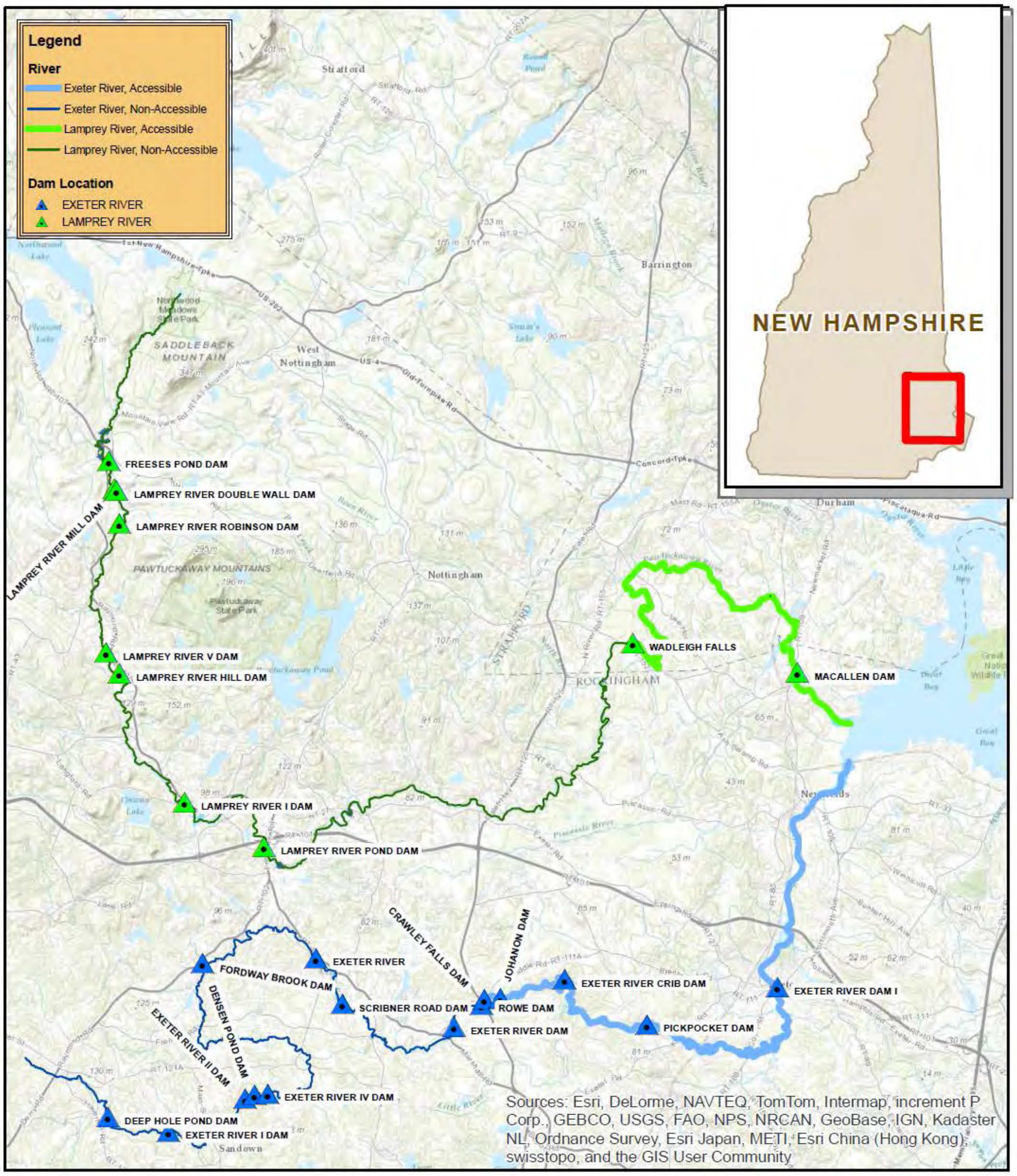
h) *Competition and predation by invasive and managed species assessment-* **DATA CURRRENTLY NOT AVAILABLE**

Table 1. Inventory of Dams on the Exeter and Lamprey Rivers

RIVER	DAM NAME	COUNTY	TOWN	TYPE	STATUS	STATUS DATE	NH DAM ID	NATIONAL DAM ID	LENGTH	HEIGHT	BUILT	REBUILT	DAM LOCATION LONG	LAT	River km
EXETER RIVER	EXETER RIVER DAM I	ROCKINGHAM	EXETER	CONCRETE	ACTIVE	2006	82.01	NH00304	140	15	1914	1968	-70.944444	42.98111	10.3
	PICKPOCKET DAM	ROCKINGHAM	BRENTWOOD	CONCRETE	ACTIVE	2004	29.07	NH00294	230	15	1920		-71.001667	42.96944	22.4
	EXETER RIVER CRIB DAM	ROCKINGHAM	BRENTWOOD	TIMBERCOMB	RUINS	1935	29.06		110	12			-71.036944	42.98417	27.6
	JOHANON DAM	ROCKINGHAM	BRENTWOOD	STONE/EARTH	RUINS	1935	29.05		60	10			-71.065	42.97806	31.5
	CRAWLEY FALLS DAM	ROCKINGHAM	BRENTWOOD	TIMBERCOMB	RUINS	1972	29.04		140	9			-71.072778	42.97778	32.2
	ROWE DAM	ROCKINGHAM	BRENTWOOD	TIMBERCOMB	RUINS	1935	29.03		80	8			-71.073889	42.97639	32.5
	EXETER RIVER DAM	ROCKINGHAM	BRENTWOOD	CONCRETE	ACTIVE	2007	29.01	NH00293	115	15	1900		-71.085833	42.96917	34.0
	SCRIBNER ROAD DAM	ROCKINGHAM	FREMONT	CONCRETE	ACTIVE	2003	89.02	NH01050	150	12	1963		-71.134167	42.97694	40.7
	EXETER RIVER	ROCKINGHAM	FREMONT	TIMBERCOMB	ACTIVE	1972	89.01	NH01876	70	7			-71.146389	42.99167	43.0
	FORDWAY BROOK DAM	ROCKINGHAM	RAYMOND	TIMBERCOMB	RUINS	0	201.1		0	1			-71.195	42.99056	49.9
	EXETER RIVER IV DAM	ROCKINGHAM	SANDOWN	STONE/EARTH	RUINS	1935	212.04		125	12			-71.166667	42.94861	62.7
	DENSEN POND DAM	ROCKINGHAM	SANDOWN	EARTH	ACTIVE	1996	212.03	NH03047	200	10	PRE 1935		-71.1725	42.94806	63.3
	EXETER RIVER II DAM	ROCKINGHAM	SANDOWN	STONE/EARTH	BREACHED	1982	212.02		100	10			-71.176667	42.94667	63.7
	EXETER RIVER I DAM	ROCKINGHAM	SANDOWN	EARTH/STONE	BREACHED	1949	212.01		0	5			-71.209722	42.93667	68.3
	DEEP HOLE POND DAM	ROCKINGHAM	CHESTER	EARTH	ACTIVE	2006	44.08	NH01003	150	15	1974		-71.2375	42.94111	71.2
LAMPREY RIVER	MACALLEN DAM	ROCKINGHAM	NEWMARKET	CONCRETE	ACTIVE	2003	177.01	NH00365	150	27	1887		-70.934722	43.08111	3.0
	WISWALL DAM	STRAFFORD	DURHAM	CONCRETE	ACTIVE	2005	71.04	NH00441	200	18	1911		-70.963333	43.10389	8.6
	WADLEIGH FALLS	STRAFFORD	LEE	CONCRETE	BREACHED	1997	135.02		300	13			-71.006667	43.09139	21.4
	LAMPREY RIVER POND DAM	ROCKINGHAM	RAYMOND		RUINS	1935	201.07		0	0			-71.167778	43.02833	48.1
	LAMPREY RIVER I DAM	ROCKINGHAM	RAYMOND		RUINS	1935	201.06		0	0			-71.2025	43.04139	54.0
	LAMPREY RIVER HILL DAM	ROCKINGHAM	DEERFIELD	STONE/EARTH	RUINS	1935	61.06		0	5			-71.230278	43.0825	61.5
	LAMPREY RIVER V DAM	ROCKINGHAM	DEERFIELD	STONE/EARTH	EXEMPT	1979	61.08	NH01656	125	2			-71.236944	43.09	62.6
	LAMPREY RIVER ROBINSON DAM	ROCKINGHAM	DEERFIELD		RUINS	0	61.05		0	0			-71.229167	43.13056	68.5
	LAMPREY RIVER DOUBLE WALL DAM	ROCKINGHAM	DEERFIELD	STONE/EARTH	RUINS	1934	61.04		0	12			-71.231111	43.14083	70.1
	LAMPREY RIVER MILL DAM	ROCKINGHAM	DEERFIELD	STONE/EARTH	RUINS	1934	61.03		0	15			-71.232222	43.14167	70.2
	FREESES POND DAM	ROCKINGHAM	DEERFIELD	CONCRETE	ACTIVE	2001	61.02	NH00472	150	12.5	1987		-71.234444	43.15028	71.4

Accessible Spawning Habitat and Barrier Inventory of Exeter and Lamprey Rivers, NH

American Shad Habitat Plan



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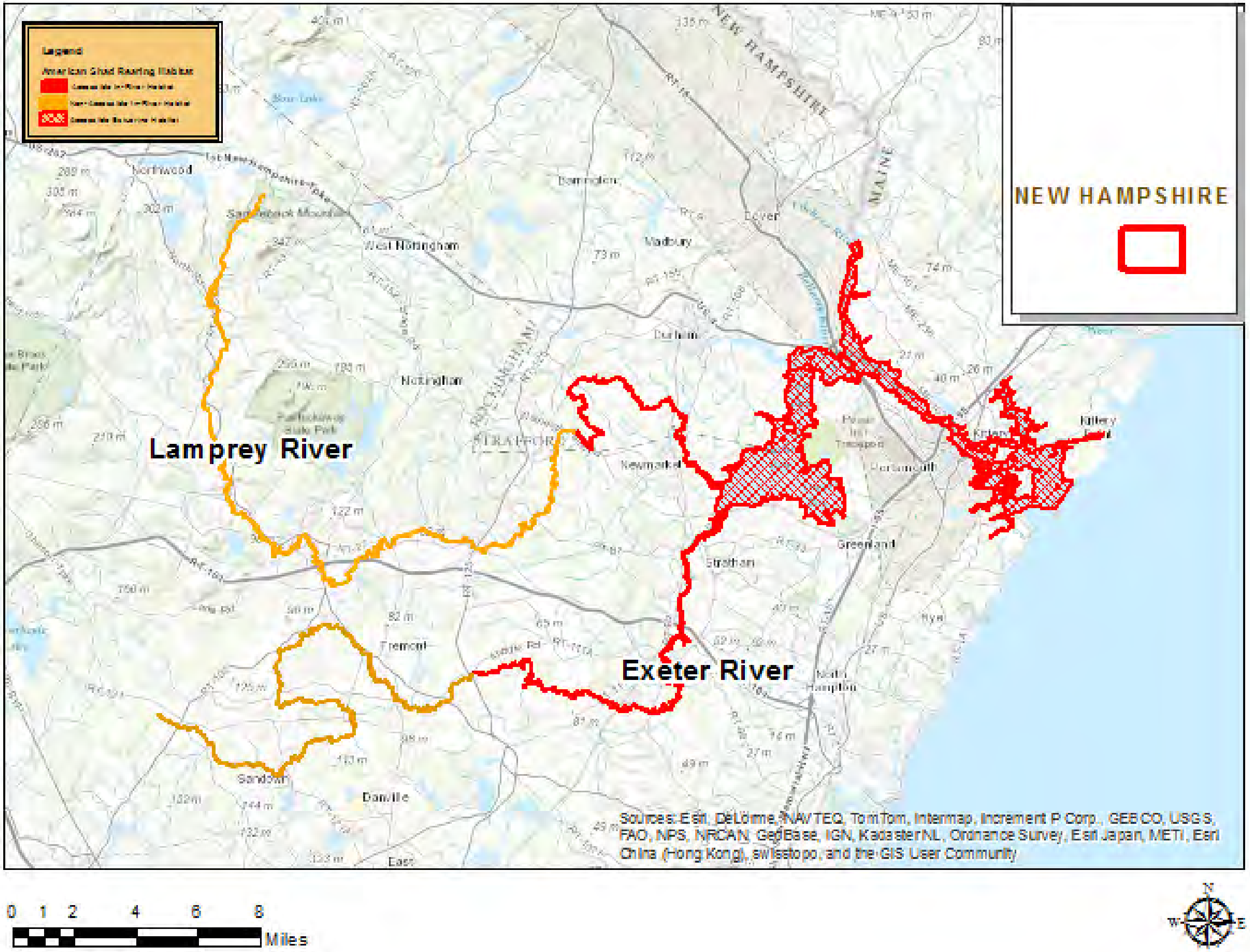
Miles

Rearing Habitat for American Shad in the Exeter and Lamprey Rivers, NH

American Shad Habitat Plan



American Shad Habitat Plan for Massachusetts Coastal Rivers

Massachusetts Division of Marine Fisheries -- January 2014

American shad spawning runs in Massachusetts occur in two large rivers bordering multiple jurisdictions and six moderate sized coastal rivers. The Connecticut River and Merrimack rivers have relatively large runs of American shad that support recreational fisheries and are managed by multi-jurisdiction management plans (CRASC 1992; and MRTC 1997). The American shad habitat plans for the Connecticut River (CRASC *in Prep*.) and Merrimack River (MRTC 2010) are reported independently from this report. The other coastal rivers with known spawning runs present are (with major drainage area in parentheses): Palmer River (Narragansett Bay), Jones River (South Shore), North River (South Shore), South River (South Shore), Neponset River (Boston Harbor), and Charles River (Boston Harbor). The principal threat identified for most shad runs in Massachusetts is **Barriers to Migration**. However, significant questions about the status of potential threats and issues such as water withdrawals and water quality impairment exist and require further investigation. This habitat plan will report on the Palmer River and Charles River because among the six coastal runs they have been identified as restoration priorities by the MA Division of Marine Fisheries (*MarineFisheries*). The Taunton River is included for future monitoring because a historical shad run and fishery were present, but the current population status is unknown. Updated versions of this plan will add other rivers as needed.

A synopsis of investigations on American shad spawning habitat requirements (Greene et al. 2009) reveals that although consensus is lacking, shad generally spawn well upstream of the tidal interface at mid-river runs in relatively shallow depths (< 4 m) with more apparent selection to moderate to high water velocity (0.3 to 0.9 m/s) than to a specific substrate type.

Palmer River

Watershed Information: The Palmer River, located in Bristol County, MA, originates in the wetlands of northern Rehoboth (Figure 1) and flows south for approximately 17 river miles (rm) through Swansea to its confluence with the Barrington River and discharges to Narragansett Bay in RI. Two impoundments created by dams are located along the course of the river: Shad Factory Pond and Perryville Pond. The former is a shallow 38 acre pond formed by an 8 ft dam last rebuilt in 1912. The dam is located at 7.7 rm with a drainage area of 27.5 mi^2. Shad are known to spawn along an unknown proportion of the upper end of the river below the dam. Upstream of the dam, there is 6.5 rm of potential spawning habitat before reaching the impassible Perryville Dam at rm 14.2. The habitat upstream of the Perryville Dam (Perryville Pond; 3.3 acres) has not been assessed, but is thought to have low potential for American shad with some potential for other diadromous species. The watershed, which also supports spring spawning runs of white perch and river herring, was documented in the 1970s as having spawning rainbow smelt and sea lamprey. The Palmer River presently has the last remaining recreational fishery for American shad in MA south of Cape Cod.

American Shad Status: No current population data are available. Fishery resource surveys were conducted by *MarineFisheries* and the MA Division of Fish and Wildlife (*MassWildilfe*) from 1968 to 1971 and by *MarineFisheries* in 1993. Water quality and creel information were collected in these surveys. Creel survey results are summarized in Table 1. In addition, shad were transplanted by *MarineFisheries* personnel from the Palmer River into the Mattapoisett River in 1968 (N = 78) and in 1969 (N = 80). Anecdotal reports suggest that recreational angling for shad continues in the Palmer River, although at low levels of catch and effort. Population monitoring and habitat assessment were considered when a fish ladder was reconstructed at Shad Factory Pond in 2007; however, this work has not been done.

Fish Ladder Specifications: A concrete weir and pool fish ladder was installed in 2007 by the Town of Rehoboth, Save the Bay and several funding partners. The fish ladder was designed by the U.S. Fish and Wildlife Service (USFWS) and the project received technical assistance from the MA Office of Fishing and Boating Access and *MarineFisheries*. The fish ladder is approximately 320 ft. in length with 19 weirs and 16 ft x 3 ft pools. No aspect of fish passage for shad has been assessed at this location. The Perryville Dam in Rehoboth has no fishway and obstructs passage to unassessed habitat (Reback et al. 2004).

Table 1. Summary of Palmer River shad creel surveys conducted between 1968 – 1971 and 1993.

Date	1968	1969	1970	1971	1993
No. Anglers	333	657	413	419	72
Total Catch	148	174	82	120	41
Hours Fished	660	1500	1297	915	108
Catch/Hour	0.22	0.12	0.06	0.13	0.38

Regulatory Authority: The owner of the dam is responsible for repairing, operating, and maintaining the fish passage facilities as prescribed in M.G.L. Chapter 130 §19. Fish passage at the Shad Factory Pond fish ladder has been historically managed cooperatively by the Town of Rehoboth and the dam owner, the Bristol County Water Authority of Bristol, RI. Wetlands habitat and water quality protections are provided by M.G.L. Chapter 131 §40 and Commonwealth of Massachusetts Regulations 10.00 and administered by the Massachusetts Department of Environmental Protection (*Mass*DEP).

Water Withdrawal Permissions: The Bristol County Water Authority maintains a water withdrawal registration (No. 4-26-247.05) issued by *Mass*DEP in the Narragansett Bay and Mt. Hope Bay Shore river basins to withdraw 2.7 million gallons per day (MGD) from three surface water sources (Swansea Reservoir, Shad Factory Reservoir and Anawan Reservoir) for public water supply. Monthly withdrawal records are required for annual submission to *Mass*DEP.

Water Discharge Data: None currently. The West Branch of the Palmer River had a gauge station (No. 01109200, drainage area 4.35 mi^2) operating during 1962-1974. The monthly mean discharge in May for this period was 9.8 cfs; however, the short duration of the data series and long distance between the West Branch gauge location and Shad Factory Pond limit the data utility.

Water Quality Monitoring: *Mass*DEP assesses waterbodies by comparing water quality to Surface Water Quality Standards (SWQC), indentifying threats to habitats and recommending remedial actions (*Mass*DEP 2007). The Narragansett Bay watershed was last assessed during 2004-2008 (*Mass*DEP 2009); however, the Palmer River segment was listed as "Not Assessed" for its capacity to support aquatic life.

Recommended action:

Currently, *MarineFisheries* does not have an ongoing project or imminent plans to initiate an assessment of the Palmer River shad run. *MarineFisheries* expects that a habitat assessment would be useful for this watershed and potentially transferable to other Massachusetts watersheds with small, poorly documented shad runs; however, the funding to undertake this effort is not presently available. We **recommend** the following actions for the Palmer River: (1) assessment of the amount and suitability of Palmer River habitat for shad spawning and rearing, (2) census counts of shad and river herring passing upstream into Shad Factory Pond, (3) passage efficiency at the Shad Factory Dam fishway and (4) the feasibility of fish passage improvements at the Perryville Dam.

Agency or Agencies with Regulatory Authority: *MarineFisheries* -- coastal waters diadromous fish, *MassWildlife* -- inland waters diadromous fish, and *Mass*DEP -- wetlands and water quality protection.

Action actively being addressed by agency: The only action taken to date has been the preparation of an Operations and Maintenance Plan for the Shad Factory Dam fishway. A draft was sent to the dam owner in 2011 requesting comments. The dam owner has not responded to the inquiry to date.

Initial Habitat Goal: Conduct the shad spawning habitat assessment for the Palmer River upstream and downstream of Shad Factory Pond and assess species presence. If suitable upstream conditions are found, seek funding for passage efficiency studies at Shad Factory Pond and fish passage feasibility studies at Perryville Dam.

Timeline for achieving goals/targets: None established. *MarineFisheries* will seek funding in 2014.

Possible metrics to evaluate progress: (1) comparison of water quality parameters to *Mass*DEP criteria (SWQC) for supporting aquatic life; (2) census counts of shad and river herring into Shad Factory Pond using a locking box trap installed at the fish ladder exit; (3) passage efficiency evaluation using PIT tag study; (4) discharge range that provides suitable water depth and velocity in fishway and water depth and velocity at river habitats.

Estimated costs: A cost estimate has not been developed yet. The primary cost item for the Initial Habitat Goal would be two short-term technicians.

Potential setbacks/areas of concern: The watershed is part of an active water supply. The municipal needs for water compete directly with water needs for aquatic life, but the effects are unknown.

Other organizations: The Town of Rehoboth has expressed an interest in shad restoration in the Palmer River. The Bristol County Water Authority has an interest and responsibility to allow diadromous fish passage at Shad Factory Pond.

Charles River

Watershed Information: The Charles River is a relatively large coastal river in Massachusetts that provides habitat for diadromous fish for nearly 80 rm as it flows to Boston Harbor (Figure 2) and borders the lands of 24 towns and cities. The drainage area of the watershed is approximately 311 mi^2. There are eight dams that fragment diadromous fish habitat in the Charles River. The upper two dams have no passageways and the lower six have passageways with unknown efficiency for passing American shad.

American Shad Status: Belding (1921) refers to the Charles River as one of the first rivers in Massachusetts to lose its shad and alewife fisheries due to pollution and dams. Reback and DiCarlo (1972) state that shad were not present in the Charles River at the time of their 1960s survey of anadromous fish; however, they note the high restoration potential and interest of *MarineFisheries* to pursue shad restoration. A river assessment was conducted by *MarineFisheries* in the late 1960s to determine the available potential spawning habitat. A total of 61 rm with suitable spawning habitat was documented and plans were launched to begin stocking fertilized shad eggs in 1971. Intensive stocking of shad eggs occurred through much of the 1970s and sporadic stocking of mature adult shad continued from 1978 to 1992. The results of the stocking effort were not evaluated, although returning adult shad were captured in low numbers while collecting river herring for stocking below the Watertown Dam during the 1990s and 2000s (Reback et al. 2005). Shad stocking efforts were renewed in 2006 to apply improved culture techniques and oxytetracycline (OTC) marking to evaluate restoration responses.

Ongoing Shad Monitoring: Starting in 2006, a cooperative effort between *MarineFisheries* and the USFWS, has stocked an average of 3 million OTC-marked larvae in potential nursery habitat upstream of the Moody Street Dam (4th barrier). Gravid American shad were collected from the Merrimack River and cultured to fry stage at the USFWS Attleboro hatchery. For the past 3 years the two agencies have electrofished downstream of the Watertown Dam (2nd barrier) in order to provide information on the status of the shad run and restoration contributions. During 2012, weekly, spawning run electrofishing trips yielded a total of 30 adult shad. The otoliths of each adult were removed and examined for an OTC mark and were aged along with scales from each fish. Of the 30 adults retained, 25 were an age (3-6) that could have originated from the restoration efforts. Of those 25 fish, 15 possessed an OTC mark. It is unknown whether non-marked fish are the result of straying, hatchery product that lost or failed to incorporate an OTC mark, or remnant of a natural population. Since the resumption of stocking in 2006 a limited effort has been made to identify if a remnant spawning run existed. This assessment operated the Denil fishway at the Watertown Dam as a fish trap.

When the trap was operated, adult shad were prevented from passing through the upstream exit by way of tightly spaced vertical bars. The trapping approach had limitations, but did document the presence of low numbers of adult shad. In 2013, *MarineFisheries* replaced this trap methodology with a video monitoring system. Video review is not complete at this time, but to date over 250,000 river herring and 36 adult shad have been observed passing through the fishway. In 2013 only 21 adult American shad were captured while electrofishing, meaning the number of shad successfully utilizing the fishway exceeded the number sampled below and supports the possibility of natural reproduction occurring in the watershed. The stocking efforts in 2013 included the release of double OTC marked fry to assist with the evaluation of stocking and marking techniques.

Fish Ladder Specifications: Detailed specifications on the Charles River fishways are provided in Reback et al. (2005). The first barrier in Boston Harbor is the Charles River Locks, built for navigation and flood control. A locking protocol is used to pass migrating fish at this location with specific timing provisions for the shad migration. The 2nd, 4th, 5th and 6th dams have large width Denil fishways designed by the USFWS to pass river herring and shad. The 3rd barrier has been partially breached to allow fish passage. The uppermost dams, the Metropolitan Circular Dam at 20.0 rm and the Silk Mill Dam at 20.2 rm have no fishways. At present, shad have access to approximately 20 rm of potentially suitable habitat.

Regulatory Authority: The owner of the dam is responsible for repairing, operating, and maintaining the fish passage facilities as prescribed in M.G.L. Chapter 130 §19. Seven of the eight dams on the Charles River are owned by the Massachusetts Department of Conservation and Recreation. The Silk Mill Dam is privately owned. Wetlands habitat and water quality protections are provided by M.G.L. Chapter 131 §40 and Commonwealth of Massachusetts Regulations 10.00 and administered by the Massachusetts Department of Environmental Protection (*Mass*DEP).

Water Withdrawal Permissions: With a large urban watershed that connects many towns, the Charles River is subject to complex water management. Communities in the metropolitan Boston area (inside Route 128) receive water from the Massachusetts Water Resources Authority's Quabbin Reservoir. Communities outside of Route 128 are allowed under 14 MA Water Management Act permits to withdraw water from groundwater wells and reservoirs.

Water Discharge Data: The importance of the Charles River for water resource management is reflected by the presence of 18 USGS stream flow gauges in the watershed. The Waltham stream flow gauge station (No. 01104500, 12.2 rm, 251 mi^2 drainage area) is on the main stem Charles River and is most proximate to the fishways. The average monthly discharge at the Waltham gauge station is 615 cfs for April and 370 cfs for May from the time series record of 1931-2012.

Water Quality Monitoring: *Mass*DEP assesses waterbodies by comparing water quality to Surface Water Quality Standards, indentifying threats to habitats and recommending remedial actions (*Mass*DEP 2007). The Charles River watershed was last assessed during 2002-2006 (*Mass*DEP 2008); with a large percentage of the potential shad habitat listed as *Impaired* due to several stressors including low dissolved oxygen, high nutrients, and invasive plant growth.

Recommended action:

The current efforts being undertaken by *MarineFisheries* have been outlined above. Stocking and monitoring efforts will continue through at least 2015. *MarineFisheries* expects that a habitat survey and assessment would be useful for this watershed and potentially transferable to other watersheds in Massachusetts, but the funding to undertake this effort is not presently available. We **recommend** the following actions for the Charles River: (1) assessment of the amount and suitability of Charles River habitat for shad spawning and rearing; (2) passage efficiency at the Watertown Dam fishway; (3) evaluate the feasibility of providing fish passage at the two upstream impassible dams; and (4) evaluate the feasibility of fish passage improvements through removal of the Watertown Dam.

Agency or Agencies with Regulatory Authority: *MarineFisheries* -- coastal waters diadromous fish, *MassWildlife* -- inland waters diadromous fish, and *Mass*DEP -- wetlands and water quality protection.

Action actively being addressed by agency: *MarineFisheries* is currently monitoring passage at the first fishway to measure potential for natural reproduction. We are also facilitating dialogue between citizen's groups and other state agencies to increase access to upstream habitat in the system through fish passage improvements.

Initial Habitat Goal: Conduct shad spawning habitat assessment for the Charles River upstream and downstream of the Watertown Dam. If suitable conditions are found, seek funding for passage efficiency studies at the Watertown Dam and next two dams upstream.

Timeline for achieving goals/targets: None established. *MarineFisheries* will seek funding in 2014.

Possible metrics to evaluate progress: (1) comparison of water quality parameters to *Mass*DEP criteria (SWQC) for supporting aquatic life; (2) passage efficiency evaluation using PIT tag study; and (3) discharge range that provides suitable water depth and velocity in fishway and water depth and velocity at river habitats.

Estimated costs: A cost estimate has not been developed.

Potential setbacks/areas of concern: The watershed is part of a heavily urbanized area with documented surface water quality and stormwater impairments. Invasive species are also of concern, as many lentic areas in the watershed are heavily impacted by water chestnut.

Other organizations: *MarineFisheries* conducts most field work in cooperation with the USFWS. The Charles River Watershed Association is also engaged in fish habitat restoration as well as the greater betterment of the Charles River.

Taunton River

Watershed Information: The Taunton River is the largest river in southeastern Massachusetts and has no barriers that impede American shad passage along the 38.5 rm main stem. The Taunton River includes a large drainage area (approximately 562 mi^2) that is supported by numerous significant tributaries. The Taunton River, which is formed by the confluence of the Matfield and Town rivers in Bridgewater, passes the borders of more than 10 towns before reaching the tidal Mount Hope Bay which connects to Narragansett Bay (Figure 1). The watershed has a legacy of industrial pollution, yet is unique in Massachusetts with no dams along its entire main stem.

American Shad Status: Belding's (1921) anadromous fish survey of the early 20th century recognized historical shad runs in the Taunton River that were rendered commercially extinct due to industrial pollution. Unlike most coastal rivers in Massachusetts, obstructions were not a problem for migratory fish in the main stem Taunton River. The next anadromous fish survey in the 1960s (Reback and DiCarlo, 1972) also cited pollution as the primary driver of low shad numbers in the Taunton system as opposed to dams. During this survey, additional work was done to identify shad habitat in the Taunton River. *MarineFisheries* surveyed the stream substrate from the Berkley Bridge in Dighton to the Jenkins Leatherboard Company dam in Bridgewater. The Berkley Bridge was the lower limit of salt water intrusion. They documented 28 rm of potential spawning habitat in this stretch and highlighted the promising outlook for shad restoration. They also named the Segreganset River and Nemasket River as Taunton River tributaries with shad present. Reback and DiCarlo (1972) noted a shad stocking project in 1969 that transferred shad eggs from Connecticut River adults to the Nemasket River. The most recent MA DMF anadromous fish survey (Reback et al. 2004) echoes the potential for shad restoration in the Taunton River but recognized that shad stocking in the 1960s and 1970s with eggs and adults from the Connecticut River produced little evidence of success. Presently, the status of shad in the Taunton River watershed is unknown with some anecdotal reports of finding individual adult shad in the last decade. For the Taunton River, the principal threat and cause of low populations is not Barriers to Migration and has not been identified.

Fish Ladder Specifications: No fishways in main stem Taunton River.

Regulatory Authority: In the absence of dams and fishways, the principal regulatory authority related to American shad is found with the state regulations of the *MarineFisheries* (coastal) and *Mass*Wildlife (inland). Wetlands habitat and water quality protections are provided by M.G.L. Chapter 131 §40 and Commonwealth of Massachusetts Regulations 10.00 and administered by *Mass*DEP.

Water Withdrawal Permissions: Three facilities have MA Water Management Act permits with authorized surface and groundwater withdrawals totaling 3.27 million gallons per day (MGD). Of these three facilities, the largest withdrawal at 3.03 MGD is for a municipal public water source.

Water Discharge Data: The main stem Taunton River has a USGS stream flow gauge in Bridgewater (No. 01108000, 261 mi^2 drainage area). The average monthly discharge at the Bridgewater gauge station is 886 cfs for April and 558 cfs for May from the time series record of 1929-2012.

Water Quality Monitoring: *Mass*DEP assesses waterbodies by comparing water quality to Surface Water Quality Standards, indentifying threats to habitats and recommending remedial actions (*Mass*DEP 2007). The Taunton River watershed was last assessed during 2004 (Rojko et al. 2005); with most of the potential main stem shad habitat listed as *Suitable* to support aquatic life or "Not Assessed".

Recommended action:

Of the three coastal rivers in the current plan, the least information is known on the status of and threats to American shad in the Taunton River. *MarineFisheries* seeks more information on the presence of shad in the Taunton River, the status of potential shad habitat, and the influence of potential threats such as historical and present pollutant loading, and water quality impairment. We expect that a habitat survey and assessment would be useful for this watershed and potentially transferable to other watersheds in Massachusetts, but the funding to undertake this effort is not presently available. We **recommend** the following actions for the Taunton River: (1) assessment of the amount and suitability of Taunton River habitat for shad spawning and rearing; and (2) monitoring to confirm the presence of a shad spawning run.

Agency or Agencies with Regulatory Authority: *MarineFisheries* -- coastal waters diadromous fish, *MassWildlife* -- inland waters diadromous fish, and *Mass*DEP -- wetlands and water quality protection.

Action actively being addressed by agency: None.

Initial Habitat Goal: Conduct both recommended actions.

Timeline for achieving goals/targets: None established.

Possible metrics to evaluate progress: (1) comparison of water quality parameters to State criteria for supporting aquatic life; and (2) discharge range that provides suitable water depth and velocity at river habitats.

Estimated costs: A cost estimate has not been developed. The Taunton River watershed is in close proximity to the Palmer River. Technicians deployed to assess the Palmer River habitat could conduct the Taunton River assessment concurrently on a similar schedule.

Potential setbacks/areas of concern: The watershed is part of an active water supply and urbanized area with documented surface water quality and stormwater impairments. The municipal needs for water compete directly with water needs for aquatic life, but the effects are unknown.

Other organizations: No active projects are underway on American shad in the Taunton River.
Several towns have active river herring wardens that would likely take an interest and perhaps participate in future shad monitoring and restoration efforts as would the Nature Conservancy and the Taunton River Watershed Alliance, active non-profit groups that works to improve the aquatic resources of the Taunton River.

Related Activities

Two ongoing *MarineFisheries* projects related to diadromous fish could benefit the interest of improving our knowledge of American shad habitat in the future. A GIS datalayer of diadromous fish habitat has been developed in cooperation with the Massachusetts Department of Transportation to provide tools for transportation and diadromous fish restoration planning. The statewide datalayer presently contains presence/absence and time-of-year entries for all diadromous fish and specific habitat locations for river herring and rainbow smelt. This datalayer can be improved in the future by adding shad habitat data. Secondly, *MarineFisheries* conducts habitat assessments for rainbow smelt and river herring to under a Quality Assurance Program Plan (QAPP) that relates habitat and water quality conditions to aquatic life and species life history thresholds (Chase 2010). The QAPP can be updated in the future to include shad habitat assessments.

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Figure 1. Palmer River and Taunton River in the Narragansett Bay Watershed. The green dots are dams that are passable to migratory fish and the red dots are impassible dams.

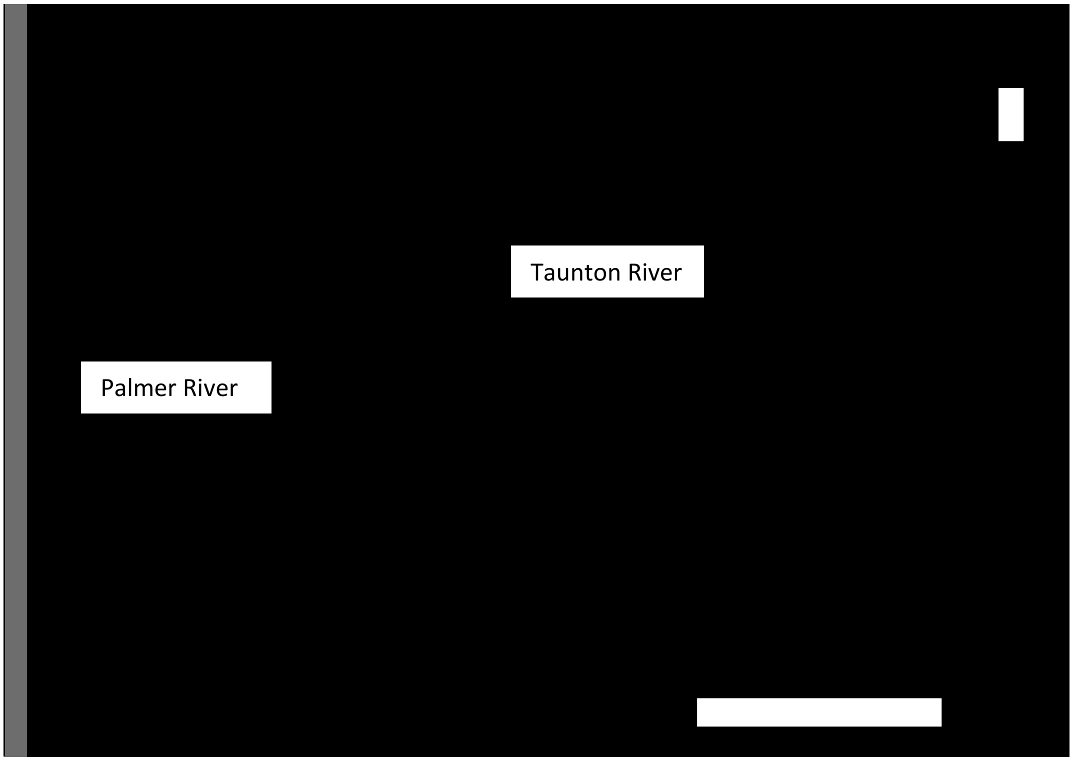
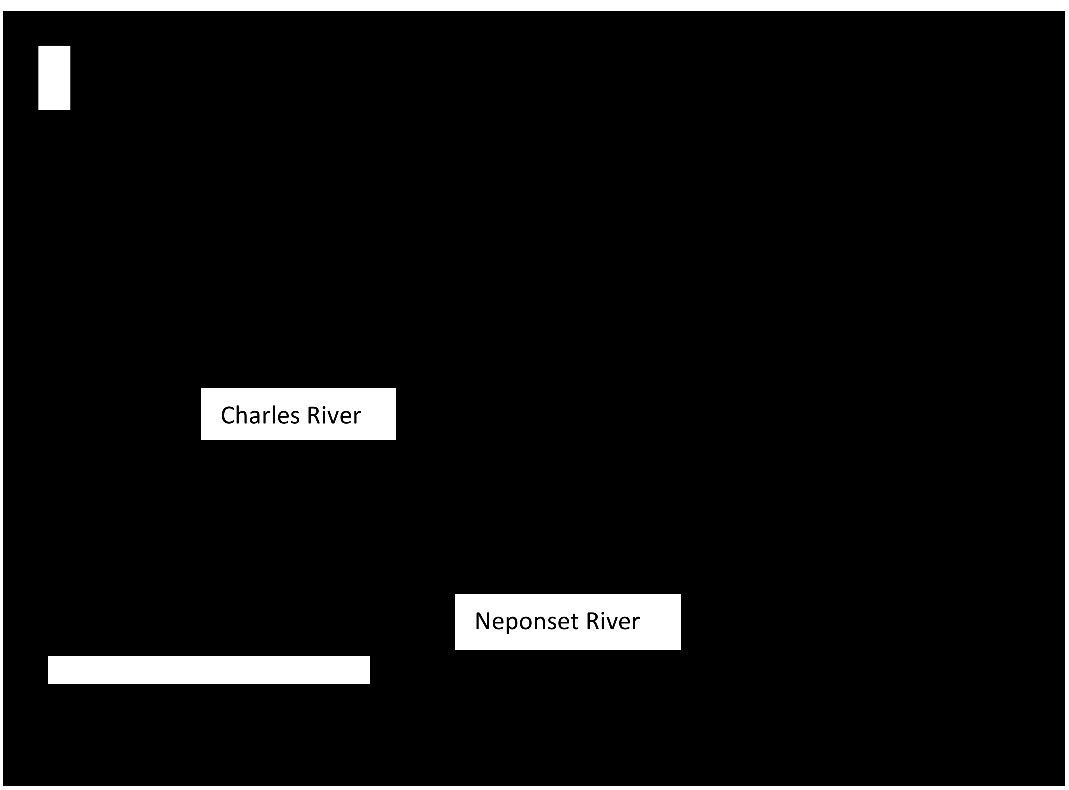
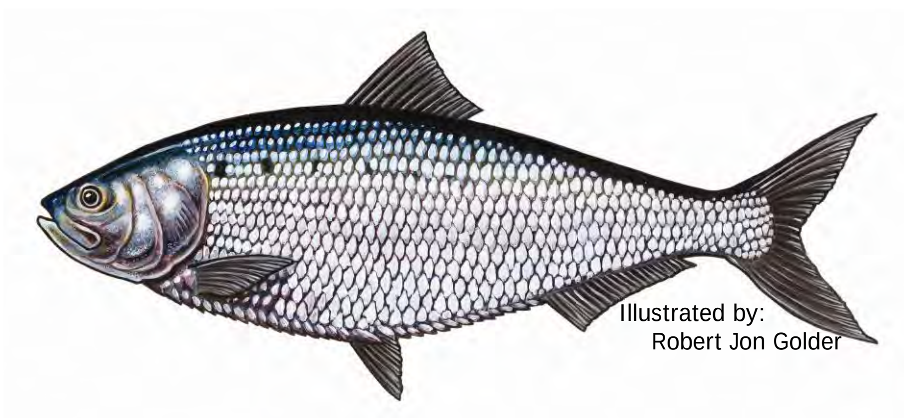


Figure 2. Charles River in the Boston Harbor Watershed. The green dots are dams that are passable to migratory fish and the red dots are impassible dams.



Rhode Island American Shad Habitat Plan
Pawcatuck River



Submitted to ASMFC
September 2013
By
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RI DEM Fish & Wildlife

Rhode Island American Shad Habitat Plan
Pawcatuck River

Habitat Assessment:

Since the 1970s, RIDEM has accomplished substantial progress in the restoration of diadromous fish to the 308-mi^2 Pawcatuck River watershed. RIDEM has been successful to date at re-establishing low-levels of self-sustaining American shad and river herring populations in the lower reach of the Pawcatuck River watershed. This work has included installation of structural fishways (1970s), limited structural fishway improvements, broodstock enhancement, and monitoring of both adult returns and juvenile recruitment (e.g., fish trap counts, juvenile seine surveys, electrofishing, and radio telemetry). Although the Pawcatuck River has historic diadromous fish runs, each of the lower three dams (White Rock, Potter Hill, and Bradford) and poorly functioning structural fishways greatly reduce the passage efficiency of anadromous fish from accessing valuable spawning and nursery habitat. Currently, the State of Rhode Island Department of Environmental Management (RIDEM), Division of Fish and Wildlife (DF&W) has committed funds and has initiated a process to assess specific passage problems at each dam (via U.S. Army Corps of Engineers (ACOE) Section 22 of the Water Resources Development Act) to document passage deficiencies and passage restoration alternatives at each of the first three dams on the Lower Pawcatuck River.

Over the past several years there has been a substantial effort to improve fish passage at dams located upstream of the three dams described above that are on the lower portion of the Pawcatuck River. This three phase upper Pawcatuck River fish passage restoration project was awarded a multi-million dollar NOAA American Recovery and Reinvestment Act and involves numerous funding and project partners. The first of the three phase project was the 2010 removal of the Lower Shannock Falls which included the installation of rock weirs and bank stabilization. In 2012, a Denil fishway and state-of-the-art eel pass was constructed at the Horseshoe Falls Dam and currently at the sixth obstruction, construction is underway for a rock ramp fishway at the Kenyon Mill Dam. The proposed fish passage restoration improvements at the first three fishways will complement the new fish passage restoration projects recently completed on the upper Pawcatuck River watershed.

The six fish passage projects described below will enhance diadromous fish passage to over 22 miles of the main stem Pawcatuck River, 48 miles of tributaries, and access to over 1,967 acres of ponds providing critical spawning and rearing habitats. The goal is to improve river connectivity for target fish species and provide passage between Little Narragansett Bay and the high-quality waters of upper Pawcatuck River. An increase in abundance of the target diadromous species, to be monitored and documented by RIDEM and partners over time, will ultimately serve as the metrics for performance of the proposed restoration projects. The long-term goal of the project is to restore self-sustaining populations of anadromous and catadromous fish species. The unimpeded access to riverine and lacustrine habitats is expected to potentially result in an annual shad run in the thousands and river herring runs in the hundreds of thousands in the watershed.

Threat: Barriers to Migration on the Pawcatuck River

Action 1: Fish Passage Efficiency Evaluation on the Lower Pawcatuck River
1) White Rock Dam

Description of Work: Each of the three lowermost dams on the Pawcatuck River has a bypass system (breached canal and fish ladders) to provide fish passage for diadromous fish species including river herring and American shad. However at each of these dams are known, but undocumented problems with the by-pass systems and this could be impacting fish passage efficiency. Currently, the State of Rhode Island Department of Environmental Management, Division of Fish and Wildlife has requested that the US Army Corps of Engineers (ACOE) provide planning assistance (Section 22 of the Water Resources Development Act of 1974) to determine the fish passage efficiency for species of diadromous fish at the three dam sites located on the lower Pawcatuck River. The study will produce a detailed report that identifies and documents the current conditions at each of the sites and determine the impact these current conditions may have on fish passage. Recommendations and preliminary plans for improving fish passage efficiency at each site will be included in the report. The study will evaluate the White Rock Dam by-pass channel, which currently allows for fish passage and the water flows at the existing dam which may attract anadromous fish towards a dead-end channel.

Agencies: RIDEM, US ACOE, CTDEEP, USFWS, WPWA, TNC and Griswold Textile

Goals/Target: Completion of a detailed fish passage efficiency study and recommendations for improvements at each site via dam removal, by-pass improvements, or construction of a new fishway. Improvements at the three lower most dams will enhance anadromous fish passage to over 22 miles of main stem Pawcatuck River habitat and over 1,900 acres of freshwater impoundments. The target goal for returning American shad on the Pawcatuck River is 5,000.

Timeline/Progress: Active, report completion date scheduled for July 1, 2014.

Costs: $100,000 for current feasibility study. Prior to final submission (October 2013), over two million dollars were awarded to USFWS for future restoration work at the first three obstructions on the lower Pawcatuck River from the US Department of Interior, Hurricane Sandy Relief Funds.

Concerns/Setbacks: Securing additional funding for recommended improvements if dam removal is selected.

Action 2: Fish Passage Efficiency Evaluation on the Lower Pawcatuck River 2) Potter Hill Dam

Description of Work: Feasibility study described above to determine the efficiency of the 1970's constructed Potter Hill Denil fishway with current dam and false attraction flow conditions.

Agencies: RIDEM, US ACOE, TNC and WPWA

Goals/Target: Same as above

Timeline/Progress: Start date 2014, pending funding availability following completion of the White Rock Dam assessment.

Costs: Not to exceed $100,000 for the three phase study. USFWS has received US DOI funds for future restoration improvements.

Concerns/Setbacks: Secure additional funds for the study and for recommended improvements if dam removal or a new fish passage alternative is selected.

Action 3: Fish Passage Efficiency Evaluation on the Lower Pawcatuck River 3) Bradford Dam

Description of Work: Feasibility study described above to determine efficiency of the 1970's Denil fishway with new modifications and current dam and false attraction flow conditions. Recent modifications were made to the Bradford fishway to enhance American shad passage. Modifications included an extended fishway entrance and a decrease in the slope at the lower fishway section.

Agencies: Feasibility study by RIDEM, ACOE, TNC and WPWA. Fishway modifications by numerous partners.

Goals/Target: Same as above

Timeline/Progress: Start date 2014, pending funding availability, fishway modifications completed 2008

Costs: Not to exceed $100,000 for three-phase study, $65,000 for fishway modifications to enhance shad passage. USFWS has received US DOI funds for future restoration improvements.

Concerns/Setbacks: Securing additional funding for recommended improvements if dam removal or new fish passage is selected.

Action 4: Upper Pawcatuck River Fish Passage Restoration Project 1) Lower Shannock Falls Dam

Description of Work: Over the past several years there has been a substantial effort to improve fish passage at dams located upstream of the three dams described above that are on the lower portion of the Pawcatuck River. This three phase upper Pawcatuck River fish passage restoration project was awarded a multi-million dollar American Recovery and Reinvestment Act grant due to its high level of restoration priority. The first of the three phase project was the removal of the Lower Shannock Falls which included the installation of rock weirs and bank stabilization.

Agencies: Wood Pawcatuck Watershed Association (WPWA)-lead, NOAA, RIDEM, CRMC, USFWS, and many others project partners and funding sources.

Goals/Target: Complete dam removal. Improvements at the three upper dams on the Pawcatuck River will provide anadromous fish passage to over 3.5 miles of main stem Pawcatuck River habitat and over 1,000 acres of freshwater impoundments. The target goal for returning American shad on the Pawcatuck River is 5,000.

Timeline/Progress: Complete, Fall 2010

Costs: Feasibility Study= $86,000 Dam Removal= $750,000

Concerns/Setbacks: Completion of Kenyon Mill rock ramp fishway.

Action 5: Upper Pawcatuck River Fish Passage Restoration Project 2) Horseshoe Falls Dam

Description of Work: Construction of a new Denil fishway, juvenile by-pass chute and self-regulating eel ramp.

Agencies: Wood Pawcatuck Watershed Association (WPWA)-lead, NOAA, RIDEM, CRMC, USFWS, and many others project partners and funding sources.

Goals/Target: Construction of new Denil fishway, juvenile by-pass channel and a self-regulating eel ramp. Improvements at the three upper dams on the Pawcatuck River will provide anadromous fish passage to over 3.5 miles of main stem Pawcatuck River habitat and over 1,000 acres of freshwater impoundments. The target goal for returning American shad on the Pawcatuck River is 5,000.

Timeline/Progress: Complete Fall 2012, RIDEM/Fish and Wildlife is currently operating and maintaining the Denil fishway and eel ramp.

Costs: Denil and juvenile by-pass chute=$1,580,000 Eel ramp=$100,000

Concerns/Setbacks: Completion of Kenyon Mill rock ramp fishway.

Action 6: Upper Pawcatuck River Fish Passage Restoration Project 3) Kenyon Mill Dam

Description of Work: Removal of existing dam and installation of a new rock ramp fishway. The rock ramp fishway will feature a series of pools, constructed of natural stones weirs to facilitate fish passage.

Agencies: Wood Pawcatuck Watershed Association (WPWA)-lead, NOAA, RIDEM, CRMC, USFWS, Kenyon Mill Industries and many others project partners and funding sources.

Goals/Target: Construction of a new rock ramp fishway. Improvements at the three upper dams on the Pawcatuck River will provide anadromous fish passage to over 3.5 miles of main stem Pawcatuck River habitat and over 1,000 acres of freshwater impoundments. The target goal for returning American shad on the Pawcatuck River is 5,000.

Timeline/Progress: Active, all permits received, construction started July 1, 2013. Completion date March 2014.

Costs: Rock ramp and engineering design costs estimated at $1,400,000.

Concerns/Setbacks: Construction delays preventing completion prior to 2014 spring fish migration.

Habitat Restoration Programs

Barrier removal:

In its *2002 Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island's Coastal Streams* (Erkan 2002), the Rhode Island Department of Environmental Management (RIDEM) recognized the potential for significant expansion of river herring and American shad habitat by restoring fish passage to the mainstem Pawcatuck River. The plan identifies the dam barriers in the Pawcatuck River watershed in Rhode Island, including the six dam sites which are addressed in this habitat plan, as barriers to anadromous fish species including shad and river herring. Currently the 2002 plan is scheduled to be updated in 2014. In addition, since 2002, RIDEM/Fish and Wildlife prepares an annual prioritize list of fish passage projects for river systems throughout the state. Since the inception, the Pawcatuck River fish passage projects have been a high priority (Edwards 2012).

Hatchery product supplementation program: Over the past several years, RIDEM has partnered with the USFWS North Attleboro Fish Hatchery with the American shad fry stocking program. Each spring adults are delivered to the hatchery where they are allowed to naturally tank spawn and the fry are released throughout the summer into the upper reaches of the Pawcatuck River.

Water quality improvement program: RIDEM/Office of Water Resources has a program in place to decrease nitrogen contributions into the Pawcatuck River and increase dissolved oxygen levels (Pawcatuck River TMDL).

Project permit/licensing review program: RIDEM has a review program in place for water withdrawals, toxic and thermal discharges, dredging, and land use development, in which permits are issued on a case by case basis (NPDES).

References

Edwards, P. A. 2012. Restoration and establishment of sea run fisheries. Rhode Island Division of Fish and Wildlife, Freshwater and Anadromous Fisheries Section. Annual performance reports to USFWS, Project F-26-R-47, Washington, D.C. Appendix A. Summary of New Initiatives for Anadromous Habitat Restoration.

Erkan, D.E. 2002. Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams. RI DEM, Division of Fish and Wildlife. Completion Report in Fulfillment of Federal Aid in Sportfish Restoration, F-55-R.

2013 RIDEM Total Maximum Daily Load (TMDL) Program Website:
http://www.dem.ri.gov/programs/benviron/water/quality/rest/index.htm

2013 RIDEM National Pollutant Discharge Elimination System (NPDES) Website:
http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/

Figure 1: Location of the Three Lower Pawcatuck River Passage Restoration Sites and Recently Completed Upper Pawcatuck River Passage Restoration Sites

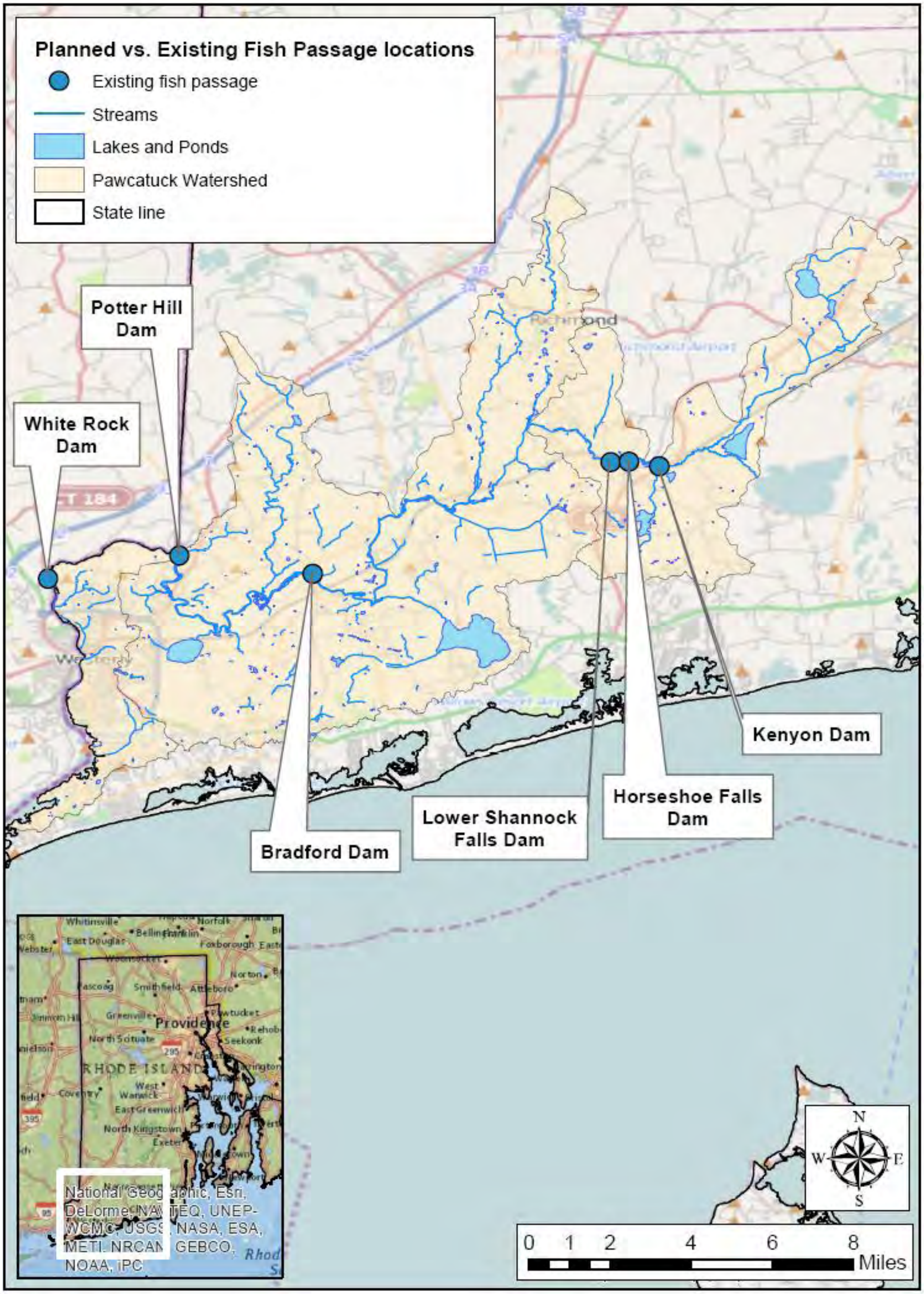


Figure 2: Photograph of the White Rock Dam, Dead End Channel at Low Flow Conditions

Figure 3: Photograph of the Potter Hill Dam and 1970's Constructed Denil Fishway with Fish Trap

Figure 4: Photograph of the Bradford Dam and 1970's Denil Fishway

Figure 5: Photograph of Dam Removal and Rock Weirs at Lower Shannock Falls

Figure 6: Photograph of the Horseshoe Falls Dam and Denil Fishway with Eel Ramp

Figure 7: Photograph of the Kenyon Mill Dam prior to construction of Rock Ramp Fishway

Figure 8: Construction of Rock Ramp Fishway at Kenyon Mill Dam

American Shad Habitat Plan

STATE OF CONNECTICUT

Connecticut Dept. Energy and Environmental Protection
Inland Fisheries Division
Marine Fisheries Division
Old Lyme, CT

August 2013

Introduction

The Atlantic States Marine Fisheries Commission (ASMFC) has a Fishery Management Plan for American shad and river herring and in February of 2010 adopted Amendment 3 to this plan. It requires all states so submit a Habitat Plan for American shad in their state. This document is that plan for Connecticut. It has three sections: (1) habitat assessment, (2) threats assessment, and (3) habitat restoration program. The report covers 16 rivers in Connecticut that are known to have supported American shad runs. It is possible that some additional smaller rivers may have supported small historic runs of American shad but for these rivers, historical documentation is lacking and present-day restoration opportunities are very limited. The list of the 16 rivers covered by this report is shown in Table 1.

Fisheries management in Connecticut is conducted by two divisions within the umbrella agency of the Department of Energy and Environmental Protection (CTDEEP). These are the Marine Fisheries Division and the Inland Fisheries Division. Both divisions have some responsibilities for managing anadromous fish populations. This document is a collaboration of the two divisions. For simplicity, the activities referred herein will be attributed to the CTDEEP, even though some are conducted by the Marine Fisheries Division, some by the Inland Fisheries Division, and some by non-fisheries-related divisions (e.g. divisions that regulate water quality).

Habitat Assessment

Objective: Assess the habitat (historic and currently available) and impediments to full utilization of the habitat.

Various sources of information including historical accounts, watershed management plans, maps, present-day fish survey data, and staff knowledge of the rivers and features (e.g. falls, dams, human infrastructure) were reviewed to identify downstream and upstream endpoints to historic and present-day shad runs and spawning and nursery habitat. The length of these stream reaches were measured using GIS. Habitat categories were assigned broadly without any effort to identify and quantify small river stretches (e.g. 300 m plots). Moreover, there can be considerable overlap with shad spawning and rearing habitat but such overlap was not considered. All river stretches were categorized as either spawning or rearing habitat.

It is relatively easy to determine the geographic extent of historical shad runs in Connecticut rivers due to our knowledge of natural waterfalls that would have blocked runs or abrupt changes in river gradient or habitat that would not have supported shad runs. However, it can be difficult to speculate what kind of habitat (i.e. spawning, rearing, or neither) existed in some river stretches that are now inundated by the headponds of dams. Most of these impounded river stretches are currently categorized as rearing habitat and for the sake of simplicity, these stretches were categorized as historic rearing habitat also. This might not be historically accurate. However, since most of the large dams are not likely to be removed, when shad runs are reconnected to their historic range, these impounded reaches will provide rearing habitat to the species and therefore the actual historic status of the habitat is irrelevant in a present-day context.

The results of these calculations are summarized in Table 2 for all 16 rivers. Historically, American shad had access to 642 km of riverine habitat in Connecticut. Currently, the species has access to 350 km. For spawning habitat, the historical habitat is estimated to have included 268 km while currently there are 125 km. For rearing habitat, the historical habitat is estimated to have included 311 km while currently there are 163 km.

Threats Assessment

Objective: Inventory and assess the critical threats to habitat quality, quantity, access, and utilization.

a. Barriers to migration- Dams and other structures are known to block shad migrations and limit the amount of accessible habitat. There are over 4,000 dams in Connecticut and there are dams built on all of the historic shad runs have dams. In order to restore shad runs, the fish must be able to get past these dams. It is the policy of the CTDEEP that dam removal is the most effective means to accomplish this. Shad are notoriously difficult to pass up fishways and when a dam is removed, the need for a fishway is avoided. Furthermore, dam removal restores historic habitat. Even with functional fishways, threats to shad remain. First, there are inevitable migratory delays associated with fishways: finding it, ascending it, resting after ascending it, and interruptions caused by debris in the fishway or flow rates above or below the prescribed range of flows for the fishway design. With rivers with multiple dams, delays can be additive, resulting in weeks of lost migratory time. Delays can limit the extent of upstream migration, resulting in reduction of spawning in key upstream habitat. Some fishways injure migrants that result in pre-spawning mortality. There are significant threats to shad during the downstream migration. Spent adults may not be able to find or use downstream passageways, resulting in death and reduction of the repeat spawning rate for the population. Fish that use the spillway may suffer injury going over the spillway and may die.

The CTDEEP has an extensive inventory of dams in Connecticut. The agency has worked with The Nature Conservancy and the Northeast Association of Fish and Wildlife Administrators on the Northeast Aquatic Connectivity Project to analyze these dams for their impact on connectivity to anadromous fish habitat. These databases are beyond the scope of this document and are not included herein but they were assessed to document their potential impact on shad runs. The results of that assessment is a list of dams that block shad runs and impact CTDEEP plans to restore shad runs found in Table 3.

It is recognized that things other than dams can create migratory barriers to shad and ASMFC has requested an inventory of all such barriers. Culverts are a concern for fragmenting habitat for anadromous fish. However, impassable culverts are more common in headwater streams and smaller rivers, upstream of the range of American shad, which tends to stay in larger rivers. There are no impassable culverts in Connecticut that block shad migrations, either currently or along migratory corridors expected to be reconnected in the coming years. Therefore, no inventory is provided. River stretches containing degraded water quality can also be barriers to shad migrations. Such degradation can include low dissolved oxygen, low flow rates, or plumes of toxic or heated effluent. Each shad river was reviewed for the presence of such water quality barriers and none of significance was found. Therefore, no inventory is provided.

b. Impingment/entrainment at dams- This threat is related to the previously listed threat: dams. In addition to creating delays to the downstream migration or the existence of an ecological trap from which fish cannot escape, downstream migrants may be drawn into industrial intakes or impinged upon and killed. The most common is the turbine intake for hydroelectric projects. Most turbines will kill most adult shad that pass through. Turbine mortality of young-of-year shad is highly variable but potentially significant. Other intakes include pumped storage projects, irrigation, cooling water systems, and drinking water intakes. If fish are drawn into these intakes, mortality can be significant.

c. Water withdrawals- In addition to potentially killing migrants by mechanically damaging the fish or drawing them into industrial filters and processes, water withdrawals can also impact the habitat by reducing the available stream flow in the river. Withdrawals from a large river like the Connecticut are typically minor with low impacts. Withdrawals from small to medium sized rivers (e.g. Quinnipiac River) can be substantial and may drastically reduce the available water during the summer rearing period. Water reduction can also result in the warming of the river water, as well.

d. Climate change- Climate change will result in changes to the ecosystems of Connecticut but severe impacts are not anticipated for the American shad populations. There are many existing shad runs south of Connecticut where water temperatures are warmer so there appears not to be an obvious threat from increasing temperature. However, the rate of post-spawning mortality and subsequently repeat spawning rate (iteroparity) is known to have a clinal trend and may be related to water temperature in the rivers. Therefore, as the water temperature in Connecticut rivers increase, a reduction in the rate of repeat spawning is a possibility. That could result in an altered population structure, reduction in total annual egg deposition, and subsequent decline in run size.

e. Threats not highlighted- There are many other threats that are on a list from ASMFC as potential threats to American shad. We will briefly review some of these and explain why they are not included in the list above.

Toxic and thermal discharges- None of the stream sections identified as critical shad habitat suffer from toxic discharges. Such discharges are carefully regulated by the CTDEEP. Both the Connecticut and Quinebaug rivers receive thermal discharges but past research on the Connecticut has shown these to have no impact on the shad run and previous assessments of the discharges in the Quinebaug River have concluded that they will also not impact shad.

Channelization- Channelization, stream straightening, burying sections of streams, and other projects that alter the morphology of streams are rarely proposed in Connecticut anymore and such activities are strictly regulated. The Inland Fisheries Division has ample opportunity to comment on permit applications and would recommend denial of any permits that would impact American shad habitat.

Competition and predation by invasive and managed species- There are many non-native fish species in Connecticut, including non-native predators in the Connecticut River where there is a strong sustained shad run. While these species may cause some diminishment in numbers of shad, it does not appear to be significant in light of the other listed threats and the opportunity to extirpate these non-native species is extremely limited.

Habitat Restoration Program

Objective: For threats deemed to be of critical importance to the restoration of American shad, each state should develop a program of actions to improve, enhance, and /or restore habitat quality and quantity, habitat access, habitat utilization and migration pathways.

Narrative: The CTDEEP is aggressively pursuing the restoration of shad runs in a number of Connecticut streams. The Connecticut River is the best known shad river in the state and hosts one of the largest and most stable American shad runs on the East Coast. It supports both recreational and commercial fisheries for shad. The CTDEEP has submitted and the ASMFC has accepted a Sustainability Plan for this population. There are no barrier dams on the Connecticut River in Connecticut, the water quality is quite good, and the harvest is sustainable. The opportunity to expand this population exists in upstream states with improvements to upstream and downstream fish passage at three mainstem dams and some tributary dams. CTDEEP is engaged in this effort through its participation on the Connecticut River Atlantic Salmon Commission, a multi-state/federal partnership that manages restoration and enhancement of diadromous species in the Connecticut River basin. The CTDEEP is also actively working to restore shad runs to three Connecticut River tributaries within Connecticut: the Farmington, Mattabessett, and Scantic rivers. These rivers are reported in this document separate from the Connecticut River.

In addition to the Connecticut River, the CTDEEP seeks to restore and enhance runs of American shad in a number of other rivers that flow into Long Island Sound. Each of these rivers is reported in this document. The CTDEEP has not submitted a sustainability plan for any of these other rivers and has initiated a process to close all harvest of shad in all of these other rivers until which time the population has grown to the level where a sustainability plan can be developed. In all cases, the impediment to full utilization of historic habitat is the presence of barrier dams. Improvements to water quality in Connecticut streams have progressed in the past 30 years to the point where it is not an impediment to restoring American shad runs. It is accurate to state that some streams could benefit from further improvement of water quality and such improvements could increase survival of young-of-year shad. However, our assessment concludes that such reduced water quality is not a significant obstacle to shad in re-colonizing historic habitat. Connecticut is a heavily dammed state with over 4,000 dams within its borders—the exact number is unknown. These dams were the major factor of the demise of all diadromous fish runs in the state and remain the most significant challenge in restoring these runs. Some runs of American shad have been totally eliminated or reduced to a very few fish so that some re-introduction of the species is necessary. The text that follows describes the main features of the agency's plan to protect and reconnect habitat for shad in Connecticut. The geographic scope of Connecticut's American shad restoration efforts is summarized in Table 4, which lists the rivers, the targeted habitat and quantifies projected spawning and nursery habitat by river. Currently, shad have access to 360 miles of habitat. The CTDEEP plan for restoration seeks to reconnect habitat and increase that to 610 miles of habitat. The amount of historic habitat is estimated to have been 640 miles.

a. Barrier removal and fish passage program- Migratory barriers are the most important threat to American shad runs in Connecticut. The CTDEEP has an aggressive fish passage program that seeks to either remove a dam or build a fishway around it. The first choice is always to remove the dam. American shad are notorious for not using fishways very well, particularly at dam higher than 25 feet. The removal of a dam precludes the need for a fishway. It also eliminates problems with downstream passage. Furthermore, it restores native habitat (perhaps historic spawning habitat long since inundated) and reduces impoundments that often favor non-native predators. However, many dams cannot be removed for a variety of reasons, most notably because they are still valued (e.g. hydroelectric projects). For these dams, the CTDEEP seeks the provision of fishways, either through a voluntary process or through regulatory processes. The CTDEEP is acutely engaged in all licensing and re-licensing procedures for hydroelectric projects in Connecticut by the Federal Energy Regulatory Commission (FERC). The CTDEEP works very closely with the U.S. Fish & Wildlife Service in these procedures. In addition, the State of Connecticut has well-used statues that authorize the CTDEEP to require a fishway at dams not regulated by FERC. However, most fish passage projects in Connecticut are not pursued through any regulatory process but instead follow a voluntary process. The CTDEEP works with many municipalities and non-governmental organizations (NGOs) like watershed groups, land trusts, fishing clubs, and larger conservation organizations in a coordinated regional approach in which the NGO sponsors the project, crafts all the necessary agreements, applies for grants to pay for design and construction, and oversees the construction while the CTDEEP provides continuous technical oversight. In a typical year, two or three fish passage projects are implemented in Connecticut and many of them benefit American shad.

b. Impingment/entrainment at dams- This problem is also addressed through the regulatory process. The most common source of this threat comes from hydroelectric projects and lack of suitable downstream passage. The CTDEEP works with the U.S. Fish & Wildlife Service and FERC, and licensees to ensure the best state-of-the-art downstream fishway facilities are installed at hydroelectric dams. Intakes for other industrial uses are assessed during the permitting process and the CTDEEP dictates the design and operation of these intakes to minimize impact on American shad.

c. Water withdrawals- All water withdrawals from Connecticut streams of significant size must be permitted by the CTDEEP. The two fisheries divisions routinely comment on permit applications and judge such applications on their potential impact on diadromous fish runs, including American shad. Connecticut has just passed new streamflow regulations that will tighten the regulation of water withdrawals. In some cases, an assessment of the proposed withdrawal is conducted. An old canal system off the Connecticut River was recently converted to a co-generation plant and there were concerns that some young-of-year shad were being both drawn into the cooling system and trapped in the terminal end of the canal. An analysis showed that the numbers of lost young-of-the-year shad equated to less than 10 adult shad back to the river in subsequent years. In a run that numbers between 300,000 and 1,000,000, this level of loss was deemed to be too insignificant to require engineering solutions. Similar analyses are performed for other withdrawals and if the losses are potentially harmful to the run, engineering or operational solutions are required. In the Quinnipiac River, existing water withdrawals have begun to impact the minimum flow levels during the summer rearing period. The CTDEEP has taken steps to eliminate some withdrawals and limit future withdrawals to protect fish habitat.

d. Climate change- Climate change is a larger problem than can be effectively addressed by fisheries management agencies. However, the CTDEEP was recently transformed into an energy agency (Department of Environmental Protection to the Department of Energy and Environmental Protection) and part of its mission it to guide the state into a more environmentally-responsive approach to generating and using energy. However, the main impact of climate change to American shad runs has been identified as increased water temperature possibly reducing the rate of repeat spawning in the state, impacting the stock's population structure and resiliency. Although this impact cannot be entirely avoided if the streams in the state experience temperature increases, the actions taken under items (a), (b) and (c) will mitigate to some extent this impact. By increasing survival at dams and reducing migratory delays, we will counteract the trend being imposed by climate change.

e. Adult Shad Transplantation program- Some runs have been extirpated but fish passage projects have now or will soon re-connect critical shad habitat to Long Island Sound. This represents an opportunity to restore a shad run. Once 'opened', a stream may receive stray shad from the Connecticut River, which will then slowly re-colonize the river. However, the pace of such a re-colonization may proceed at a socially-unacceptably slow rate. To accelerate the pace of restoration, the stream must be 're-seeded'. This has been done via hatchery rearing and stocking in other states. The CTDEEP does not endorse this approach for its streams. Hatcheries are expensive to operate and may introduce undesirable genetic and phenotypic traits. Due to the strong run size of shad to the Connecticut River and the presence of modern, efficient trapping facilities at the first dam at Holyoke, MA, the CTDEEP has implemented an active transplantation program in which pre-spawned adults from the Connecticut River are collected at the Holyoke Dam Fishlift, placed in a specially-designed transport tank truck, and driven to the restoration rivers where they are released into suitable habitat, typically upstream of dams that either have a fishway or is expected to have a fishway in the near future. Assessments of this technique have always shown that young-of-year American shad are found in the receiving habitat, attesting to the efficacy of the method. Based upon the genetic data available as well as the fact that some of these streams are currently devoid of any remnant native run of shad, it is believed that such a program does not have negative impacts on native shad stocks. The Connecticut River provides most of the donor fish but the Shetucket River run has grown to a sufficient size and there are suitable trapping facilities at the first dam on that river (Greeneville Dam) so that currently all shad that are transplanted into the Shetucket-Quinebaug river basin originate from the Shetucket River. The amount of fish transplanted into each river varies from year-to-year but typically ranges between 80 and 200 adult shad per river. The CTDEEP conducts all of these transplantation activities except for some transplantation in the Shetucket River that is conducted by the City of Norwich, Department of Public Utilities, which operates two hydroelectric projects with fishways. They transplant some shad using their own truck under the guidance of the CTDEEP. A list of rivers with active transplantation programs is shown in Table 5.

f. Habitat Improvement program- The Inland Fisheries Division includes a Habitat Conservation and Enhancement program that seeks to protect and restore fish habitat statewide. This includes staff assigned to review permit applications for marine activities, such as dredging, dock construction, etc. This program has close ties to the Diadromous Fish Program and routinely reviews permit applications with the impacts to American shad in mind. Not only are conditions placed in permits to avoid or reduce any impacts to American shad habitat and runs but sometimes habitat can be improved beyond its current condition due to mitigation agreements. Staff also proactively works on restoration projects to improve habitat for American shad, often with municipalities and NGOs. Once example is the Moosup River Project in which six migratory barriers to American shad will be addressed in this former shad river. This project is funded through a mitigation fund provided by an upstream power plant and is supported by a partnership between the CTDEEP, three federal agencies, a municipality and an NGO.

Table 1. List of rivers in Connecticut known to have supported historical runs of American shad.

	Name of stream*	Name of present-day Connecticut town(s) at mouth of river
1	Housatonic River	Stratford & Milford
2	Naugatuck River	Derby
3	Pomperaug River	Southbury
4	Shepaug River	Southbury and Bridgewater
5	Quinnipiac River	New Haven
6	Hammonassett River	Madison & Clinton
7	Connecticut River	Old Saybrook & Old Lyme
8	Mattabesset River	Middletown & Cromwell
9	Farmington River	Windsor
10	Pequabuck River	Farmington
11	Scantic River	East Windsor
12	Shetucket River	Norwich
13	Willimantic River	Windham
14	Natchaug River	Windham
15	Quinebaug River	Preston
16	Moosup River	Plainville

*left justified streams flow into Long Island Sound; indented streams are tributaries of the left justified stream listed above

Table 2. Assessment of historic and current habitat for American shad in Connecticut.

	Historic			Present day			total kilometers of habitat by type					
							spawning		rearing- estuarine**		rearing- in-river	
River*	upstream end point	Town	Total km	Upstream end point	Town	Total km	historic^	current	historic	current	historic^	current
Housatonic	Great Falls	New Milford	46.9	Derby Dam	Shelton	21.1	21.7	1.4	19.4	19.4	21.6	0.9
Naugatuck	jct of E & W branches	Torrington	63.7	Tingue Dam	Seymour	9.7	24.3	3.5	0	0	19.6	6.2
Pomperaug	confluence w/Nonewaug R.	Woodbury	26.3	no run to mouth	n.a.	0	9.2	0	0	0	17	0
Shepaug	Roxbury Falls	Roxbury	6.4	no run to mouth	n.a.	0	1	0	0	0	5.4	0
Quinnipiac	Interstate 84	Southington	47.8	Carpenters Dam	Cheshire	37	14.2	8.8	10.9	10.9	22.7	17.3
Hammonassett	CT Route 80	Madison	18.1	Old Papermill Dam	Madison	12.8	5.6	1.6	6.5	6.5	6	4.7
Connecticut	MA state line	Enfield	108	MA state line	Enfield	108	32.3	32.3	24.3	24.3	51.4	51.4
Mattabesset	CT Route 71	Berlin	36.3	Kensington Dam	Berlin	36.3	15.65	15.65	0	0	20.65	20.65
Farmington	MA state line	Colebrook	94.1	Lower Collinsville Dam	Avon	60.3	59.7	29.8	0	0	33.4	29
Pequabuck	Dutton Ave. Bridge	Bristol	15.9	Middle Street Dam	Bristol	12.4	4.9	3.1	0	0	11	9.3
Scantic	MA state line	Somers	34.8	Springborn Dam	Enfield	22.4	14.75	11.2	0	0	21.95	11.2
Shetucket	Willi-Natchaug conf.	Windham	28	Scotland Dam	Windham	17.9	12.9	8.2	24.1	24.1	15.6	10.2
Willimantic	source	Stafffford Springs	37.7	no run to mouth	n.a.	0	20.8	0	0	0	18.1	0
Natchaug	falls at Mansfield Hollow	Mansfield	5.8	no run to mouth	n.a.	0	2.5	0	0	0	3.3	0
Quinebaug	Cargill Falls	Putnam	57.5	Aspinook Dam	Griswold	11.9	21.2	9.8	0	9	36.3	2.1
Moosup	confluence w/Quanduck Bk	Sterling	14.5	no run to mouth	n.a.	0	7	0	0	0	7.5	0
totals			641.8			349.8	267.7	125.35	85.2	94.2	311.5	162.95

*left justified streams flow into Long Island Sound; indented streams are tributaries of the left justified stream listed above

**estuarine habitat is only listed for the river in which it is located even though runs in upstream tributaries (e.g. the Naugatuck) may benefit from such habitat. However, estuarine habitat within the Thames River (all estuary) are included under the Shetucket River, its main freshwater tributary.

^ "historic" habitat refers to existing habitat within the historic range. For example, historically a 5 mile stretch may have included free-flowing habitat that might have included spawning habitat but now that habitat is inundated by a dam which is unlikely to be removed and that habitat is now classified as rearing. When shad are reconnected to this habitat in the future, it will be in the historic range but will now be considered rearing habitat not spawning habitat. In any case, it is hard to categorize what kind of habitat existed historically under a dam's present-day impoundment.

Table 3. An inventory of key dams that block existing or planned runs of American shad in Connecticut.

River	dam*	purpose	current fish passage	plan for future fish passage	comments
Housatonic	Derby	hydroelectric	none	fishway	under design, currently
	Stevenson	hydroelectric	none	fishlift	FERC required timetable
	Shepaug	hydroelectric	none	fishlift	FERC required timetable
Naugatuck	Kinneytown	hydroelectric	Denil	continued monitoring	passes shad currently
	Tingue	none	none	fish bypass channel	under construction, currently
	Plume-Atwood	none	none	removal	near top of targeted watershed
Pomperaug	Trap Factory	none	none	removal	owner considering hydro
Quinnipiac	Wallace	industrial water	Denil	continued monitoring	passes shad currently
	Hanover Pond	town park	Denil	continued monitoring	may pass shad currently
	Carpenters	none	none	removal	project under development
	Clark Brothers	none	none	removal	project under development
Hammonassett	Old Papermill	none	partial barrier?	removal	dam is breached
Connecticut	Enfield	none	full passage w/o fishway	none	dam was naturally breached
Mattabesset	StanChem	fire protection	Denil	continued monitoring	passes shad currently
Farmington	Rainbow	hydroelectric	vertical slot	fish lift	fishway performs poorly; fishlift under design
	Spoonville	none	full passage w/o fishway	none	dam removed in 2012
	Winchell-Smith	none	partial barrier?	removal or fishway	project under development
	Lower Collinsville	future hydro	none	Denil	part of FERC licensing
	Upper Collinsville	future hydro	none	Denil	part of FERC licensing
Pequabuck	Middle Street	none	none	removal	awaiting full funding, aka Bristol Brass
Scantic	Springborn	none	none	removal	under design
	Somersville	none	none	Denil	after Springborn is removed; state-owned

Table 3
(continued)

Shetucket	Greeneville	hydroelectric	fishlift	continued monitoring	passes shad currently
	Taftville	hydroelectric	Denil	continued monitoring	passes shad currently
	Occum	hydroelectric	Denil	continued monitoring	passes shad currently
	Scotland	hydroelectric	none	fish lift	undergoing relicensing
Willimantic	4 willimantic dams	hydroelectric	none	none	will consider restoring if other parties remove dams
Natchaug	Willimantic Water Works	water supply	none	none	restoration plans end at base of dam
Quinebaug	Tunnel	hydroelectric	fishlift	continued monitoring	passes shad currently
	Aspinook	hydroelectric	none	Denil	will press during future relicensing
	Rajak	hydroelectric	none	uncertain	will press during future relicensing
	Rogers	uncertain	none	uncertain	will investigate after Rajak
Moosup	Lower Kaman	none	none	removal	project underway
	Upper Kaman	none	none	removal	project underway
	Griswold Rubber	comic relief	none	removal	project underway
	Brunswick #1	none	none	removal	project underway
	Brunswick #2	none	none	Denil	future hydro development?

Table 4. Summary of plans to restore and enhance runs of American shad in Connecticut with quantification of habitat types.

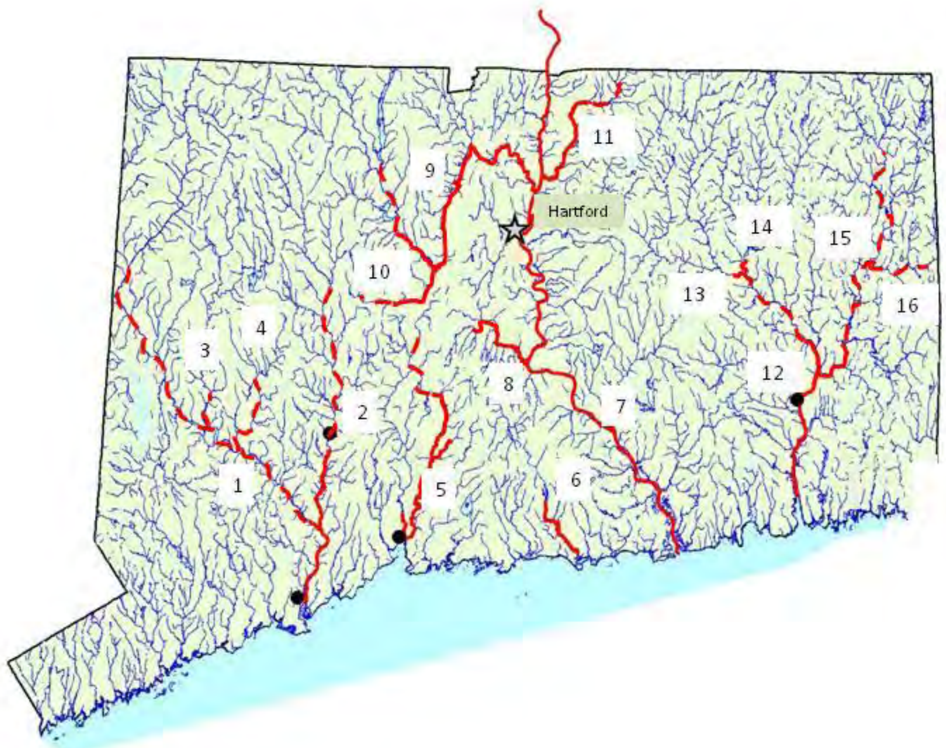
	Existing			Targeted for Restoration			total kilometers of habitat by type: spawning		rearing- in-river	
River*	Upstream end point	Town	Total km	upstream end point	Town	Total km	current	targeted	current	targeted
Housatonic	Derby Dam	Shelton	21.1	Bulls Bridge Dam	New Milford	68.5	1.4	33.4	0.9	25.1
Naugatuck	Tingue Dam	Seymour	9.7	Thomaston F.C.D.	Thomaston	49.1	3.5	24.3	6.2	19.6
Pomperaug	no run to mouth	n.a.	0	mouth of Nonewaug	Woodbury	26.3	0	9.2	0	17
Shepaug	no run to mouth	n.a.	0	Roxbury Falls	Roxbury	6.4	0	5.4	0	6.15
Quinnipiac	Carpenters Dam	Cheshire	37	Plantsville	Southington	47.8	8.8	14.2	17.3	22.7
Hammonassett	Old Papermill Dam	Madison	12.8	CT Rt. 80	N. Madison	18.1	1.6	5.6	1.7	6
Connecticut	state line	Enfield	108	state line	Enfield	108	32.3	32.3	51.4	51.4
Mattabesset	Kensington Dam	Berlin	36.3	Kensington Dam	Berlin	36.3	15.65	15.65	20.65	20.65
Farmington	Lower Collinsville Dam	Avon	60.3	Colebrook Dam	Hartland	94.1	29.8	59.7	29	33.4
Pequabuck	Middle Street Dam	Bristol	12.4	Dutton St.	Bristol	15.9	3.1	4.9	9.3	11
Scantic	Springborn Dam	Enfield	22.4	MA state line	Somers	34.8	11.2	14.75	11.2	21.95
Shetucket	Scotland Dam	Windham	28	Willi-Natchaug conf.	Windham	28	8.2	12.9	10.2	15.6
Willimantic	no run to mouth	n.a.	0	first dam	Windham	1.2	0	1.2	0	0
Natchaug	no run to mouth	n.a.	0	Willimantic Reservoir	Windham	3.4	0	1.5	0	1.9
Quinebaug	Aspinook Dam	Griswold	11.9	Cargill Falls	Putnam	57.5	9.8	21.2	2.1	36.3
Moosup	no run to mouth	n.a.	0	confluence w/Quanduck Bk	Sterling	14.5	0	7	0	7.5
totals			359.9			609.9	125.35	263.2	160	296.25

*left justified streams flow into Long Island Sound; indented streams are tributaries of the left justified stream listed above

Table 5. Connecticut rivers that receive transplanted American shad as part of the restoration effort.

River	Source of fish	Comments
Naugatuck	Connecticut River	Released above two dams
Quinnipiac	Connecticut River	Released above two dams
Mattabessett	Connecticut River	To begin in 2014
Farmington	Connecticut River	Released above Rainbow Dam
Scantic	Connecticut River	Not yet implemented
Shetucket	Shetucket River	Fish from Greeneville Dam
Quinebaug	Shetucket River	Fish from Greeneville Dam
Moosup	Shetucket River	Not yet implemented

Figure 1. Map of existing runs of American shad, Connecticut. Numbers correspond to the numbers next to river names in Table 1. Solid red lines represent the extent of existing runs (including those extended by fishways) and dashed lines represent river stretches targeted for future restoration.



American Shad Habitat Plan for the Connecticut River

Connecticut Division of Marine Fisheries
Massachusetts Division of Marine Fisheries
Massachusetts Division of Fisheries and Wildlife
New Hampshire Fish and Game Department
U. S. Fish and Wildlife Service

Introduction

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the American Shad and River Herring Fishery Management Plan (FMP) requires all states to submit a Habitat Plan for shad stocks in their jurisdiction. This document is that plan for the Connecticut River basin for the states of Massachusetts and New Hampshire with input from Vermont and Connecticut. The ASMFC requested a collaborative effort on larger, multi-jurisdictional river plans and this approach among basin members was adopted for this document with input provided by the State of Connecticut, which chose to submit its own plan that addresses their portion of this river basin independently. The Connecticut River's American shad population is under active restoration through the multi-agency Connecticut River Atlantic Salmon Commission (CRASC), signed into federal law in1983 with complimentary State legislation (Gephard and McMenemy 2004). The CRASC has served as the lead in obtaining both upstream and downstream passage measures at main stem dams and in coordinating state and federal agencies, commercial river users, and other partners on management topics for this species. The CRASC Technical Committee, under the policy guidance of the Commission, maintains a Shad Studies, Fish Passage, and newly designated Habitat subcommittees that actively work on topics including shad habitat and access to habitat.

Habitat Assessment

The historic upstream extent of the species range on the main stem is Bellow Falls, Vermont, at rkm 280, with three main stem dams located within this range (Table 1 and Figure 1). Surveys for shad eggs and larvae and spawning behavior have been conducted in the main stem within the state of Connecticut (Marcy 1976) and from Holyoke Dam (rkm 139) to the Turners Falls Dam (rkm 198), Massachusetts. Marcy (1976) identified American shad spawning in the lower main stem river at river kilometer (rkm) 26 to his most upstream study site at rkm 87, Enfield, Connecticut, with major spawning areas identified as Windsor Locks (rkm 78), Wilson (rkm 74) and Rocky Hill (rkm 51). Research by the University of Massachusetts has shown a relatively wide range of documented spawning primarily from egg and fish behavior surveys between the Holyoke Dam, Massachusetts (rkm 139) and the Turners Falls Dam, Massachusetts (rkm 198)(Watson 1970; Gilmore 1975; Layzer 1974; Kuzmeskus 1977). Shad spawning habitat, as described in Greene et al. (2009), is located to varying degrees upstream of dam impoundments on both the main stem and identified tributaries and are subject to shifting with changing river discharge. The University of Massachusetts conducted studies in the late 1960s and 1970s that showed shad spawning starting at rkm 140, just upstream of Holyoke Dam, to rkm 192, at 22 sampled sites (Kuzmeskus 1977). Most of the preferred habitat in this main stem reach begins upstream of the Holyoke Dam's impoundment, beginning approximately at rkm 180 and extending upstream to the Turners Falls Dam (rkm 198). Based on available information, a summary on main stem habitat types is provided in Table 2. In the absence of habitat specific data, assessment assignments of fixed percentage of potential suitable habitat by type were used based upon known habitat features and the extent of impoundments. It is important to note that there is no understanding of the variation in habitat quality, in addition to quantity, among the identified management reaches which effects the interpretation of these habitat designations.

Table 1. Main stem dams on the Connecticut River from rkm 0 upriver to the historic upstream extent of American shad range, Bellow Falls, Vermont, at rkm 280.

River kilometer	Barrier	Designated extent of impoundment/habitat break (rkm)[A]	Purpose	Status
110	Enfield Dam (historic site), Enfield CT	0	Barge canal use	no longer present
139	Holyoke Dam, Holyoke, MA	177	Hydroelectric power	Active, with fishways
198	Turners Falls Dam, Montague, MA	223	Hydroelectric power	Active, with fishways
228	Vernon Dam, Vernon, VT	273	Hydroelectric power	Active, with fishways
280	Bellows Falls Dam, Bellows Falls, VT		Hydroelectric power	Active with fishways

[A] reported impoundment distance may vary slightly, designations attempt to take into account transition in habitat features in these dynamic area

There have been no studies on main stem spawning habitat upstream of the Turners Falls Dam. However, annual monitoring of juvenile shad has occurred upstream of Vernon Dam, in the lower impoundment and immediately below Vernon Dam (several km) by the owners of Vermont Yankee Nuclear Power Station for over 15 years. In addition several special studies on juvenile shad have been conducted by the owners of the Northfield Mountain Pumped Storage Facility (NMPS), focused on entrainment and near field studies, and the University of Massachusetts/Conte Anadromous Fish Research Center, focused on age structure, size, and movement. As part of the Federal Energy Regulatory Commission's (FERC) ongoing relicensing process of the Turners Falls Dam, Northfield Mountain Pumped Storage Facility (NMPS), Vernon Dam, and Bellows Falls Dam, study requests by both state and federal resource agencies have been submitted for FERC's review to determine shad spawning locations and habitat use relative to these hydro-electric projects and their operations, which are expected to be conducted beginning in 2015.

Table 2. Connecticut River main stem river distance by state, to Bellows Falls, Vermont (rkm 280) and American shad habitat types by distance.

State	Main stem distance (rkm)	River kilometers of main stem habitat type			
		Spawning		Rearing	
		Historic	Current	Historic	Current
Connecticut	113.9	34.2	34.2	79.7[A]	79.7[A]
Massachusetts	105.5	n. a.	39.2[B]	n. a.	66.3[B]
New Hampshire[C]	60.6	n. a.	16.9[B]	n. a.	43.7[B]
Total	280.0		90.3		189.7

[A] Includes estuarine habitat

[B] Designated unimpounded habitat was assigned as 60% spawning habitat and designated impounded areas was assigned as 20% spawning habitat with balances designated as rearing; refer to Table 1 for designation point of dam impoundment break

[C] State of New Hampshire boundary extends to historic (un-impounded) western shoreline of State of Vermont

Historic and, in some cases, current American shad distribution include three tributaries in the State of Connecticut, five in the State of Massachusetts, one in the State of New Hampshire, and one in the State of Vermont (Table 3). Habitat information is based on the best information available which often is based on a limited qualitative assessment. It is important to note that it is difficult to categorize what type of habitats may have existed under current dam impoundments and no effort has been made on that topic.

Table 3. Tributaries of the Connecticut River identified as having historic and or currently accessible American shad habitat.

Distance from main stem river mouth (rkm)	Tributary name and location	Historic total habitat (rkm)	River kilometers of habitat type Spawning Historic	Spawning Current	Rearing Historic	Rearing Current
52	Mattabesset River, Middletown, CT	36.3	15.7	15.7	20.7	20.7
92	Farmington River, Windsor, CT	60.3	59.7	29.8	33.4	29.0
	Pequabuck River, Bristol, CT – tributary to Farmington River	12.4	4.9	3.1	11.0	9.3
96	Scantic River, South Windsor, CT	22.4	14.8	11.2	22.0	11.2
121	Westfield River, West Springfield, MA	29.4	29.4	29.4	29.4	29.4
130	Chicopee River, Chicopee, MA	unknown	n. a.	1.6	n. a.	1.6
150	Manhan River, Easthampton, MA	unknown	n. a.	n. a.	n. a.	n. a.
192	Deerfield River, Deerfield, MA	21.5	21.5	21.5	21.5	21.5
203	Millers River, Erving, MA	unknown	n. a.	n. a.	n. a.	n. a.
225	Ashuelot River, Hinsdale, NH	60.0	n. a.	n. a.	n. a.	n. a.
240	West River, VT	31.0	n. a.	n. a.	n. a.	2.0

Habitat accessibility

Adult shad have access to main stem habitat to the historic extent of their range up to Bellow Falls Dam (VT) through the use of a fish lift system at the Holyoke Dam (MA), the fish ladders at Turners Falls Dam (MA), and the Vernon Dam fish ladder (VT). However, fish passage efficiency remains a major concern and has been demonstrated to vary widely among these main stem facilities, with the Turners Falls fishway complex determined to be problematic for upstream shad passage (Appendix 1). The U. S. Geological Survey's Conte Anadromous Fish Research Center (USGS Conte), in cooperation with the dam owner, has conducted numerous studies to understand the issues and implement modifications for passage improvements in advance of the current relicensing process, with limited success. The Connecticut River Atlantic Salmon Commission's (CRASC) Management Plan for Connecticut River American Shad (1992) identifies a management objective of 40-60% passage, based on a five year running average, at each successive upstream barrier on the main stem. Shad passage upstream of Turners Falls Dam has averaged 3.8% annually, since its fishways became operational in 1980 through 2013, based on counts of shad passed upstream of Holyoke Dam, thus restricting access to upstream habitat (Appendix 1). Alternatively, the Vernon Dam fish ladder, following the recent identification and repairs of ladder issues, has achieved passage rates of 39% and 53% for 2012 and 2013 respectively, from the number of shad passed upstream of Turners Falls Dam (Appendix 1).

Access to tributary habitat is often limited due to the presence of dam(s) that often are located a short distance from the confluence with the main stem river (Table 4).

Table 4. Identified American shad tributaries of the Connecticut River basin with first and second dam locations and status of passage.

Tributary	Distance to first upstream dam (rkm)	First Dam	Passage provided by	Second Dam (rkm)	Status
Mattabesset River	11	StanChem	Denil Ladder	Kensington (36)	unladdered, but beyond historic range
Farmington River	13	Rainbow	Vertical slot	Lower Collinsville (60)	None, pending FERC action
Pequabuck - tributary of Farmington River	12	Bristol Brass	None, planned for removal	Polkville Brook (17)	Beyond historic range
Scantic	32	Springborn	Planned removal	Somersville (37)	unladdered
Westfield River	7	West Springfield	Denil Ladder	Woronoco (30)	None, not planned
Chicopee River	2	Dwight	None, not planned	Chicopee (5)	None, not planned
Manhan River	5	Manhan	Ladder to be completed 2013	Unnamed (18)	None, not planned
Deerfield River	21	TransCanada Dam #2	None, not planned		
Millers River	14	Erving Paper	Partial breach	New Home (22)	unladdered
Ashuelot River	3	Fiske Mill	Fish lift	Ashuelot Paper (5)	unladdered
West River	31	Townshend	None, not planned		

Distances of unobstructed access to the first barrier and type of available passage are noted with status of the next barrier, in Table 4. However, as is the case on the main stem, fish passage efficiency is poorly documented on tributary dam fishways. The first dam on the Farmington River has the Rainbow Fishway, in operation since 1976, which is known to not effectively pass shad upstream. This State-owned facility is planned for replacement with a fish lift. The Westfield River (MA) is the next major tributary with substantial access provided by a Denil fishway at the West Springfield Dam. This fishway has not been evaluated, but shad passage efficiency is believed to be fairly good as shad passage counts have increased to over 10,000 adults in 2012. Other substantial, but not studied tributaries that may provide shad spawning and nursery habitat include the lower Deerfield River (MA) up to its first dam, a distance of 21 rkm and the Millers River (MA), which like the Deerfield quickly transitions into higher gradient reaches and larger substrate types, but also includes more reaches of run habitat between riffles than the Deerfield River.

Figure 1. The current range of American shad in the Connecticut River basin (figure courtesy of The Nature Conservancy).

Threat Assessment

Threat: Barriers to Migration

Recommended Action: Continue the implementation of the CRASC's Management Plan for Connecticut River Shad (1992) which includes the following two management objectives: 1) achieve annual passage of 40 to 60%, based on a five year running average, at each successive upstream barrier on the main stem; and 2) maximize outmigrant survival for juvenile and spent adult shad.

Tributary fishways should be evaluated for upstream passage performance and enumeration of passed fish should occur annually. Downstream passage performance should be evaluated at both main stem and tributary fishways for both adults and juveniles. Recent research suggests delays in both upstream and downstream passage of adult shad are occurring and should be more closely examined and as issues are noted, measures should be implemented and/or developed to reduce delay or otherwise reduce other project impacts. FERC relicensing shad studies are to occur in 2015 and 2016 for Turners Falls Dam, NMPS, and Vernon Dam. Information obtained on movement, behavior, delay and survival in relation to dams, power plant facilities and fishways should be utilized in development of operational and structural (fishway prescriptions) recommendations by the agencies with respective legislative authorities. Completion of the analyses from the 2011 and 2012 shad migration and survival study from river mouth to Vernon Dam by USGS Conte and USFWS, must occur and should also be utilized in this process. The State and Federal agencies should coordinate in the review and development of recommendations to provide safe, effective and timely fish passage measures.

The timing, relative magnitude, and duration of the juvenile shad outmigration, and possible negative effects from barriers and or the associated power station operations and or structures of those facilities, should be understood and be the focus of further study. As part of the FERC relicensing studies scheduled for 2015 and 2016, information to assess potential project effects will be examined at Turners Falls Dam, NMPS, and Vernon Dam. Information obtained by these studies on movement, behavior, delay and survival in relation to dams, power plant facilities, and fishways should be utilized in development of operational and structural (fishway prescriptions) recommendations by the agencies. The State and Federal agencies should coordinate in the review and development of these recommendations.

Adult upstream passage main stem -
As described earlier, American shad have access in the main stem Connecticut River to the historic upstream extent of their range, Bellows Falls, Vermont, through the use of fishways of varied design and operation and efficiencies (Table 1, Figure 1, Appendix 1). Upstream passage for shad includes a fish lift system at Holyoke Dam, upgraded in 2005, as part of that dam's FERC relicensing process. Based on both historic and recent unpublished studies on shad movement, the Holyoke Dam may pass between 40 to 60% of the adult shad that enter the river mouth in the spring. A large scale shad movement and survival study using radio telemetry conducted in both 2011 and 2012 by the USGS Conte and the U. S. Fish and Wildlife Service, supports this previous finding but also provided evidence for concerns of migratory delay at this dam and others. On this topic, Castro-Santos and Letcher (2010) have developed a shad migration model study using Connecticut River American shad related variables, which highlighted the potential negative impacts to adult shad survival as outmigrants through the mechanisms of delay on both upstream and downstream migrations, in relation to limited energy reserves. The shad movement study conducted in 2011 and 2012 is still being analyzed but will provide important information on this potential issue. As described earlier, the FERC has initiated the relicensing process for the owner/operators of the Turners Falls Dam, the Northfield Mountain Pumped Storage Facility and the

owner/operators of the Vernon Dam and Bellows Falls Dam (including the next upstream Wilder Dam, outside of shad range) as their licenses are set to expire in 2018. Comprehensive telemetry studies are planned to examine movements in habitat up to the dams, at the dams, and through the various fishways in relation to other managed (generation schedule) and unmanaged (spill occurrences at dams) variables.

Upstream shad passage at Turners Falls Dam has been problematic since the opening of its three fishways in 1980. The Cabot Station (power house), at the end of a 3.4 km power canal off the Turners Falls Dam, is the primary location of shad attraction on their upstream migration and has a modified "Ice Harbor" design ladder. Fish that successfully pass that ladder must then proceed up the power canal to the Gatehouse, which contains the Gatehouse Fish Ladder (vertical slot design), that has two entrances from the canal. One entrance is a newer "extended" entrance, developed and installed for 2008 as part of the collaborative studies of the owner with the USGS Conte Lab and input with state and federal agencies. Shad may also move up the "bypass" reach (distance of 4.3 km) to the base of Turners Falls Dam where they may use the Spillway Ladder, which is also a modified Ice Harbor design. The Spillway Ladder still requires shad reaching the top of that ladder to pass along an entry flume to access the entrance to the Gatehouse ladder. Therefore, all fish must pass two of three fishways regardless of route used. Evaluations of the Cabot fish ladder were conducted by the USGS Conte Lab from 1999 through 2005, with no success in improved passage so work was shifted to address the other issue of getting shad to pass out of the power canal and through Gatehouse. This work was conducted from 2006 through 2012 and has led to eventual structural and operational changes that indicate a positive effect starting in 2008 (extended entrance flume) for improved fish passage out of the canal (Appendix 1), although overall passage for the dam remains a major concern and is well below management objectives defined in the CRASC Shad Plan.

Upstream shad movement past the Northfield Mountain Pumped Storage Facility is not well understood. The 2011 and 2012 shad movement study did obtain some data from this area, but further examination is deemed necessary and will occur with planned relicensing studies. This facility typically pumps from the river during off-peak hours (pumping capacity is up to 15,000 CFS) of the evening and is generating (generation capacity is up to 20,000 CFS) during peak load, daytime hours. Agency concern has been more focused on entrainment of juvenile life stages at this facility (to be discussed later).

Upstream passage at Vernon Dam is made possible through a fish ladder that is a modified Ice Harbor design in its lower section and serpentine vertical slot design in its upper section. This ladder became operational in 1981. Following some modifications and instances of issues with structures or operations, passage of American shad has been shown to meet CRASC Plan target rates in many years (Appendix 1). However, reduced shad passage efficiencies became noticeable in 2005 and it was not until analyses of data from the 2011 shad movement study that it was determined that approximately 90% of tagged fish were reaching the dam but not passing. A structured annual, pre-season field review for all fishways was subsequently developed by the agencies. This review located issues prior to 2012 and company fixes were made. As a result, both 2012 and 2013 shad passage numbers were viewed as dramatic improvements to rates seen in prior years (Appendix 1).

Agencies with regulatory authority: The CRASC has signed agreements with main stem hydropower operators that led to the installation and or operation of facilities to facilitate upstream passage on the main stem dams identified. The individual States have their independent authorities and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act, used in connection with FERC. The CRASC operates a Fish Passage Subcommittee, under its Technical Committee, which has been a forum to coordinate inter-agency staff, researcher, and activities with the various power companies in both official and unofficial capacities, in a regular and ongoing process. The CRASC issues a schedule of Upstream Passage Operation Dates through the Connecticut River Coordinator, annually in March that specifies species, lifestage, dates and hours of operations.

Goal/Target: CRASC's Management Plan for Connecticut River Shad (1992) includes the objective: achieve annual passage of 40 to 60%, based on a five year running average, at each successive upstream barrier on the main stem. Through the FERC relicensing process, more information to better define known upstream passage issues and those that may not yet be identified with planned studies in 2015 and 2016 will be obtained. Based on results and findings of these studies, agency staff will develop recommendations that may include fishway prescriptions, modifications and possible operational or other structural measures to address existing project impacts and upstream fish passage. Agency staff may recommend additional work required to identify measures to address issues of other management concern.

Progress: FERC relicensing is ongoing for Turners Falls Dam, Northfield Mountain Pumped Storage, Vernon Dam and Bellows Falls Dam, where licenses will expire in 2018. Field studies to obtain more information on shad upstream movement and passage at from downstream of Turners Falls Dam to Bellows Falls will begin in 2015 as part of FERC process; as of this date, Revised Study Plans have been filed with FERC. The 2011 and 2012 shad migration and survival study data is still under analyses; preliminary results have been produced including a draft report using 2011 data at Vernon Dam, which facilitated the successful measures to restore passage efficiency at that facility.

Cost: Dam operators will cover costs of FERC requested agency studies as part of relicensing, including fish movement (telemetry based) studies that will be used to inform fish passage evaluations and recommendations. Agency staffs have invested substantial time in the review, development, interaction, and planning of activities associated with the identified main stem hydropower projects that are covered by the agencies that will continue up to and after licensing. Additional costs will be incurred by the USGS Conte and USFWS in analyses and report writing of the 2011 and 2012 shad migration and survival study. Upstream fish passage operation costs and fish counting at Holyoke Dam are covered by the owner as part of the FERC 2003 relicensing. Fish count evaluations at Turners Falls fishways are the responsibility of State of Massachusetts, but the owners have covered that cost and operation for the last 15 years. Fish count evaluations at Vernon Dam are the responsibility of the State of Vermont.

Timeline: Studies required as part of FERC relicensing are scheduled to occur in 2015 and 2016. Subsequent data analyses and report preparation will occur in following years. The agencies will use information from these studies as well as the results from the 2011 and 2012 USGS/USFWS shad migration and survival study and other data remaining to be analyzed to develop appropriate recommendations for license requirements by FERC in 2018.

Adult upstream passage tributaries -

Farmington River (CT) - Currently upstream passage at the Rainbow Dam on this largest tributary in the State of Connecticut is a management issue (Table 3). The Rainbow Fish Ladder became operational in 1976 and is a vertical slot design that has been targeted for replacement by the State of Connecticut. The Winchell Smith Dam, next upstream structure, is a possible barrier to upstream movement of shad at some flow levels. The Lower and Upper Collinsville Dams are at the upstream extent of shad habitat on the Farmington River and will be considered for ladder installation should FERC grant licenses for proposed hydro-power development. The Pequabuck River is a tributary of the Farmington River with historic habitat blocked by the Bristol Brass Dam.

Agencies with regulatory authority: The Rainbow Dam is not a FERC licensed jurisdictional dam and the fish ladder was installed by the State of Connecticut using its own funds through an

agreement with the owners. The State of Connecticut continues to work through an agreement process with the owners but also has legal authorities regarding dams and fish passage at noted dams. The Lower and Upper Collinsville dams are being considered for hydro-power development and are expected to require FERC involvement and as result will involve the federal resource agencies. If this development proceeds, fish passage installations are expected.
Goal/Target: Install a state-of-the-art fish lift system at the Rainbow Dam and discontinue the use of the ladder for shad passage. Explore the possibility of either the removal or installation of a ladder at The Winchell Smith Dam. Provide input and recommendations on fish passage needs at the Lower and Upper Collinsville dams as hydropower development continues to be explored. Remove the Bristol Brass Dam and open access to historic habitat in this tributary.
Progress: Design plans for the Rainbow Dam fish lift are in process. Removal of the Bristol Brass Dam is pending. The Winchell Smith Dam project is under development. Both lower and Upper Collinsville fish passage will proceed as part of any planned hydropower development.
Cost: The construction cost for the Rainbow Dam fish lift is expected to be approximately $5 – 6 million. The Bristol Brass and Winchell Smith dam removal project costs remain to be determined. If warranted, fish passage at Lower and Upper Collinsville also remains to be determined.
Timeline: Once design plans have been completed, a search for sources of funding will be initiated, possibly in 2014, for the Rainbow Dam fish lift. The Bristol Brass Dam should be removed in 2014. The Winchell Smith Project is in development. The Lower and Upper Collinsville dams' future use remain uncertain at this time.

Scantic River (CT) – Currently, accessible shad habitat extends upstream to the Springborn Dam, which is planned for removal (Table 3).

Agencies with regulatory authority: The State of Connecticut has legal authorities regarding dams and fish passage at this small non-hydropower dam.
Goal/Target: To remove this dam which would open another 5 km of river habitat to the next upstream dam (Somersville), which is planned for a fish ladder following the successful removal of the downstream barrier.
Progress: The dam removal is in design.
Cost: The removal cost is estimated at $2-4 million due to contaminate issues.
Timeline: To be determined.

Chicopee River (MA) – Accessible habitat in this tributary is restricted to approximately 2 km to its confluence with the Connecticut River. There is a high density of closely placed hydropower dams that proceed upstream from that point.

Agencies with regulatory authority: The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for these lower dams.
Goal/Target: There have been unexecuted plans to stock pre-spawn shad, transferred from Holyoke Fish Lift, into the impoundments of the upstream dams with follow up sampling to determine if there is juvenile production.
Progress: No pre-spawn stocking of shad or herring has occurred to date. It is possible that these stockings, with evaluation for production, may occur in the near future.
Cost: Should stocking produce juveniles, an assessment and development of a plan for shad would need to be developed to consider the types and extent of upstream passage.

Timeline: Unknown relative to passage needs.

Ashuelot River (NH) – In 2012, the Fiske Mill Dam, the first barrier 3 km from confluence with the Connecticut River, had its fish lift become operational. The owner operator conducted visual inspections of lifts and never observed any shad. The McGoldrick Dam, which had been the next upstream dam, was completely removed in 2001. As shad passage at Fisk Mill Dam becomes documented, upstream passage options to pass fish upstream of both Ashuelot Paper and Lower Robertson hydropower dams will be developed. Once fish are able to pass these additional two dams, the vast majority of targeted spawning and nursery habitat will be completely accessible as two additional unmaintained dams have been completely removed from identified shad habitat in recent years.

Agencies with regulatory authority: The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the identified dams.
Goal/Target: A Plan to Restore Migratory Fishes to the Ashuelot River Basin (1998) by New Hampshire Fish and Game (NHFG) outlines clupeid stocking, dam removals, and fish passage targets. A NHFG habitat survey estimated approximately 140 ha of shad habitat that at a production rate of 124 adults/ha, translates to a run potential of approximately 17,000 adults.
Progress: Annual stockings of approximately 750 pre-spawn shad have occurred beginning in 1998. Upstream passage options for the remaining dams will be explored as adult fish are documented passing the Fiske Mill Dam.
Cost: Stocking of transferred pre-spawn fish is conducted by NHFG, USFWS, and state partners. Upstream passage installation and operation costs are the responsibility of the dam owner operators. The noted three dam removals were completed with grant funding support from many sources and state funds.
Timeline: Upstream passage measures for shad around the second and third dams on the lower Ashuelot will be implemented as returning adult shad are documented at the Fiske Mill Dam fish lift.

Adult downstream passage main stem -
The CRASC shad plan's objective to maximize outmigrant survival for juvenile and spent adult shad is based on the iteroparous nature of the Connecticut River stock. The State of Connecticut Marine Fisheries Division has documented the long-term decline in the proportion of repeat spawners of this stock. Theories on the mechanisms for these declines have included reduced survival of spent shad with increased access to upstream habitat from fishways (Leggett et al. 2004). Other research has suggested that the decline in repeat spawners occurred prior to increased upstream access (Castro-Santos and Letcher 2010). In either case, there is an interest by fishery managers to provide effective and timely downstream passage past the main stem hydropower facilities and address impacts from delays on the outmigration. However, each dam presents its own unique structure, operations, facility design, surrounding landscape and other unique features which often restrict available options more frequently resulting in the development of novel approaches for passage improvements.

Numerous and varied downstream measures have been explored and implemented at the Holyoke Dam. Currently, the Holyoke Dam operates a Bascule Gate with a specially designed "Alden Weir" to facilitate downstream passage of spent fish moving towards the power stations intake/forebay to the proximally located gate. This gate is operated for downstream passage of fish from April through July, with dates or operation specified in a CRASC Downstream Passage Notification Letter, issued by the Connecticut River Coordinator. There are concerns with the survival of passed shad at this gate as the water spills onto the dam's cement apron and also partially hits a cement retaining wall off this apron. A current Settlement Agreement among the state and federal resource agencies and several non-profit groups is designed to address downstream passage for shortnose sturgeon and American eel, but also includes improvements with the discharge area of the bascule gate for down running shad. Design work is in process.

A second route for downstream shad passage at Holyoke includes the power canal, which has a gatehouse located at its upstream end, adjacent to the dam structure. Shad that are directed or move into the canal will swim and/or drift to a full depth angled weir that covers the entire canal. The weir bar spacing is designed for juvenile fish field based guidance as well. At the downstream corner of this acutely angled weir is the entrance to the downstream fish passage pipe. The pipe conveys fish into the tailrace of the Holyoke power station, where the pipe discharges directly into deep water from a height of several meters.

> **Agencies with regulatory authority:** The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the identified dams. The CRASC issues a schedule of Downstream Passage Operation Dates through the Connecticut River Coordinator, annually in March that specifies species, lifestage, dates and hours of operations.
> **Goal/Target:** There are no current numeric targets or values for downstream passage of adult shad in the CRASC shad plan or anywhere else. The existing Settlement Agreement with the dam's owner includes provisions that will seek to improve situation with the spill of the Bascule Gate described earlier.
> **Progress:** There have been several submitted plans that have been pulled back due to a variety of issues. The Settlement Agreement will require resolution in the near term on this matter.
> **Cost:** Planned modifications to enhance downstream passage water discharge, via the Bascule Gate, will be covered by the owner operator.
> **Timeline:** Existing Settlement Agreement is in place. Resolution of downstream plans should occur in 2014, with possible construction in 2015.

Downstream passage of shad at the Turners Falls Dam is complicated by the design of the dam, gatehouse, and power canal described earlier. Downstream passage of adult shad occurs either by spill at the dam through a bascule gate required to spill for upstream passage flow in the bypass reach (400 cfs or when flows exceed canal capacity) or the primary designed emigration route via the Gatehouse, into the power canal and then to the downstream bypass structure at the Cabot Power Station. The modified log sluice bypass at the Cabot Station utilizes an Alden Weir, which fish reach after passing across the trash racks (partial depth reduced bar spacing) of the intakes to the powerhouse. Only juvenile shad and herring downstream passage has been examined at this facility. As part of the FERC relicensing process currently underway, studies will occur in 2015 to track radio tagged adult fish, assess downstream passage routes, timing, conditions (operational and natural), and survival as fish approach Turners Falls Dam from upstream. The 2011 and 2012 shad movement and migration study, as well as previous years' data from USGS Conte studies with radio tagged shad in this canal, suggest substantial delays of tagged down running fish in the canal.

Downstream shad movement past the Northfield Mountain Pumped Storage Facility is not well understood. The 2011 and 2012 shad movement and migration study remains to be fully examined for effects in this area. Further examination for possible delays, directional or other behavior modifications and possible entrainment will be examined as part of the FERC relicensing study on downstream shad movement in 2015.

Downstream passage for adults at Vernon Dam is made possible by a partial depth (15 feet) and partial length louver in the forebay that directs fish into the primary fish bypass pipe (350 CFS) with a secondary, smaller bypass pipe (40 CFS) on the Vermont near-shore side. No studies on adult shad use of the bypass systems have been successfully conducted. As part of the FERC relicensing process underway, studies tracking radio tagged adult fish in 2015 will assess downstream passage routes, timing, conditions (operational and natural), and survival.

Agencies with regulatory authority: The CRASC has signed agreements with main stem hydropower operators that led to the installation and/or operation of facilities for downstream fish passage at Turners Falls Dam, Northfield Mountain Pumped Storage (juvenile Atlantic salmon only) and Vernon Dam with the CRASC 1990 MOA for downstream passage development. The individual States have their legislative authorities and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act in connection with FERC. The CRASC operates a Fish Passage Subcommittee, under its Technical Committee, which has been a forum to coordinate inter-agency staff, researchers and work with the various power companies in both official and unofficial capacities, in a regular and ongoing process. The CRASC issues a schedule of Downstream Passage Operation Dates through the Connecticut River Coordinator, annually in March that specifies species, lifestage, dates and hours of operations.

Goal/Target: No current numeric targets or other values exist for downstream passage of adult shad in the CRASC shad plan or elsewhere. Through the noted FERC relicensing process, more information to better define known and yet to be identified issues through planned studies in 2015 and 2016 will be obtained. Based on results and findings of these studies, agency staff will develop recommendations that may include fishway prescriptions, modifications and possible operational or other structural measures to address existing project impacts and upstream fish passage. Agency staff may recommend additional work required to identify measures to address issues of other management concern.

Progress: FERC relicensing is ongoing for Turners Falls Dam, Northfield Mountain Pumped Storage and Vernon Dam (licenses expire in 2018). Field studies to obtain information on shad downstream movement and passage will begin in 2015 as part of the FERC process; as of this date, Revised Study Plans have been filed with FERC. The 2011 and 2012 shad migration and survival study data from USGS/USFWS is still under analyses.

Cost: Dam operators will cover costs of FERC requested agency studies as part of relicensing, including fish movement (telemetry based) studies that will be used to inform fish passage evaluations and recommendations. Agency staffs have invested substantial time in the review, development, interaction, and planning of activities associated with the identified main stem hydropower projects that are covered by the agencies that will continue up to and after licensing. Additional costs will be incurred by the USGS Conte and USFWS in analyses and report writing of the 2011 and 2012 shad migration and survival study.

Timeline: Studies required as part of FERC relicensing are scheduled to occur in 2015 and 2016. Subsequent data analyses and report preparation will occur in following years. The agencies will use information from these studies as well as the results from the 2011 and 2012 USGS/USFWS shad migration and survival study and other data remaining to be analyzed to develop appropriate recommendations for license requirements by FERC in 2018.

Adult downstream passage tributaries -

Dams with fishways that do not operate hydropower facilities were not included in the following list of tributaries due to their perceived lack of known threat(s) at this time. Evaluation of downstream passage survival, delay, or other deleterious effects and uses of any alternate routes that may be presented should be examined at dams that have active hydropower facilities, including those listed below.

Farmington River (CT) – The first dam, Rainbow, has a reduced bar trash rack spacing and a surface orientated bypass to guide fish to a bypass pipe that discharges to the tailwater.

Westfield River (MA) – The first dam, West Springfield, has reduced bar trash rack spacing and a surface orientated bypass to guide fish away from the gate house/intake for the power canal. In addition, spill is provided at the dam to ensure adequate flow for fish either still migrating upstream in this period and or for downstream migration.

Ashuelot River (NH) - The first dam, Fiske Mill, has reduced bar trash rack spacing and a surface orientated downstream bypass pipe that discharges to the tailwater.

Juvenile downstream passage main stem -
The Holyoke Dam has had ongoing development with downstream fish passage measures since the 1980s, involving FERC (added license Articles) and then relicensing, CRASC with the 1990 MOA signed with the main stem dam operators on downstream fish passage development, and most recently the still open Settlement Agreement. Over time, the current existing downstream passage measures were developed consisting of a partial depth reduced bar spacing trash rack in front of the turbine intakes, spill at the Bascule Gate, and lastly in the canal, the full depth, full span, angled louver array with fish bypass pipe.

At Turners Falls Dam, downstream passage of juvenile shad principally occurs via the Gatehouse at the dam and then, through the power canal, leading to the Cabot Station. However, the timing, magnitude and frequency of spill at the dam once the canal capacity is exceeded, also provides a downstream passage route. In addition, for a one week period typically scheduled for mid to late September, the power canal's water is shut off at the Gatehouse for maintenance purposes of the canal. This situation results in all river flow directed through gate structures at the dam and the eventual draining of the canal principally through the Cabot Station turbines. The downstream fish bypass installed as part of the 1990 MOA with CRASC was evaluated for juvenile shad and blueback herring passage in the mid-1990s. The company study demonstrated that of those juveniles that utilized the bypass, relatively high survival was demonstrated (~90%). However, the evaluations did not determine timing, magnitude, or duration of the wild juvenile fish run and their route selection or other management concerns such as conditions that direct fish to use the dam's spill gates and survival of those fish; these are scheduled to be addressed by planned FERC relicensing studies. The relicensing studies will also include an examination of potential juvenile shad migrational impacts in relation to the operation of the NMPS facility. As noted earlier, concerns on NMPS also include entrainment, which will be discussed later.

Downstream passage for juvenile shad at Vernon Dam is made possible by a partial depth and partial length louver which directs fish into the primary fish bypass pipe with a secondary, smaller bypass pipe on the Vermont near-shore side. No studies on juvenile shad use of the bypass systems have been successfully conducted. As part of the FERC relicensing process, 2015 studies will assess downstream passage routes, timing, conditions (operational and natural), and survival as fish approach this project from upstream.

Agencies with regulatory authority: The CRASC has signed agreements with main stem hydropower operators that led to the installation and or operation of facilities for downstream fish passage at Turners Falls Dam, Northfield Mountain Pumped Storage (juvenile Atlantic salmon only) and Vernon Dam with the CRASC 1990 MOA for downstream passage development. The individual States have their legislative authorities and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC. The CRASC operates a Fish Passage Subcommittee, under its Technical Committee, which has been a forum to coordinate inter-agency staff, researchers and work with the various power companies in both official and unofficial capacities, in a regular and ongoing process. The CRASC issues a schedule of Downstream Passage Operation Dates through the Connecticut River Coordinator, annually in March that specifies species, lifestage, dates and hours of operations.

Goal/Target: No current numeric targets or other values exist for downstream passage of juvenile shad in the CRASC shad plan or elsewhere. Through the noted FERC relicensing process, more information to better define known and yet to be identified issues through planned studies in 2015 and 2016 will be obtained. Based on results and findings of these studies, agency staff will develop recommendations that may include fishway prescriptions, modifications and possible operational or other structural measures to address existing project impacts and downstream fish passage. Agency staff may recommend additional work to identify measures to address issues of other management concern.

Progress: FERC relicensing is ongoing for Turners Falls Dam, Northfield Mountain Pumped Storage and Vernon Dam, whose licenses will expire in 2018. Field studies to obtain information on juvenile shad downstream movement and passage will begin in 2015 as part of FERC process. Revised Study Plans have been filed with FERC as of this date.

Cost: Dam operators will cover costs of FERC requested agency studies as part of relicensing, including fish movement (telemetry based) studies that will be used to inform fish passage evaluations and recommendations. Agency staff has invested substantial time in the review, development, interaction, and planning of activities associated with the identified main stem hydropower projects that are covered by the agencies and that will continue up to and after licensing.

Timeline: Studies required as part of FERC relicensing are scheduled to occur in 2015 and 2016. Subsequent data analyses and report preparation will occur in following years. The agencies will use information from these studies as well as the results from the 2011 and 2012 USGS/USFWS shad migration and survival study and other data remaining to be analyzed to develop appropriate recommendations for license requirements by FERC in 2018.

Juvenile downstream passage tributaries

Dams with fishways that do not operate hydropower facilities were not included in the following list of tributaries due to their perceived lack of known threat(s) at this time. Evaluation of downstream passage survival, delay, or other deleterious effects and uses of any alternate routes that may be presented should be examined at dams that have active hydropower facilities, including those listed below.

Farmington River (CT) – The first dam, Rainbow, has a reduced bar trash rack spacing and a surface orientated bypass to guide fish to a bypass pipe that discharges to the tailwater.

Westfield River (MA) - The first dam, West Springfield, has reduced bar trash rack spacing and a surface orientated bypass to guide fish away from the gate house/intake for the power canal. In addition, spill is provided at the dam to ensure adequate flow for fish either still migrating upstream in this period and or for downstream migration.

Ashuelot River (NH) – The first dam, Fiske Mill, has reduced bar trash rack spacing and a surface orientated downstream bypass pipe that discharges to the tailwater.

Threat: Hydropower Dam and Hydropower Facility Discharge Fluctuations and Operations

Recommended Action: The operation of hydropower facilities includes peaking operations, which can result in substantial alterations to river discharge (timing, magnitude, duration) downstream of the facilities as well as upstream (e.g., impounding periods and the operation of NMPS), and may alter shad habitat types, quantity, and quality at a sub-hourly time scale and on a daily basis. An inventory and assessment of all hydropower facilities that are not required to operate as "run-of-the-river" should be identified and evaluated. This should occur on both the main stem river and identified tributaries. The FERC relicensing process for the five identified main stem hydropower projects will include studies to determine shad spawning locations, habitat features, success, and any operational effects on these measures. Relicensing of FERC projects in recent years, such as Holyoke Dam, have stipulated run-of-river operations.

Agencies with regulatory authority: The States have legal authorities regarding dams and hydropower operation through FERC, Water Quality Certification (401) and Coastal Zone Management Act, as applies. The U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act. Fish and Wildlife Coordination Act. And Endangered Species Act.
Goal/Target: The State and Federal agencies will seek to develop and implement measures to reduce any documented impacts of water use (e.g., generation) on shad spawning habitat based upon available information. A natural flow regime, to the extent possible, is preferred.
Progress: The FERC relicensing process has resulted in planned studies to examine any project operation discharge effects on identified shad spawning habitat and behavior below Turners Falls Dam, in the Turners Falls impoundment, below the Vernon Dam, in the Vernon Dam impoundment, and below the Bellows Falls Dam.
Cost: FERC relicensing study costs will be covered by the power company. However, agency staff planning, review, discussions, input and evaluation will be ongoing over coming years.
Timeline: The noted FERC relicensing studies are expected to occur in 2015 and possible 2016.

Threat: Water Withdrawal

Recommended Action: An inventory and assessment of all permitted water withdrawals from the main stem and targeted tributary shad habitat should be conducted using state agency permit data. At this time, there are water withdrawals for cooling water intake structures permitted by appropriate state and or federal agencies from the main stem river. The list of water users includes from upstream to downstream: Vermont Yankee Nuclear Power Station, Vernon, VT; Mount Tom Power Station, Holyoke, MA (coal); West Springfield Generation Station, MA (fossil fuels); Algonquin Power, Windsor, CT (natural gas); South Meadow Plant, Hartford, CT (fossil), GenConn, Middletown, CT (natural gas/fossil), and possibly others that remain to be identified. In addition the NMPS facility in Northfield, MA has a pumping capacity, to its storage reservoir, of up to 15,000 cubic feet per second, and is regulated by the FERC. Details of the type and extent of water withdrawal and subsequent discharge for these plants and others that remain to be collectively examined should be reviewed for potential impacts to American shad habitat and population impacts. The NMPS facility did conducted an entrainment study of shad eggs, larvae and juveniles in 1992 that reported an estimated 13.2 million yolk sac and post yolk larvae, and 37,260 juvenile/out migrants entrained. Fish entrained at this facility are considered lost to the Connecticut River population. As part of the FERC relicensing study, a hydroacoustic study at the intakes and radio tagged juvenile shad will be used to evaluate potential project impacts at NMPS. Vermont Yankee's cooling water intake structures are monitored for juvenile shad entrainment and reported to the State and Federal agencies on an annual basis. Vermont Yankee is scheduled for shut down in December 2014, when it has been reported that water discharge (intake) will be reduced by 98% from current maximum level of approximately 800 CFS.

Agencies with regulatory authority: Regulatory authority for the withdrawal of water is under State authorities and/or legislation. In the case of the NMPS facility, licensed through FERC, both the Massachusetts and the federal resources agencies have specific authorities.
Goal/Target: The State and Federal agencies will seek to develop and implement measures to reduce documented impacts of water withdrawals on early life stages and outmigrants (e.g., entrainment and/or impingement) through available regulatory or other mechanisms.
Progress: An inventory of water withdrawals remains to be considered as a management task by the fishery agencies relative to American shad and river herring habitat. However, increased workloads for both State and Federal agency staff will likely delay this activity in order to address other higher priorities. Through the ongoing FERC relicensing process, study plans are still being considered for NMPS evaluation of entrainment impacts to shad life stages (juveniles through adults) with implementation in 2015 and or 2016. Fish entrainment monitoring of the Vermont Yankee intake structure is an ongoing State of Vermont permit requirement.
Cost: Permitting and monitoring of water withdrawal permits are typically handled by State agencies. FERC relicensing study costs will be covered by the power company. However, agency staff planning, review, discussions, input and evaluation will be ongoing over coming years.
Timeline: Review and permitting by the states is ongoing. The examination of this information by the fisheries agencies remains to be identified

Threat: Thermal Discharge

Recommended Action: An inventory and assessment of all permitted thermal discharges from the main stem and targeted tributary shad habitat should be conducted using state agency permit data as well as data from the Environmental Protection Agency (EPA) which has responsibility for the National Pollution Discharge Elimination System (NPDES) and/or its delegation to approved State agencies, to varying levels. Permitted water withdrawals and discharge for cooling water intake structures occur on the main stem river, from upstream to downstream, at: the Vermont Yankee Nuclear Power Station, Vernon, VT; Mount Tom Power Station, Holyoke, MA (coal); West Springfield Generation Station, MA (fossil); Algonquin Power, Windsor, CT (natural gas); South Meadow Plant, Hartford, CT (fossil); GenConn, Middletown, CT (natural gas/fossil); and possibly others.

Agencies with regulatory authority: NPDES authority has been delegated by the EPA to the states of Connecticut and Vermont. Whereas, the Commonwealth of Massachusetts and the State of New Hampshire have not been delegated authority and work with the EPA to issue NPDES permits.
Goal/Target: Varies by authorizing agency. A NPDES permit will generally specify an acceptable level of a pollutant or pollutant parameter in a discharge (e.g., water temperature). The permittee may choose which technologies to use to achieve that level. Some permits, however, do contain certain generic 'best management practices'. NPDES permits make sure that a state's mandatory standards for clean water and the federal minimums are being met.

Progress: Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters since passage of this law in 1972. An inventory of NPDES permitted thermal discharges, remains to be considered as a management task by the fishery agencies relative to American shad and river herring habitat in this basin. However, increased workloads for both State and Federal agency staff will likely delay this activity.
Cost: Permitting and review of monitoring data review are covered by both State and Federal agencies, depending on the location of the discharge. Costs of technologies or other measures to reduce impacts and to monitor discharge levels are covered by the permittee.
Timeline: The Clean Water Act limits the length of NPDES permits to five years. NPDES permits can be renewed (reissued) at any time after the permit holder applies. In addition, NPDES permits can be administratively extended if the facility reapplies more than 180 days before the permit expires, and EPA or the state regulatory agency, which ever issued the original permit, agrees to extend the permit.

<u>Threat: Water Quality</u>

Recommended Action: State and Federal agencies should regularly assess water quality monitoring data to ensure water quality does not become impaired and to support recommendations on proposed activities that may affect water quality. Physical, chemical, and biological monitoring of water quality should be adequately supported, primarily through existing State agency authorities, by designated agencies, to ensure sufficient temporal and spatial coverage, sampling design, and sampling intensity. Classification standards and data among the four basin states should be coordinated and shared along with necessary monitoring measures. Communication between professional fishery agency staff and water quality staff should continue to be strengthened.

Agencies with regulatory authority: The Clean Water Act of 1972 is the foundation for surface water quality protection in the United States. Sections of this Act provide direction on standards to the states. The states of Vermont, New Hampshire, Massachusetts, and Connecticut all maintain surface water monitoring programs.
Goal/Target: Varies by authorizing agency and standards cannot be weaker than federal identified designations. The State of New Hampshire designates the main stem as Class B. The State of Vermont classifies the main stem as Class B and also as coldwater fish habitat. The Commonwealth of Massachusetts designates the main stem as Class B and also as warmwater fishery habitat. The State of Connecticut also classifies the main stem and tributaries as Class B. Standards associated with these designations are available on respective state agency web sites.
Progress: Water quality on the main stem and tributaries are monitored directly by respective state agencies, federal agencies (e.g., U. S. Geological Survey) non-profit watershed groups, power companies and others. With the previously mentioned FERC relicensing process, more intensive and diverse water quality studies are scheduled to occur in 2015.
Cost: State and Federal agencies conduct ongoing monitoring and review of other data sources. Power companies cover monitoring costs for existing permits (NPDES) and or new licenses such as through FERC.
Timeline: State agency monitoring for standard assessments is ongoing as are other programs including USGS gauge stations with water quality instrumentation. New, shorter duration assessments include the FERC relicensing studies associated with operation of the Turners Falls Hydroelectric Project upstream to the Bellows Falls Dam. Other special studies in recent years have included an EPA Study in 2005 done in collaboration with state agencies.

<u>Threat: Land Use</u>

Recommended Action: State, Federal, and local governments should continue to support existing protective measures to address poor land use practices that may affect shad habitat either directly or indirectly. These measures may occur at multiple levels of government as noted. Riparian zone vegetation protection and bank protection are examples of concerns that poor land use (e.g., agriculture, residential, commercial uses) regulation or enforcement may result in degraded habitat. States should work in collaboration to develop and support consistent regulations and enforcement measures.

Agencies with regulatory authority: Land use regulatory authority may reside at the local, state and/or federal government level.
Goal/Target: The codification of rules and adequate enforcement to provide riparian vegetation protection and bank protection/stability and address other potential negatively impacting land use activities will help protect aquatic habitats.
Progress: Status of existing state and local government rules are not summarized. Examples of measures that have improved protections for land use include the Rivers Protection Act, under the Wetlands Protection Act of the Commonwealth of Massachusetts.
Cost: Unknown.
Timeline: Ongoing.

<u>Threat: Climate Change</u>

Recommended Action: State and Federal agencies should identify data of value in the detection and monitoring for climate change effects on shad habitat and associated shad population dynamics or other responses (e.g., run timing) and whether those changes can successfully be adapted to by those populations. Sources of important data should be evaluated for ongoing value and whether any modifications may be necessary. Data that would be of value in this effort and are not being collected should be identified with measures to develop appropriate data collection programs explored collaboratively by the State and Federal agencies. In freshwater, the timing, frequency, and magnitude of river discharge should be evaluated at regular intervals (spring run-off, droughts, pulse events) and related to fishery data including, but not limited to, fishway operational schedules, fish movement and behavior data, spawning success, habitats, and juvenile recruitment and outmigration. In the near-shore and marine environment, monitoring and studies to assess shifts in conditions and habitats (e.g., water temperatures, currents, food sources, predators) should occur at regular intervals

Agencies with regulatory authority: Regulatory authorities for climate change are not clearly in place at this time. However, both State and Federal resources agencies have recognized the need to incorporate the reality of climate change as physical scientists work to develop future scenarios on effects (e.g., temperature regimes, river discharge, rainfall, snowpack) that may to varying degrees, affect species occurrence, population viability, and habitat quantity and quality.
Goal/Target: It will be desirable to understand any trends in population metrics or other parameters, and any linked climate change drivers that may affect population structure, distribution, abundance, and viability. The resource agencies will seek to mitigate negative climate change impacts and other related exacerbating human impacts that may accelerate these impacts. Ultimately the agencies will seek to ensure the full restoration and long-term sustainability of this population given it is not at the extreme end of its distribution range.
Progress: New or updated federal resource plans are required to include climate change.
Cost: Unknown.
Timeline: Ongoing.

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Appendix 1. American shad fish passage counts from 1980 through 2013 for the Holyoke Dam (MA), Turners Falls Dam (MA), and Vernon Dam (VT).

Year	Holyoke Dam Fish Lift	Turners Falls Dam Gatehouse	% Gate vs. HFL #	Vernon Dam Fish Ladder	% Vern vs. Gate #
1980	380,000	298	0.1		
1981	380,000	200	0.1	97	48.5
1982	290,000	11	0.0	9	81.8
1983	530,000	12705	2.4	2597	20.4
1984	500,000	4333	0.9	335	7.7
1985	480,000	3855	0.8	833	21.6
1986	350,000	17858	5.1	982	5.5
1987	270,000	18959	7.0	3459	18.2
1988	290,000	15787	5.4	1370	8.7
1989	350,000	9511	2.7	2953	31.0
1990	360,000	27908	7.8	10894	39.0
1991	520,000	54656	10.5	37197	68.1
1992	720,000	60089	8.3	31155	51.8
1993	340,000	10221	3.0	3652	35.7
1994	170,000	3729	2.2	2681	71.9
1995	190,000	18369	9.7	15771	85.9
1996	280,000	16192	5.8	18844	116.4
1997	300,000	9216	3.1	7384	80.1
1998	320,000	10527	3.3	7289	69.2
1999	190,000	6751	3.6	5097	75.5
2000	225,000	2590	1.2	1548	59.8
2001	270,000	1540	0.6	1744	113.2
2002	370,000	2870	0.8	356	12.4
2003	280,000			268	
2004	192,000	2192	1.1	653	29.8
2005	116,511	1581	1.4	167	10.6
2006	155,000	1810	1.2	133	7.3
2007	158,807	2248	1.4	65	2.9
2008	156,492	4000	2.6	271	6.8
2009	160,649	3813	2.4	16	0.4
2010	164,439	16422	10.0	290	1.8
2011	244,177	16798	6.9	46	0.3
2012	490,431	26727	5.4	10386	38.9
2013	392,967	35494	9.0	18220	51.3
Mean			**3.8**		**39.8**
SD			3.2		33.9
Low			0.0		0.4
High			10.5		116.4

Delaware River
Habitat Plan for American Shad

Prepared by:

The Nature Conservancy

and

The Delaware River Basin Fish & Wildlife Management Cooperative

Delaware Division of Fish and Wildlife • New Jersey Division of Fish and Wildlife

Pennsylvania Fish and Boat Commission • New York State Division of Fish, Wildlife and Marine Resources

U. S. Fish and Wildlife Service • National Marine Fisheries Service

For:

The Atlantic States Marine Fisheries Commission

Shad and River Herring Management Board

October 7, 2013

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1. Overview

The Delaware River begins in Hancock, NY and flows more than 454 kilometers (330 miles) before emptying into Delaware Bay (Fig 1). The tidal portion extends from the head of the bay to near Trenton, NJ (rkm 214, rm 133[1]). The East and West Branches, Lackawaxen, Neversink, Lehigh and Schuylkill rivers are the major tributaries. The 33,038 square kilometer basin includes parts of four States: Pennsylvania (50 percent of the basin), New Jersey (23 percent), New York (19 percent), and Delaware (8 percent). As the drinking water supply for 15 million people (Philadelphia – New York City (NYC) metropolitan area), vast areas of the basin's headwaters have been protected from development and much of the river corridor retains its wild, free flowing character.

The Delaware River is unique along the Atlantic Coast in that it is free-flowing along the entire length of the mainstem, which allows numerous species of migratory fish and freshwater mussel species to persist far up into its headwaters where in similar East coast aquatic systems they've been long extirpated. Since colonial times, however, the basin's resources have been exploited and depleted. By the early 20th century the estuary was considered one of the most polluted waterbodies in the United States and a recurring pollution block in the tidal portion of the upper Delaware Estuary severely hindered migratory fish runs, which were already severely depleted from overfishing and habitat degradation.

The tide began to turn in the late 1960s. The recognition of the need to conserve the valuable resources of the basin led to the formation of the Delaware River Basin Commission (DRBC) in 1961. The passage of the Clean Water Act in 1972, which established water quality standards to reduce municipal and industrial discharges, eventually led to improved water quality and the near elimination of the pollution block on the lower river. In 1978, two sections of the river covering 181 km (113 mi) were designated as National Wild and Scenic Rivers to be administered by the National Park Service: 117 km (73 mi) as the Upper Delaware Scenic and Recreational River, and 64 km (40 mi) as the Middle Delaware National Scenic and Recreational River. In 1992, DRBC adopted the special protection regulations to protect the high water quality of the river sections that had been designated as part of the National Wild and Scenic River system. The special protection regulations do not allow any degradation of "existing water quality" as defined by numeric standards for a number of water quality parameters. Through a series of amendments between 1994 and 2008, the special protection waters designation was expanded to apply to point and non-point discharges along the entire mainstem downstream to Trenton, NJ. In 2000, the U.S House of Representatives passed a measure to include an additional 63 km (39 mi) of mainstem and tributaries in Lower Delaware Scenic and Recreational River. Presently, three-quarters of the non-tidal Delaware River is now included in the National Wild and Scenic Rivers System.

[1] A river mileage excel table and maps can be found on the DRBC website. http://www.nj.gov/drbc/basin/river/

The tidal river, however, is densely populated and home to a large freshwater port (in 2007, handled 167,413 twenty-foot equivalent units). Losses of freshwater tidal wetlands and other riparian habitat in this area are significant. Although the mainstem Delaware is free of physical barriers, many important tributaries that once supported large runs of American shad are blocked or have reduced access and/or degraded habitat. In addition to dams, the building of multiple canal systems including the Delaware and Raritan canals, extirpated shad from many mainstem tributaries.

Within the Delaware River Basin, the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) is responsible for the management of diadromous fishes inclusive of the American shad. The Co-op was established by Charter in 1973 and primarily develops unified approaches to anadromous fish management. It is comprised of U. S. Fish & Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Delaware Department of Natural Resources and Environmental Control (DNREC), Pennsylvania Fish and Boat Commission (PFBC), Pennsylvania Game Commission (PGC), New York Division of Fish, Wildlife, and Marine Resources (NYDEC), and New Jersey Division of Fish and Wildlife (NJDFW). A Coordinator from the U. S. Fish and Wildlife Service serves as secretary to the Co-op and acts as a liaison and technical specialist primarily on aquatic issues to the National Park Service (NPS), the DRBC, the Delaware Estuary Program, and the USFWS's Delaware Bay Estuary Project.

The Atlantic States Marine Fisheries Commission (ASMFC) has required all states to submit a Habitat Plan (1 August 2013, extended to 15 September 2013) for American shad as part of their Implementation Plan as per Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring. The Habitat Plan was to focus on threats that are deemed most significant to American shad. As such, it is likely that data and/or monetary support may not yet be available to address specific topics. In these cases, this plan identifies the threat and offers potential direction for rectification but indicates the states abilities in those identified directions are limited. In accordance with guidelines provided in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010), the Co-op on behest of all members, submits the following Habitat Plan.

2. Mainstem Habitat Assessment

2.1 Historic

Historically American shad spawned throughout the mainstem freshwater Delaware River and its tributaries as well as tributaries connected to the Delaware Bay (Stevenson, 1899). The location of the salt front would have determined the extent of the potential spawning habitat in the freshwater tidal section of the river. Prior to the construction of the NYC reservoirs and subsequent diversions, the salt front was variable seasonally within and among years depending on the total volume of water being discharged from the Delaware River at any given time. Management of reservoir releases was thought to reduce the extreme variation of salinity in the estuary and hence moderate the migration of the salt front (Ketchum 1952). Today the average location of the salt front is at rkm 111 (rm 69). During the drought of record in the 1960's the salt front reached rkm 164 (rm 102) upstream (Fig 2).

During the late 1800's there was evidence indicating that shad were spawning in the freshwater tidal areas of the mainstem as well as several tributaries of the lower Delaware River. It was presumed that the principal spawning area was located south of Philadelphia, PA prior to 1900 just above Gloucester, NJ (rkm 157, rm 97) (U. S. Fish Commissioners, 1887; Cable, 1945; Walford, 1951; Mansueti and Kolb, 1953.) Furthermore, the Howell family fishery, in existence for 200 years at Woodbury, NJ, kept catch records before 1830's documenting annual American shad hauls of greater than 130,000 fish at rkm 150 (rm 93) (Harding 1999).

As early as the 1800's, exploitation, pollution and dams in the Upper Delaware River and tributaries were already having a significant impact on the shad population in the Delaware. The construction of the extensive canals and locks in the late 1800's along the mainstem Delaware, Lehigh, and Schuylkill rivers extirpated American shad from historic spawning and nursery habitats. In 1828, a 16-ft dam was built across the Delaware at Lackawaxen, Pa. by the Delaware and Hudson Canal Company for a period of approximately 50 years. Until dismantled, this dam decimated the upper river spawning run according to reports in the New York Times (NYT 1889). Still on-going to the present, dredging the main channel for navigation has also resulted in major changes to the mainstem channel in the lower basin from Philadelphia, Pa to the ocean. Table 1 illustrates the historic and incurring changes to the width and depth of the channel. These changes to the channel allowed the salt front to reach further upstream. Significant loss of side channel habitat as well as shallow water habitat was lost.

Water pollution since colonial times was severe, culminating in anoxic conditions in the lower Delaware River. During the 1940s and 1950s, heavy organic loading around Philadelphia, Pa. caused severe declines in dissolved oxygen (D.O.). A remnant of the American shad run in the Delaware River survived by migrating upstream early in the season, when water temperatures were low and flows were high, before the D.O. block set up. These fish, because of their early arrival, migrated far up the Delaware to spawn. Out-migrating juveniles survived by moving downriver late in the season during high flows and low temperatures, thus avoiding the low oxygen waters present around Philadelphia earlier in the fall.

By the 1820's, fishermen noted the drastic decline in the size of shad and eight-pounders, which were once common, became hard to find (Harding 1999). By the early 1900's, as a result of exploitation and habitat loss, the shad fishery collapsed and the Gloucester fishery which had been in existence for 200 years ended (Harding 1999).

During the 1960's, the Tri-State Shad Surveys as described by Chittenden (1976) showed that the greatest numbers of adults were captured from Minisink Island near Milford, PA (rkm 392) up to Skinners Falls near Narrowsburg, NY (rkm 475); none were captured downstream from Manunka Chunk (rkm 325). Pollution continued to be a major factor until passage of the Federal Clean Water Act in 1972. During the 1980's water quality of the Delaware River mainstem began to improve, particularly in the freshwater tidal reaches. Specifically, improvements to sewage treatment plants have also substantially reduced the occurrence of the D. O. block allowing passage of fishes to occur once again between the freshwater river and estuary.

2.2 Current (1990 onward)

Currently, American shad spawning is thought to be primarily in the middle and upper Delaware mainstem spanning an area of approximately 236 river kilometers (147 river miles) from near Easton, Pa. (rkm 296, rm 184) to Hancock, NY (rkm 532, rm 330). Yet, American shad also appear to be using the lower non-tidal reaches and freshwater tidal reaches of the Delaware River. Entrainment of Alosine eggs and larvae in industrial water intakes, suggest the lower freshwater reaches and upper tidal reaches of the Delaware River are nursery grounds. In addition, observed adult shad spawning behaviors support this assumption, however, ichthyoplankton surveys for documenting the occurrence of American shad eggs in this region should be a priority research topic (Maurice et al. 1987).

3. Tributary Habitat Assessment

Historically, shad utilized many, if not all, medium to large tributaries for spawning in addition to the mainstem habitat. Although the mainstem Delaware is free of physical barriers, many important tributaries that once supported large runs of American shad are blocked or have reduced access and/or degraded habitat. In addition to dams, the building of multiple canal systems included the Delaware and Raritan canals extirpated shad from many mainstem tributaries. These canal systems to date still preclude shad from utilizing historic spawning and nursery grounds. Tidal gates in coastal tributaries likely have restricted access as well.

Except for in a few select places, i.e. the Lehigh and Schuylkill, very little information on the size of these tributary spawning runs or their production of young is available. Using historical and current information a brief description of known historic and/or current status of spawning runs in all tributaries, as well as known habitat impacts can be found in Appendix 1 beginning in the headwaters and moving downstream. Figure 3 highlights the known spawning runs as of 2010.

A summary of the habitat status of major shad tributaries by state is below.

3.1 <u>New York</u>

The major spawning tributaries for shad in New York were the East and West Branches of the Delaware and, to a lesser extent, the Neversink River. Most of the East and West Branches of the Delaware no longer support shad spawning runs due to the cold water releases from the NYC reservoirs and direct loss of habitat due to the reservoirs themselves (Chittenden 1976). Shad historically migrated 68 km (42 miles) up the East Branch to former town of Shavertown (Bishop 1936), which is now submerged beneath New York City's Pepacton Reservoir. There have been reports from fishermen of shad as far as 25 km (15.5 mi) up the East Branch, to the confluence with the Beaver Kill (Saunter 2001). Chittenden (1976) reported that shad ran up 6 km (3.7 mi) up the Beaver Kill, an East Branch tributary, but it is unclear whether they spawn there. Other reports have shad going as far as a mile up into the Little Beaver Kill, a tributary of the Beaver Kill (McPhee 2005).

In the early 1800's the shad run in the Neversink River was large enough to support a seine fishery in the lower part of the river (Gumaer 1890). It is believed that shad went upstream approximately 24k (15 miles) to the Neversink Gorge, which is the natural barrier due to gradient on this river. The Southwest Cuddebackville Dam built in 1904 restricted passage 16km (10 miles) upstream from the mouth until 2004 when the dam was removed. Shad now have access to their full historic habitat in the Neversink River and are not impacted by cold water releases from the Neversink Reservoir due to the large distance from the reservoir; however, it is not clear if shad are utilizing this newly opened habitat (Horwitz et al. 2008).

3.2 <u>Pennsylvania</u>

Two of the largest shad spawning tributaries in the Delaware Basin are wholly located within the Pennsylvania; the Schuylkill River has a drainage area of 5,180 km^2 and the Lehigh River has a drainage area of 3,484 km^2. In the late 1880's shad were extirpated from all waters associated with the Schuylkill and Lehigh basins with the construction of various dam and canal systems. The building of the Delaware Canal on Pennsylvania's shoreline also disconnected many smaller tributaries from the mainstem, precluding shad access. In addition to physical barriers, water quality is also an issue in the Lehigh. Just south of the municipality of Palmerton, PA water quality is poor due to impacts from several large municipalities that have discharges to the drainage and historic inputs from a former metal smelting operation.

The Schuylkill is the largest tributary to the Delaware River and once supported very large numbers of American shad until the construction of dams in the early 1800's. Point of entry of the Schuylkill is at 149 rkm in the upper tidal estuary, in Philadelphia, PA. Shad historically migrated 193 km (120 miles) upstream to Pottsville, Pa. In 1820, the Fairmount Dam was constructed nine miles from the mouth of the Schuylkill; an additional nine other dams were also constructed in the watershed effectively eliminating the shad runs in the Schuylkill system for 150 years.

Located upriver in the non-tidal reach of the Delaware, the Lehigh enters the Delaware River at Easton, Pa at 294 rkm. Prior to the construction of a series of dams for supporting the Lehigh Coal and Navigation Canal system in the early 1800's, shad migrated at least 58 km (36 miles) upriver to Palmerton, Pa where native Lenape Indians annually harvested shad at the confluence of the Aquashicola Creek. Although no written record has been found documenting the occurrence of shad further upriver of Palmerton, PA, it is reasonable to assume they continued their migrations for some distance upriver. Construction of the Easton Dam (0 rkm) in 1829, at the confluence of the Lehigh and Delaware rivers, extirpated shad from the Lehigh basin for 165 years until the subsequent installation of a fishway in 1994.

3.3 New Jersey

In New Jersey, most tributaries that were tidally influenced had runs of shad that could support fisheries. In 1896 the Cohansey River ranked 3rd in New Jersey as a shad producing stream, surpassed only by the Hudson and Delaware (Stevenson 1899). Currently, there is no documented shad run in the Cohansey. Historic water quality issues likely impacted many of the shad streams in New Jersey. Current habitat impacts include dams, canals, tidal gates and water quality.

3.4 Delaware

In the late 1600s, before the first dams were constructed, the Brandywine supported tens of thousands of American shad. But even in the 1700's the Brandywine Lenape Native Americans were complaining to commissioners in PA that dams were preventing the rockfish and shad from "coming up" as formerly and causing great injury to their people (Weslager, 1989, Schutt 2007).

The current status of shad in most of the tributaries that are found in State of Delaware is unknown, but few have been caught in any of these tributaries during the past century and it is unlikely that any of them currently support spawning runs. However, shad were found historically in most tributaries (Mansueti and Kolb 1953, Stevenson 1899). In Wilmington, the Christina watershed (including White Clay Creek and the Brandywine) had a major spawning run of shad before dams and water pollution effectively eliminated the run. The majority of tributaries that once supported shad runs are impacted by dissolved oxygen and nutrient issues (DNREC 2005).

4. Nursery Habitat - Historic and Current

Juvenile shad remain in the rearing area of their natal river which is usually located downstream from where they were spawned. Juveniles then move from the nursery areas to the ocean in October and November as water temperatures decrease (Limburg et al. 2003). Historically the tidal Delaware was probably an important nursery area with thousands of acres of saltwater and freshwater tidal marshes of highly productive systems with extensive food and shelter for juvenile shad. More than 145,000 hectares of brackish and salt marshes remain in the Delaware Estuary, roughly half in Delaware and half in New Jersey. However, only five percent of freshwater tidal marshes in the Delaware River Basin remain (Kreeger et al. 2010). Concentrated along the mainstem Delaware River between Wilmington, DE and Trenton, NJ, the condition of these marshes reflects the effects of negative impacts of intensive land conversion and industrial activities in this urban corridor (Simpson et al. 1983). Residential and commercial development has left only fragments of freshwater tidal marsh fringing the Delaware and its tributaries in this section of the basin.

In the upper Delaware River, prior to the construction of NYC reservoirs Chittenden (1969) reported that juvenile shad were repeatedly captured in the West Branch of the Delaware River. In 1964 and 1966, after cold water releases began, Chittenden was unable to document juvenile shad in the West Branch. In other studies Miller (1975) and Chittenden (1972) both demonstrated that juvenile shad are adversely impacted by cold water releases in the West Branch and would abandon the affected areas. The East Branch is utilized as nursery habitat though the extent probably varies with temperature in any given year and warrants further study.

Ross and Johnson (1997) found relatively general habitat use by juvenile shad in the mainstem upper Delaware River with some affinity for riffles and submerged aquatic vegetation (SAV). Chittenden (1976) found the chief nursery in 1966 was apparently located upstream from Dingmans Ferry (rkm 385, rm 239) and was especially centered near Tusten, NY and Lordville, NY. Ross et al. (1997) found no overall effect of habitat type on juvenile American shad relative abundance in the upper Delaware River, indicating that juveniles use a wide variety of habitat types to their advantage.

The hypothesis that young of year (YOY) shad utilize all mainstem habitats is assumed to be true. With the improved water quality, particularly in the freshwater reach of the upper estuary, the presence of YOY shad has been observed throughout the entire mainstem. Furthermore, the presence of YOY shad has been observed in those tributaries in which existing dams were outfitted with fishway passages. However, the utilization of these tributaries by American shad for spawning and subsequent nursery habitat is presumed minimal, given the ineffectiveness of the fishways to facilitate the successful passage of returning shad.

5. Threats Assessment & Habitat Restoration/Mitigation

5.1 Barriers

Although the mainstem Delaware is free of dams, the Northeast Aquatic Connectivity Project evaluated 1,547 dams on 20,320 km of river in the Delaware River Basin (Martin and Apse 2010). This corresponds to a density of one dam for every 13 km of river. A table with information on each dam in the basin can be found in Appendix 2. The Paulinskill, Schuylkill, Lehigh, Brandywine, and White Clay Creek are systems with shad runs that would benefit the most from dam removal. For more information on ranking and results please refer to the report which can be accessed here http://rcngrants.org/content/northeast-aquatic-connectivity.

A continuing challenge in the Delaware system to removing dams is the historic status and values of many of the dams and canals such as the Fairmount Dam on the Schuylkill and the canal system on the Lehigh. This historic status complicates or even precludes the possibility of removal even though the dams no longer serve any significant purpose.

Restoration/Mitigation

The Lehigh River is considered one of the most important tributaries for American shad restoration in the Delaware River Basin. Full utilization of this habitat is prevented by multiple dams and water quality issues. There are five dams impairing or blocking fish movement into and within the Lehigh River. They are Easton Dam (rkm 0), Chain Dam (rkm 5), Hamilton St. Dam (rkm 27), Cementon Dam (rkm 38), and the Francis E. Walter Dam (rkm 125). The Easton (owned by PA Dept. of Conservation and Natural Resources) and Chain (owned by the City of Easton) dams represent legacies from the canal/lock navigation systems from the 1800's. Presently these dams are only used to provide flooding of short sections of canals, principally for aesthetics and for the benefit of concessionaires that operate canal boats as a tourist attraction. The Hamilton St. Dam, owned by the City of Allentown, provides recreation and water supply to Allentown, PA; whereas the Cementon Dam is privately owned by LeFarge Corporation for industrial water supply to their daily operations. The Francis E. Walter Dam, owned and operated by U. S. Army Corps of Engineers, is the political result of devastating flooding from hurricanes in the 1950's. Its primary purpose is flood control but it is secondarily managed for recreational activities, principally whitewater rafting and tailwater trout fishery.

Although there are fishways on the Easton and Chain dams, they have been fairly ineffective at passing American shad. Passage has been documented since their construction, with annual average passage of 1,662 individuals at Easton Dam and 499 individuals at Chain Dam, since 1995. Passage through the Hamilton St. Dam fishway is unknown at this time, but assumed nominal. The Cementon Dam and Francis E. Walter Dam are presently without fish passage facilities.

Recognizing the anticipated return of an annual American shad run into the Lehigh River of at least 160,000 individuals has not materialized, even after significant modification to the fishway structure at the Easton and Chain dams, other options must be explored to improve passage on the Lehigh. A feasibility study was just completed that assessed options for improving fish passage through both the Easton and Chain dams (http://www.google.com/url?sa=t&rct=j&q=easton%20dam%20feasibility%20study%20wildlands%20conservancy&source=web&cd=1&cad=rja&ved=0CDQQFjAA&url=http%3A%2F%2Fwildlandspa.org%2FPDF%2FfishpassageStudy2013.pdf&ei=BWyaUb_IKIfa4AOd7YC4CQ&usg=AFQjCNFF_BG4nHRwvcXMi1vtPqzO_f1ZVA). This study concluded that complete removal of the Easton and Chain dams was the only alternative which was certain to improve fish passage into the Lehigh River. If both Easton and Chain dams were removed or significantly altered to provide improved fish passage, it would provide for nearly 27 km of restored fish habitat up to the base of the Hamilton St. Dam located in Allentown, PA. Any action involving modification/removal of these structures would impact numerous stakeholders, and would be dependent on the willingness of the dam's owners to pursue the goal of complete removal. The Co-op members agree with the conclusions of the study, i.e., that complete removal of both the Easton and Chain dams, is the only alternative which is certain to maximize fish passage into the Lehigh River. To this end Co-op members hope that by speaking as one voice on this issue, that our state-federal partnership will be influential in persuading stakeholders to eventually seek removal of the Easton and Chain dams.

The Cementon Dam has also been identified as a blockage to fish passage, due to the lack of any kind of fish passage device. The DRBC Docket D-1974-189-2, approved May 10, 2012 addresses dam removal and fish passage of the Cementon Dam (www.state.nj.us/drbc/library/documents/dockets/1974-189-2.pdf). The docket, provides for the LeFarge Corp. conducting a dam removal/fish passage feasibility study be completed by 10 May

2017. Improved fish passage at this facility will open an additional 85 rkm up to the base of the Francis E. Walter Dam.

The Schuylkill River is the largest tributary to the Delaware River. The USFWS estimated that the Schuylkill River has habitat to support 700,000 to 800,000 shad (USFWS 1999). However, the numerous dams that have been built for various reasons since colonial days effectively extirpated American shad from the river. During the 1970's shad were detected below the Fairmount Dam on the Schuylkill River. This eventually led to the installation of a fish ladder on this dam; however, it was poorly designed and few shad were successfully passed. The Fairmount Dam fish ladder underwent major renovation in 2008 and the new fish ladder expected to pass 200,000 to 250,000 shad yearly. However, current passage numbers are far lower than the restoration goals, with approximately 3,500 shad passed in 2011. Passage through the Fairmount Dam fishway will continue to be monitored by the Philadelphia Water Department (PWD).

Fish passage on the Schuylkill River is further constrained by the series of dams upriver of the Fairmount Dam. In recent years, fish ladders or dam removal have led to significant improvements in the opportunity for passage through this system, though shad still have to navigate through four fishways. The following list details the recent improvements in passage.

a. Fairmount Dam (rkm 14.5) - Fishway underwent major renovation in 2008 by the owner, City of Philadelphia.
b. Flat Rock Dam (rkm24) - Fishway was completed by the owner, PA Department of Environmental Protection (PA DEP), and became operational in 2006.
c. Plymouth Dam (rkm 29) - Dam was removed in 2010, by the owner, PA DEP.
d. Norristown Dam (rkm 34) - Fishway was completed by Exelon Energy in January, 2008 and opened to fish passage.
e. Black Rock Dam (rkm 59.5) - Fishway went into service on June, 2009 installed by the owner Exelon Energy.
f. Vincent Dam (rkm 67.5) - Dam was removed in 2009, the owner, PA DEP.
g. Felix Dam (rkm 127) - Remnants of this breached dam, owned by PA DEP, was removed in December, 2007.

In addition to the efforts to improve passage on both the Lehigh and Schuylkill rivers, the PFBC has been stocking otolith-marked American shad fry in both rivers since 1985. Shad eggs for the stocking program are collected from Delaware River shad. Since 2000, all Delaware River shad fry have been primarily allocated to the Lehigh and Schuylkill rivers. But occasionally excess production has been stocked back into the Delaware River at Smithfield Beach (2005 – 2008). Since 1985, egg-take operations on the Delaware River have resulted in the use of an average of 765 adult shad brood fish per year. Eggs from these shad are fertilized and transported to the PFBC's Van Dyke Anadromous Research Station, located on the Juniata River at Thompsontown, Pa, where they are hatched and otolith-marked with oxytetracycline (OTC).

The contribution of hatchery-reared fry to the returning populations of the Delaware, Lehigh and Schuylkill Rivers has been estimated by analysis of daily tagging patterns from OTC within the otolith microstructure of adult fish (Hendricks et al. 1991). The total hatchery contribution at Smithfield Beach on the mainstem Delaware, which is located upstream of the confluence of the Lehigh and Schuylkill Rivers, has been low, ranging from 0.0 to 7.8%. In contrast, on the Lehigh River the average contribution of hatchery fish has been 74%. At the Fairmount Dam on the Schuylkill River, about 96% of the fish returning to spawn are of hatchery origin. Hendricks et al. (2002) demonstrated the occurrence of hatchery stocked shad in the Raubsville collections on the Delaware River. Hatchery origin fish favored the west side of the river, presumably homing to the Lehigh River where they were stocked as fry.

The PFBC plans to reevaluate its stocking program in the Delaware River system in the near future relative to the findings of the Lehigh River Fish Passage Feasibility Study mentioned above.

Currently there are 11 dams on Brandywine Creek in the City of Wilmington. The Brandywine Conservancy and partners completed a feasibility study in 2009 to assess migratory fish passage options in this watershed. Initiatives by DNREC and others are working towards removal of multiple dams, while improving passage at other dams.

A feasibility study was completed in 2010 is to assess the possibility of restoring fish passage and habitat on White Clay Creek in the White Clay Creek National Wild and Scenic River watershed (http://www.ipa.udel.edu/publications/ShadRestoration.pdf). In 2012, funding was secured from NOAA/American Rivers to remove the first dam, which will open up 5.5 km of river.

5.2 Dissolved Oxygen

Major strides have been taken to improve dissolved oxygen levels in the Delaware and by the late 1980s, dissolved oxygen began to regularly exceed the 3.5 mg/L water quality criterion set in 1967 for the urban zones of the estuary (PDE 2012). Although water quality in the mainstem has improved dramatically, "D.O." sags near Philadelphia, PA still occur during summer months. There have been many episodes since 2000 in which dissolved oxygen has dropped below 3.5 mg/L (DRBC 2010b, PDE 2012, USGS-NWIS 2013) creating conditions lethal to some life stages of American shad. Additionally, most of the coastal tributaries that drain into the Delaware River and Bay from the State of Delaware are impaired due to nutrients and/or dissolved oxygen (DNREC 2005). For American shad, Stier and Crance (1985) report that D.O. of at least 4.0 mg/l is necessary in spawning areas and that mortality of eggs and larvae exposed to D.O. concentrations of 2.5 to 2.9 mg/l was about 50% with 100% mortality of eggs at D.O.'s below 1.0 mg/l. Larvae lost equilibrium at a D.O. of 3.0 mg/l; many died at D.O.'s below 2.0 mg/l; and all died at 0.6 mg/l. Juvenile shad seem to prefer high D.O. concentrations when exposed to a gradient but can probably survive low D.O. (0.5 mg/l) for several minutes if they have access to D.O. above 3.0 mg/l. Minimum D.O.s of 2.5 -3.0 mg/l are probably sufficient to allow juvenile migration through polluted waters but severely low D.O. concentrations in rivers can prevent the passage of adult shad to spawning areas upstream.

Recent observations, by Co-op members indicate that shad spawning has returned to the tidal areas of the Delaware. Therefore all life stages of shad may be found in areas of potential D.O. sag. Given the above D.O. requirements, it appears that there is potential for adverse impact to American shad in the Delaware Estuary, especially in juvenile life stages.

Restoration/Mitigation

Any future management actions taken to improve dissolved oxygen and other water quality conditions in the Delaware Estuary and River basin will benefit American shad and the Delaware River ecosystem in general. The DRBC is assessing the feasibility of increasing dissolved oxygen standards in the urbanized corridor to better support aquatic life.

The State of Delaware has either developed or is developing Total Maximum Daily Loads (TMDL's) for nutrients for its impaired coastal tributaries; however, progress on developing strategies to address nutrients and dissolved oxygen has been slow.

5.3 Flow Alteration

River flows on the Delaware River have long been manipulated by the combined outflow from three NYC reservoirs. Management of these reservoirs is linked to a 1954 U. S. Supreme Court Decree, which provides for the supply of up to 800 million gallons per day of water to the NYC metropolitan area. The Decree stipulates the use of reservoir releases for maintaining a river flow objective of 1,750 cfs at Montague, NJ. Over the years since the 1954 Decree, reservoir releases have been managed through a series of evolving programs based on unanimous agreement by the Parties to the Decree (States of New Jersey, New York and Delaware, Commonwealth of Pennsylvania, and New York City). The "Flexible Flow Management Program" (FFMP) is the current framework for managing diversions and releases from NYC's Delaware River Basin reservoirs. This program was designed by the Decree Parties to support multiple flow management objectives, including water supply; drought mitigation; flood mitigation; protection of the tailwater fisheries; a diverse array of habitat needs in the mainstem, estuary and bay; recreational goals; and salinity repulsion in the Delaware Estuary related to maintaining adequate water quality for municipal water supply withdrawals from the estuary. River reaches immediately below the NYC reservoirs are managed as cold-water trout tailwaters, which has been shown to preclude American shad from utilizing these reaches of river.

Restoration/Mitigation

The FFMP was implemented in 2007 and successively modified annually thereafter for the management of the three NYC reservoir releases. The FFMP was designed to provide a more natural flow regime and a more adaptive means than the previous operating regimes for managing releases and diversions from these reservoirs, inclusive of improved modeling tools. Changes to the FFMP involve complex negotiations among Decree Party principals. The long-term goals of the PFBC and NYDEC have been to develop and promote the cold-water trout fishery via releases from the

NYC water supply reservoirs. Extensive modeling studies are needed to explore the potential of managing reservoir releases for the concomitant utilization of the upper Delaware River by both trout and American shad. These types of studies, however, are not a principal focus.

5.4 Emerging Containments

Contaminants of emerging concern (CECs) are chemicals that have entered the environment through human activities. They have been detected in humans or other living organisms and have been found to persist in the environment, but they are not routinely monitored and are currently unregulated. Examples include phthalates, perfluoroalkyl and polyfluoroalkyl substances (PFASs), brominated flame retardants (PBDEs), nanoparticles, pharmaceuticals and personal care products (PPCPs). Many of the CEC's are known endocrine disrupting chemicals (EDCs) and are thought to be especially important at the larval or developmental stages of fish, disrupting sexual development, behavior, and fertility (Pait and Nelson 2002, Vajda et. al. 2008).

Restoration/Mitigation

A number of efforts have been undertaken within the Delaware River Basin to identify, understand, and prioritize CECs, including a three year effort by DRBC to investigate the presence and concentration of PPCPs, PFASs, and PBDEs in the ambient waters of the tidal Delaware River (MacGillivray 2007). Future research and potential legislation regulating these chemicals will be important to understanding their potential impacts to shad and other aquatic life in the urbanized part of the river.

5.5 Natural Gas Development

As shale-gas development is poised to move into the Delaware River Basin (fully 36% of which is underlain by Marcellus Shale), it will bring with it an industrial activity with a risk of environmental consequences. Potential effects may include surface and groundwater contamination related to hydraulic fracturing and disposal of drilling fluids, decreased stream flows resulting from surface water withdrawals, air quality degradation, soil contamination and compaction, forest fragmentation, and increased erosion and sedimentation due to large-scale development and changes in land use. All of these factors can result in additional water quality impacts. The cumulative impact potential of these effects on American shad of the Delaware River is unknown at this time.

Restoration/Mitigation

Strict compliance with Best Management Practices, coupled with prioritized protection of forested tracts, adequate site restoration and erosion and sedimentation controls, and sufficiently protective riparian buffers, may help to mitigate some of the threats posed by natural gas development. Currently, development of natural gas wells within the Delaware River Basin is under a DRBC moratorium, pending development of regulations.

5.6 Impingement and Entrainment

The U. S. EPA performed a case study of cumulative impacts from impingement and entrainment (I & E) at numerous industrial intakes in the Delaware Estuary (EPA 2002) and reported that fish losses (all species) were greater than 500 million age-1 equivalents annually and represented an economic loss of between $23.4 to $48.5 million each year (in year 2000 dollars).

The Co-op acquired 316b reports for five companies with cooling water intake structures (CWIS) on the Delaware River or its tributaries as well as annual biological monitoring reports for the Salem Generating Station. The Co-op reviewed the reports for I & E impacts on shad and found that impingement and/or entrainment is very significant at some sites (Fig. 5). In particular, American shad entrainment is very high at the Eddystone and Fairless Hills generating stations. Additional withdrawals exist in the river and estuary, but the Co-op has not reviewed CWIS data on these intakes.

Although there is a significant loss of America shad due to I&E, studies characterizing the loss are infrequent and companies are not required to provide mitigation. Furthermore, studies tend to characterize I&E losses by individual plants and not the cumulative impacts to the entire basin.

<u>Restoration/Mitigation</u>

Losses from I & E constitute a significant threat to American shad in the Delaware River. State fisheries agencies will need to work closely with the regulatory agencies and policy administrators to reduce losses. Cumulative losses and impacts need to be evaluated. The Co-op is determining potential avenues for obtaining mitigation for I & E losses and is working with appropriate agencies to advocate for Best Management Practices.

5.7 American Eel Weirs

In the Delaware and Neversink rivers in New York an American silver eel weir fishery exists. At times in the recent past up to 10 weirs were operating in one year on the Delaware River and two to three weirs on the Neversink. American shad are captured as bycatch in this fishery. The cumulative impact of all the weirs on American shad is unknown at this time.

<u>Restoration/Mitigation</u>

There is no current action to address the threat of eel weirs; however, the eel fishery could possibly be reduced or eliminated depending on how the ASMFC management action related to Addendum III to the ASFMC American Eel Fishery Management Plan is implemented.

5.8 Climate Change

Stream flow and temperature provide significant cues for shad migration and spawning in streams. Changes in the timing of peak spring flow have already been documented in the last 50 years (Frumhoff et al. 2007). Some predictions indicate that by 2040–2069 mean annual temperatures for the Delaware River Basin will be significantly warmer than experienced between 1971 and 2000 (DRBC 2008). This change may have implications for American shad in the basin. Increased flooding frequency and magnitude during critical migratory and spawning times may lead to higher potential for recruitment failure as flood conditions have a greater potential to sweep shad egg and fry out of nursery habitats. Extreme water temperature fluctuations during these times could also decrease productivity.

A recent analysis of flow data in the Upper Delaware by Moberg et al. (2009) found that at the Cooks Falls reference gage on the Beaver Kill the mean annual flow has increased from 532 to 597 cfs (12%) between the pre- and post-reservoir periods[2]. Median monthly flows have increased in summer, fall, and winter months, and have decreased during spring months (March-June). Low and high flows, including 3-, 7-, and 30-day events, have increased by 4 to 54%. In general, the post-reservoir period was wetter than the pre-reservoir period, as represented by both monthly median flows and the magnitude of low and high flow events. This pattern is consistent with long-term climatic trends published by Burns et al (2007).

Over their history, diadromous fish, in general, have shown to be resilient and adaptable to environmental changes and stressors. Large ranges, diverse habitats and extremely abundant populations account for this resilience (McDowall 2001). With the current status of American shad stocks at historic lows, however, changes in flow, temperature and extreme flooding events as a result of climate change are likely a more significant threat to the status of this species than if populations of shad were near historical abundances and if their full range of habitats were available. It is possible that tributary habitat may become important refugia for juveniles in certain years due to mainstem conditions i.e. major flood events. Sea level rise may impact the remaining freshwater tidal marshes in the lower basin and this potential could further degrade nursery habitat in this area.

Restoration/Mitigation

Historically, the notion of climate change has not been a focus of investigation for the Delaware River Basin. Yet, climate change is gaining momentum in the formation of various consortiums, groups, and governmental agencies releasing reports, models, and scenarios demonstrating the occurrence of climate change and potential forecasted impacts. While, there is no specific climate change restoration program aimed at American shad, within the Delaware River Basin, multiple initiatives, such as the current William Penn Watershed Initiative, seeks to protect and restore forests and floodplains to protect water quality in key shad watersheds in the basin could be

[2] The pre- impact period does not represent a natural�much or unaltered state, as the Upper Basin has a history of logging and land use conversion that have and continue to influence river processes.

important to improving and increasing habitat diversity and potentially provide additional refugia habitat. The DRBC has and is currently participating in panel discussions among peers, and continues exploring funding opportunities to further investigate this topic. The DRBC's State of the Basin Report (2008) includes a feature on climate change (in the hydrology section), which highlights the need for more localized studies, mapping, monitoring, and modeling, as well as for planning initiatives that integrate the reality of a changing climate. State agencies from all Co-op members also maintain programs for addressing climate change (http://www.state.nj.us/drbc/hydrological/climate/). Continued efforts to remove barriers will also allow shad access to tributary habitat that could increase resilience to climate change stressors.

5.9 Altered Trophic Structure

In the past the American shad in the Delaware River co-existed with fewer types of predatory fish than occur today. Since the late 1800's several species of piscivorous fish have been introduced and subsequently naturalized in the Delaware, including: largemouth bass, walleye, smallmouth bass, muskellunge, rainbow trout, and brown trout. Others including flathead catfish, northern snakehead, and Asian swamp eels have only recently begun to invading the lower reaches of the Delaware River Basin. During 2010 fall sampling, PFBC biologists collected numerous YOY and adult flathead catfish at both the Sandts Eddy, Pa (rkm 293) and Point Pleasant, Pa (rkm 251) stations. The PWD has documented flathead catfish inhabiting the fishway in Fairmount Dam, and these fish were likely targeting American shad as a food source during the spring spawning run. In 2008, the NJDFW documented the occurrence of Asian swamp eels in the Cooper River drainage in Silver Lake. Invasions outside of this water have not yet been documented.

In addition, the striped bass population has increased to historic highs coastwide and some studies have shown that river herring and shad can make up a substantial proportion of their diet (Walter *et al*., 2003; Savoy and Crecco 2004). With other prey species at historic lows, such river herring, and others entirely gone from the Delaware River, e.g. rainbow smelt, increased predation by striped bass and other piscivores may be having an adverse impact on the shad population.

Restoration/Mitigation

This type of threat is difficult to address and highlights the importance is ecosystem based management in fisheries. Based on stomach content analysis and direct observation of flathead catfish predation on alosine species, PWD actively targets and removes flathead catfish from the Fairmount Fishway during periods of heavy upstream migration of American shad, hickory shad, and river herring. The NJDFW will continue eradication and monitoring of swamp eels in the Cooper River drainage. Future studies such as stomach analysis on naturalized non-native species and the development of ecosystem level fish population models are critical to understanding if shad populations are being impacted by abundant prey populations. Because the non-native piscivores have themselves become prized by numerous groups of anglers, eradication of them is unlikely.

5.10 Dredging and Other In-Water Construction

The federal navigation channel in the Delaware River is presently 40 foot deep. The Delaware Deepening Project, which is now underway within the existing navigation channel, will deepen it from 40 ft to 45 feet from Philadelphia Harbor, Pa/ Camden, NJ along a 165 km distance into the Delaware Bay. In addition to direct habitat loss due to dredging and blasting, a salinity model completed by the U. S. Army Corp of Engineers indicates that deepening the existing navigation channel will result in salinity increases in the Philadelphia, Pa area in the event of a recurrence of the drought of record. In addition to dredging, there is a threat from the use of shoaling fans. These fans are used to keep water moving around docks to reduce frequency of dredging at docks; however, these fans can also entrain fish.

Restoration/Mitigation

The Co-op works closely with the U. S. Army Corps of Engineers to try and minimize the impacts of dredging and other encroachment activities on aquatic species. Co-op members have developed a document outlining preferred in-river construction activities, to best protect affected species for the Delaware River and Bay (DRBFWMC 2012).

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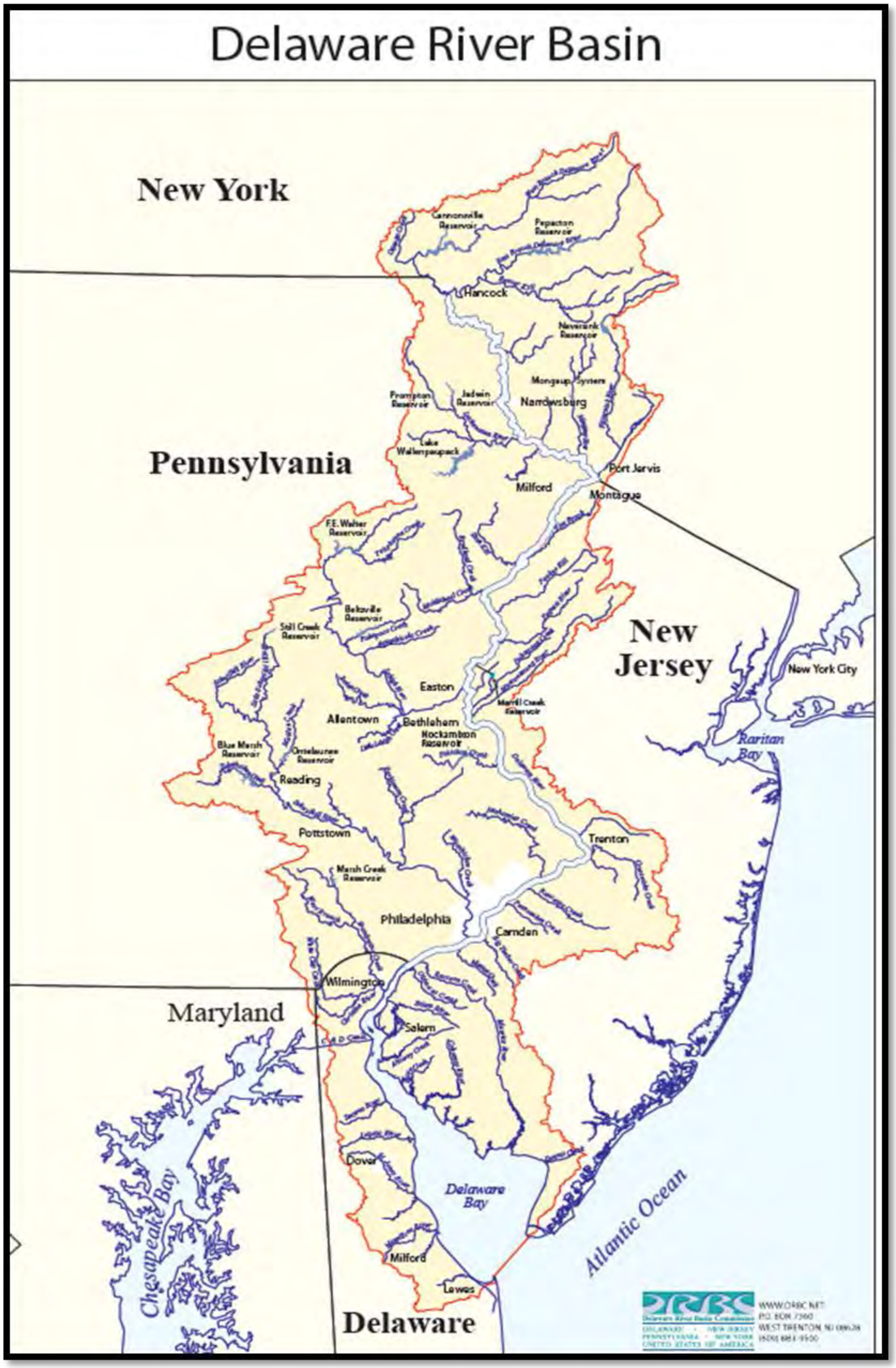

Figure 1: Delaware River Basin

Table 1: Historic and Contemporary Channel Deeping and Widening. Source: http://www.nap.usace.army.mil/Missions/CivilWorks/DelawareRiverMainChannelDeepening.aspx			
Delaware River, Philadelphia to the Sea			
Authorization	Depth (Ft)	Width (Ft)	Complete
NATURAL CONDITIONS (pre-1885)	17'-24'	175'-600'	n/a
January 1885 Board of Engineers recommendation	26'	600'	1898
March 1899 improvement plan	30'	600'	1905
June 1910 River and Harbor Act	35'	800'	1934
June 1938 River and Harbor Act	40'	800'-1000'	1942
Water Resources Development Act 1992	45'	400'-1000'	est. 2017

Figure 2: Historical and present day generalized location of the salt front. During the drought of record in the mid-1960's, the salt front reached river mile 102, just upriver from the Ben Franklin Bridge (rm 100). The present day location of the salt front is located at river mile 69.

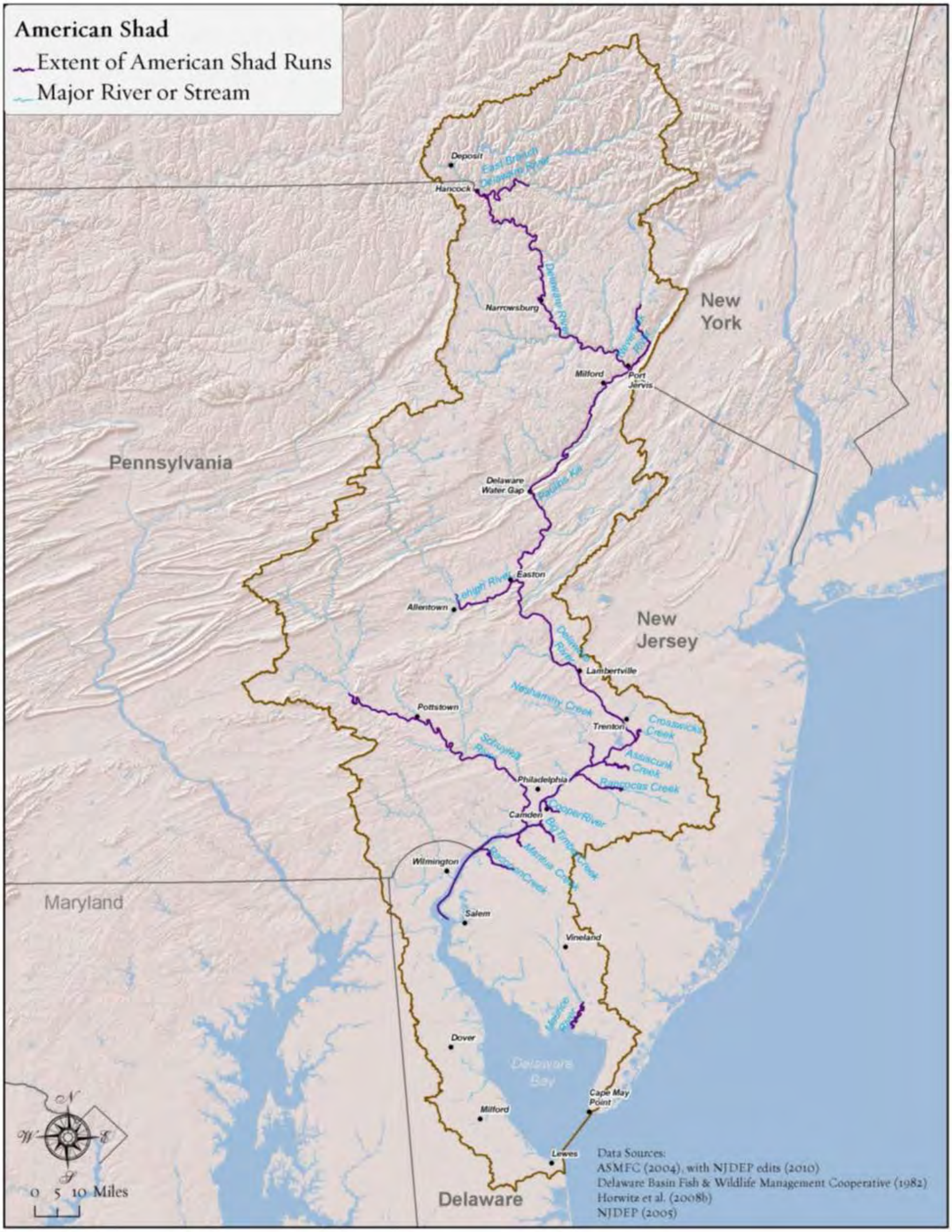

Figure 3: Shad runs (as of 2010).

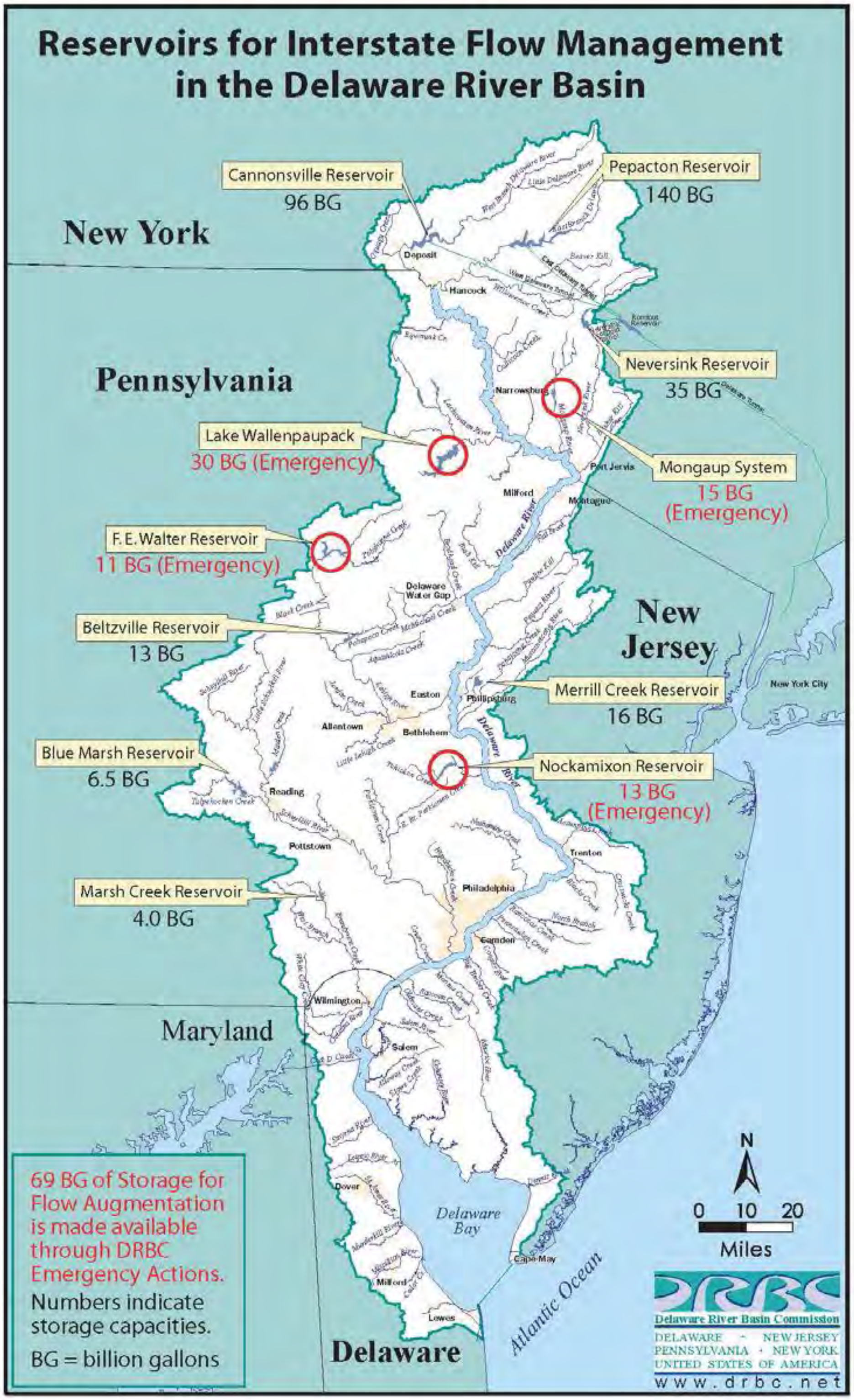

Figure 4: Delaware Basin Regulated Reservoirs.

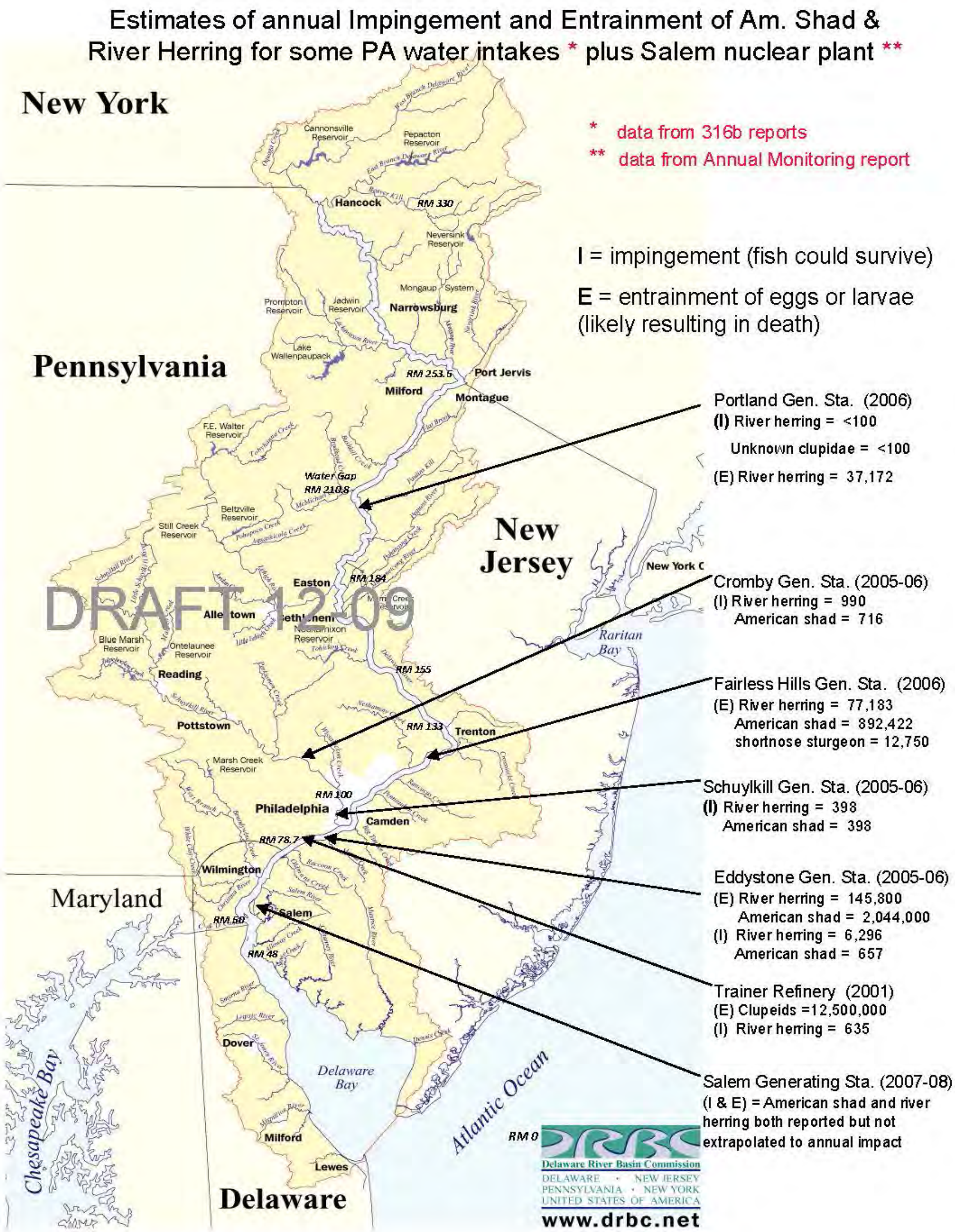

Figure 5: I&E losses.

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
Joseph P. Gill, Secretary
Frank W. Dawson III, Deputy Secretary

Maryland's American Shad Habitat Plan

Submitted to the
Atlantic States Marine Fisheries Commission

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15 September 2013

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Maryland’s American Shad Habitat Plan

Habitat Assessment

Spawning Habitat:
Historical in-river spawning habitat: 448.5 km
Currently available spawning habitat: 441.6 km
Rearing Habitat:
Historical in-river rearing habitat: 382.2 km
Currently available rearing habitat: 382.2 km

Spawning and rearing habitat were calculated only for Maryland waters under Maryland jurisdiction (Funderburk et al. 1991; Table 1). Habitat behind dams with fish passage facilities were considered currently available habitat. Most of the dams in Maryland are located far enough up the watershed so as not to impact American shad use of habitat in Maryland waters.

Threat: Barriers to Migration

The inventory of dams included in this report can potentially be encountered by American shad (Table 2). As stated previously, most of the dams in Maryland are located far enough up the watershed so as to not impact American shad use of habitat in Maryland waters. Barriers to migration are primarily considered a threat in Maryland because the Conowingo Dam (the first dam in the Susquehanna River) is located in Maryland and affects the passage of American shad to other states’ portions of the river.

Recommended Action 1 (See Task A1 in SRAFRC Habitat Plan): Develop and implement upstream passage plans and performance measures at the Conowingo hydroelectric dam to ensure that the facility passes at least 85 percent of the adult American shad reaching the tailrace. Incorporate upstream passage plans and evaluation requirements in FERC licenses. Recommend or conduct evaluation studies as necessary. Require additional fish passage capacity, as needed, to meet fish passage targets. Report fish passage results annually.

> **Agencies with Regulatory Authority:** SRAFRC (made up of MDNR, PFBC, SRBC, and USFWS members), and FERC.
> **Goal/Target:** Goals listed in the recommended action are to be met in conjunction with FERC relicensing and compliance.
> **Progress:** FERC relicensing is ongoing.
> **Cost:** SRAFRC member agencies are responsible for overhead. The dam owner’s cost is dependent on the level of fishway improvement required to meet target levels.
> **Timeline:** Action goals are to be accomplished upon completion of FERC relicensing in 2014.

Recommended Action 2 (See Task A2 in SRAFRC Habitat Plan): Develop and implement downstream passage plan and measures for adult alosine species at the Conowingo hydroelectric dam to ensure at least 80 percent survival. Incorporate adult downstream passage plan and evaluation requirements in FERC licenses.

Agencies with Regulatory Authority: SRAFRC (made up of MDNR, PFBC, SRBC, and USFWS members), and FERC.
Goal/Target: Goals listed in the recommended action are to be met in conjunction with FERC relicensing and compliance.
Progress: FERC relicensing is ongoing.
Cost: SRAFRC member agencies are responsible for overhead. The dam owner's cost is dependent on the level of fishway improvement required to meet target levels.
Timeline: Action goals are to be accomplished upon completion of FERC relicensing in 2014.

Recommended Action 3 (See Task A3 in SRAFRC Habitat Plan): Develop and implement juvenile downstream passage plan and performance measures at the Conowingo hydroelectric dam to ensure 95 percent survival of juvenile alosine species at this facility. Incorporate juvenile downstream passage plan and evaluation requirements in FERC licenses. Include operational measures at the hydroelectric dam as needed to enhance downstream passage survival of juvenile alosine species.

Agencies with Regulatory Authority: SRAFRC (made up of MDNR, PFBC, SRBC, and USFWS members), and FERC.
Goal/Target: Goals listed in the recommended action are to be met in conjunction with FERC relicensing and compliance.
Progress: FERC relicensing is ongoing.
Cost: SRAFRC member agencies are responsible for overhead. The dam owner's cost is dependent on the level of fishway improvement required to meet target levels.
Timeline: Action goals are to be accomplished upon completion of FERC relicensing in 2014.

Recommended Action 4 (See Task A9 in SRAFRC Habitat Plan): Minimize delays at the Conowingo hydroelectric dam to foster adult spawning fish migration to the upper limits of historical spawning habitat in the watershed.

Agencies with Regulatory Authority: SRAFRC (made up of MDNR, PFBC, SRBC, and USFWS members), and FERC.
Goal/Target: Goals listed in the recommended action are to be met in conjunction with FERC relicensing and compliance.
Progress: FERC relicensing is ongoing.
Cost: SRAFRC member agencies are responsible for overhead. The dam owner's cost is dependent on the level of fishway improvement required to meet target levels.

Timeline: Action goals are to be accomplished upon completion of FERC relicensing in 2014.

Recommended Action 5: To continue to provide for fish passage at dams, and remove stream blockages wherever necessary to restore passage for migratory fishes to historical spawning grounds.

Agencies with Regulatory Authority: MDNR (Fish Passage Program), in cooperation with the Chesapeake Bay Program, Pennsylvania, Virginia, and the District of Columbia.
Goal/Target: MDNR has been part of the Chesapeake Bay Agreement (to provide fish passage at dams and remove stream blockages) since 1987. The current goal of the Agreement is to open 2,807 miles by 2014 and favors dam removals over fish ladders.
Progress: To date, MDNR's Fish Passage Program has completed 78 projects, reopening a total 454.2 miles of upstream spawning habitat (in Maryland).
Cost: Total cost and responsible agencies depend on the project. In Maryland, participants include but are not limited to MDNR, American Rivers, NFWF, NOAA, Simkins Industries, CBP, EBTJV, and the USFWS.
Timeline: The original goal of the Chesapeake Bay agreement was to reopen 1,300 miles in the Chesapeake Bay watershed for anadromous species (such as shad and herring) so they could reach upstream spawning habitat. After surpassing the original goal (1,838 miles reopened by 2005), the goal was expanded to 2,807 miles by 2014.

Threat: Land Use

MDNR has various programs that work to assess the health of Maryland's watershed and the impacts of development. There are few, if any, direct studies on the effects of land use on American shad in Maryland. The MDNR Fisheries Habitat and Ecosystem Program (FHEP) assesses the impacts of development on alosine (river herring, American shad, hickory shad) eggs and larvae in Piscataway Creek and the Bush River (higher levels of development), and Mattawoman and Deer Creeks (lower levels of development). The proportion of samples where alosine eggs and/or larvae were present was negatively correlated with the level of development, and alosine spawning became more variable in streams as watersheds developed (i.e., presence in new spawning sites and absence from past spawning sites; Uphoff et al. 2012b). Variability at higher levels of development could signify the redistribution and deterioration of spawning habitat due to urban and natural stream processes.

Fisheries managers do not have authority to manage land use and are limited to managing the harvest of fishes that may be threatened. The FHEP works to tie land use and fisheries management together; this program's research supports the 10% impervious surface threshold as the 'tipping point' beyond which little success is expected in maintaining sustainable fisheries. American shad fisheries are closed in Maryland, but an explanation of Maryland's watershed fishery management priorities are as follows (Figure 1):

- Conserve - areas with less than 5% impervious surface; recommend harvest restrictions and stocking for effective fisheries management and watershed conservation for sound land management.
- Revitalize – areas with 5-10% impervious surface; recommend options to decrease harvest and increase stocking to compensate for effective fishery management, and conserve and revitalize watershed for sound land management.
- Re-engineer – areas with 10-15% impervious surface; fisheries are highly variable; traditional fishery management tools are not reliable. Recommend conserving and reconstructing degraded watershed for land management – typically re-engineering will address nutrient reductions for larger scale TMDL, but this is not expected to have local biological lift.
- 15% impervious – from a fishery management point of view, investments to enhance large scale fisheries are not expected to be effective; local re-engineering can address localized habitat stability needs, but are not expected to provide additional ecological lift.

Recommended Action: To continue to promote the conservation and revitalization of watersheds, especially in areas vulnerable to growth. Conserving watersheds at a target level of development is ideal [0.27 structures per hectare (C/ha) or 5% impervious surface cover; Uphoff et al. 2012a]. Once above this level of development, revitalization and reconstruction could consist of measures such as road salt management, stemming leaks in sewage pipes, improving septic systems, stormwater retrofits, stream rehabilitation, replenishment of riparian buffers, creation of wetlands, planting upland forests, and "daylighting" of buried streams (Uphoff et al. 2012b). Other effects that may exacerbate development related habitat stressors (i.e., climate change) should also be considered.

Agencies with Regulatory Authority: The planning authority is typically the local government, with the Maryland Department of Planning serving in an advisory capacity. Fisheries managers do not have authority to manage land use and are limited to managing the harvest of fishes that may be threatened.
Goal/Target: Maryland does not have a specific goal for protecting American shad from land use impacts, aside from the harvest controls that were put in place when Maryland established a moratorium in 1980. If the fishery reopens, fisheries managers can manage American shad differently at different levels of development.
Progress: Maryland established a moratorium in 1980 to help protect American shad populations from declining further due to a variety of causes, including habitat degradation.
Cost: NA
Timeline: NA

Threat: Climate Change Assessment

American shad may be vulnerable to climate change, although this risk is probably not high in Maryland. Alewife and blueback herring (alosine species), are considered to have a relatively high adaptive capacity to impacts of climate change because they are found throughout the region and are not inhibited in the watershed (except where there are dams; Kane 2013). As anadromous fish, American shad spend their adult lives in the Atlantic Ocean and migrate inshore to spawn. Migration and spawning are heavily influenced by water temperature. In Maryland, peak spawning time is mid-April through early June, with temperatures ranging from 55 to 68°F. Changes in water temperature may affect the timing of migration, which may affect spawning and juvenile success and lead to a match-mismatch between predator and prey species (Boesch 2008). Many fish and bird species are dependent on American shad throughout the watershed, and reduced spawning or juvenile success could affect these predators. The migration of juvenile American shad to the ocean in the fall is triggered by decreasing water temperature, and migration to the ocean may be delayed due to warmer fall temperatures (Kane 2013). If temperatures in the Chesapeake Bay region warm to resemble those of North Carolina or Florida, a northward shift in species distribution may affect species composition in the Chesapeake Bay and its tributaries. The Chesapeake Bay is at the mid-range for American shad, which may minimize distributional shifts of this species due to warmer water temperatures. However, competition for resources may be altered due to shifts in other species' distributions. Along with increases in water temperature, increased intense storm events and sea-level rise will affect salinity, dissolved oxygen, and sediment in the water column and may affect efforts to effectively manage water quality.

Recommended Action: Promote the assessment of climate change effects on American shad, and continue to promote water quality control efforts, habitat restoration, and reduction of ocean bycatch.

> **Agencies with Regulatory Authority:** MDNR, ASMFC, MAFMC and NMFS
> **Goal/Target:** Maryland does not currently have a goal for addressing the threat of climate change. It is likely that American shad will have a relatively high adaptive capacity.
> **Progress:** NA
> **Cost:** NA
> **Timeline:** NA

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Uphoff, J.H., Jr., and coauthors. 2012b. Marine and estuarine finfish ecological and habitat investigations. Performance Report for Federal Aid Grant F-63-R, Segment 3, Job 1. Maryland Department of Natural Resources, Annapolis, Maryland.

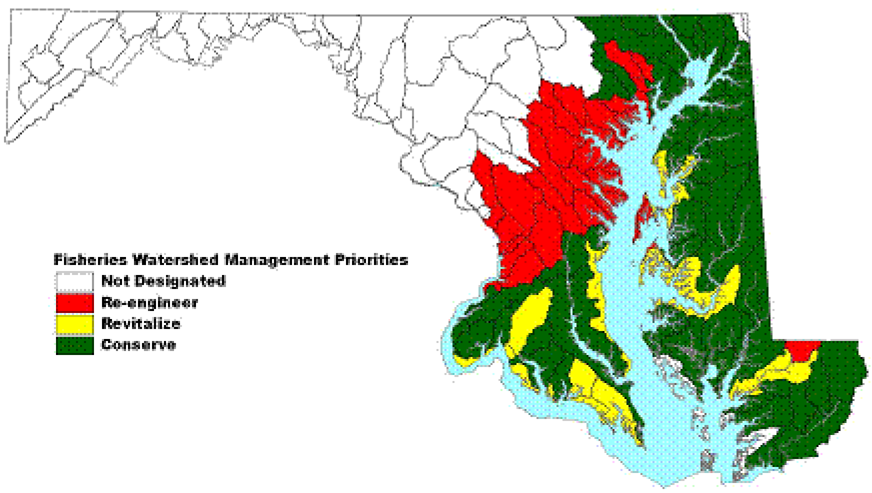
Table 1. Historical and currently accessible spawning and rearing habitat for American shad in waters regulated by the state of Maryland. Most of the dams in Maryland are located far enough up the watershed so as not to impact habitat use of American shad in Maryland waters.

Habitat Type	River (MD portion only)	Historical Habitat (km)	Current Habitat (km)	Percent Available	Limited By
Spawning	Susquehanna	22.5	22.5	100%	State Line
	Upper Bay/Susq Flats	21.4	21.4	100%	Habitat
	Principio Creek	2.4	2.4	100%	Natural Falls
	North East	13.2	13.2	100%	Natural Falls
	Elk Main	26.6	26.6	100%	Habitat
	C/O Canal	8.9	8.9	100%	Habitat
	Elk Trib	8.0	8.0	100%	Habitat
	Elk Trib	5.0	5.0	100%	Habitat
	Bohemia Main	20.1	20.1	100%	Habitat
	Sassafras Main	19.3	19.3	100%	Habitat
	Chester Main	43.5	43.5	100%	Habitat
	Chester Trib	7.1	7.1	100%	Habitat
	Chester Trib	5.8	5.8	100%	Habitat
	Tuckahoe	15.6	15.6	100%	Habitat
	Choptank Main	25.7	25.7	100%	Habitat
	Choptank Trib	6.6	6.6	100%	Habitat
	Marshyhope	35.9	35.9	100%	Habitat
	Nanticoke	16.9	16.9	100%	State Line
	Wicomico East	27.8	20.9	75%	Man Made Dam
	Manokin	14.5	14.5	100%	Habitat
	Pocomoke	45.1	45.1	100%	Habitat
	Patuxent	56.6	56.6	100%	Habitat
	TOTAL	**448.5**	**441.6**	**98%**	
Rearing	Upper Bay	156.1	156.1	100%	
	Chester	43.5	43.5	100%	
	Choptank	25.7	25.7	100%	
	Nanticoke	16.9	16.9	100%	
	Wicomico	24.1	24.1	100%	
	Manokin	14.5	14.5	100%	
	Pocomoke	45.1	45.1	100%	
	Patuxent	56.3	56.3	100%	
	TOTAL	**382.2**	**382.2**	**100%**	

Table 2. Inventory of dams in Maryland that American shad can potentially encounter. Most of the dams in Maryland are located far enough up the watershed so as to not impact American shad use of habitat (in Maryland). Data on height, width, length and storage come from the Maryland Department of the Environment's Dam Safety List/Database.

Dam Name	Passage Type	Latitude	Longitude	Dam Height (ft) 0=unknown	Dam Length (ft) 0=unknown	Surface Area (acres) 0=unknown	Normal Dam Storage (acre feet) 0=unknown
LITTLE FALLS DAM - POTOMAC RIVER	Notch	38.94816947	-77.13063919	12	1,300	0	0
WILLISTON MILL DAM	Denil	38.82775591	-75.84685157	18	630	52	390
BLOEDE DAM	Denil	39.24689315	-76.76182877	34	220	31	256
TUCKAHOE STATE PARK DAM	Denil	38.96752257	-75.9425857	14	1,700	86	26
REWASTICO POND	None	38.41072883	-75.75367182	10	460	16	40
JONES LAKE DAM	Steepass	39.24697315	-75.81795339	13	1,180	36	33
CONOWINGO DAM	Lift	39.66121204	-76.17317693	94	4,648	8,563	301,400
MILL CREEK DAM	None	38.59483626	-75.82670033	11	300	0	0
LAKE CHAMBERS	None	38.69635252	-75.76461336	0	0	0	0
HIGGINS MILL POND	None	38.51896254	-75.96464395	0	0	0	0
ANDERSON MILL POND	None	38.35571295	-75.67386571	11	240	15	39
ALAN TOWN POND	None	38.28323503	-75.68891565	8	400	35	96
ISABELLA ST. WEIR	None	38.37188718	-75.60276893	3	0	0	0
ELKTON DAM	Denil	39.61236765	-75.81723297	3	0	0	0
FT MEADE DAM	Denil	39.0927176	-76.76833659	9	0	0	0
WILSONS MILL DAM	Denil	39.61459477	-76.20603991	4	0	0	0
VAN BIBBER DAM	Steepass	39.46862521	-76.33476293	2	0	0	0

Figure 1. Fisheries watershed management priorities in Maryland. *Conserve* - areas with less than 5% impervious surface; recommend harvest restrictions and stocking for effective fisheries management and watershed conservation for sound land management. *Revitalize* – areas with 5-10% impervious surface; recommend options to decrease harvest and increase stocking to compensate for effective fishery management, and conserve and revitalize watershed for sound land management. *Re-engineer* – areas with 10-15% impervious surface; fisheries are highly variable; traditional fishery management tools not reliable. Recommend conserving and reconstructing degraded watershed for land management.



District of Columbia's American Shad Habitat Plan

District Department of the Environment

This habitat plan is being submitted by the District Department of the Environment and covers the portions of the Potomac and Anacostia Rivers which fall within the borders of the District of Columbia. Historically adult and juvenile American shad populations have been present through all portions of the Potomac and Anacostia rivers within the borders of the District of Columbia. This plan will show what habitat is available for spawning and juvenile American shad within the District of Columbia.

Habitat Assessment

Potomac River

A) Spawning Habitat
Historical and current accessible in river and estuarine spawning habitat extends roughly 18.8 km and covers 1,388 hectares. This habitat represents the entire portion of the Potomac River as it flows though the District of Columbia.

B) Rearing Habitat
Historic and currently utilized in river and estuarine rearing habitat extends roughly 18.8 km and covers 1,388 hectares. This habitat represents the entire portion of the Potomac River as it flows though the District of Columbia.

Anacostia River

A) Spawning Habitat
Historical and current in river and estuarine spawning habitat stretches roughly 11 km and covers 378 hectares. This habitat represents the entire portion of the Anacostia River as it flows though the District of Columbia.

B) Rearing Habitat
Historical and currently utilized rearing habitat stretches roughly 11 km and covers 378 hectares. This habitat represents the entire portion of the Anacostia River as it flows through the District of Columbia.

Threats Assessment

Barriers to Migration

A) Inventory of Dams
There are no dams on the main stem of the Potomac or Anacostia rivers within the District of Columbia. The only dam of note is the dam at Peirce Mill on Rock Creek, a tributary of the Potomac River. This dam is managed by the National Park Service and serves as a historic and aesthetic site for the park service. The dam is located 11 km upstream from the mouth of Rock

Creek. Although the dam presents a barrier to migration for river herring, there is no evidence that American shad have ever reached the base of the dam. A Denil fish ladder has been constructed to allow passage of fish around the dam. Data is currently not available as to the effectiveness of the ladder for herring. Additional Information regarding the dam at Peirce Mill can be found at www.nps.gov/pimi/index.htm.

B) Inventory of other human induced physical structures
No data available

C) Inventory of altered water quality/quantity
No data available

Water withdrawals

A) Inventory of water withdrawals
No data available

B) Assessment of water withdrawals
No data available

Toxic and Thermal discharge

A) There is one known thermal discharge located within the District of Columbia: Blue Plains Sewage Treatment Facility. This facility is managed by DC Water located at:
5000 Overlook Ave SW
Washington, DC 20032
Current actions:
The District Department of the Environment has no evidence that the discharge has any detrimental effects on the migration and utilization of spawning habitat for American Shad. A complete overview of the operations and regulatory oversight of this facility is available at www.dcwater.com

B) Additional discharges within the District of Columbia include combined sewer overflows. This is a system in which high rain events cause storm water runoff to mix with sanitary sewers, and excess loads are discharged into the Potomac and Anacostia rivers as well as Rock Creek. This system of sewer lines are also managed by DC Water located at:
5000 Overlook Ave SW
Washington, DC 20032
Current actions:
The District Department of the Environment, Fisheries Research Branch has no regulatory authority regarding these discharges. DC Water has detailed records and reports with oversight from the U. S. Environmental Protection Agency. Currently there are multiple projects in place to help update the city's sewage treatment facilities, ultimately reducing the number of discharges into the rivers and Rock Creek. A complete list of these projects as well as their progress can be found at www.dcwater.com.

Channelization and Dredging

A) The only known Channelization or dredging project located within the District of Columbia at this time is the runway extension project at Reagan National Airport. This project is being managed by the Metropolitan Washington Airports Authority located at:
1 Aviation Circle
Washington, DC 20001
Current actions:
District Department of the Environment currently has no data to determine possible impacts on American shad migration and utilization of historic habitat. A detailed account of this project can be found at www.metwashairports.com.

Land use

A) Inventory of land use
No data available

Atmospheric Deposition

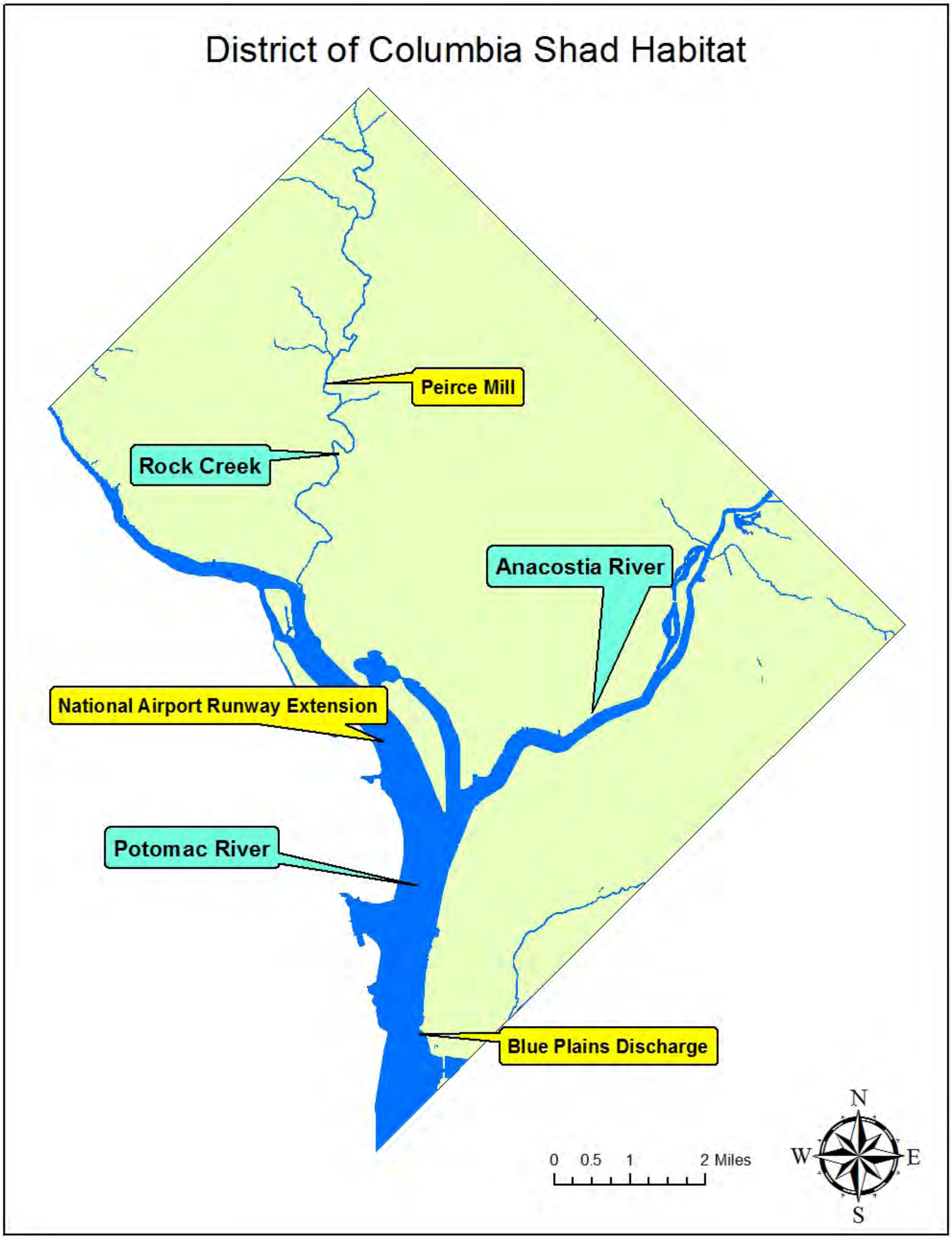
A) Atmospheric deposition assessment
No data available

Climate Change

A) Climate change assessment
No data available

Competition and Predation by Invasive and Managed Species

A) Invasive species assessment
The District Department of the Environment has been monitoring the population trends of two invasive species within the District of Columbia. These species include the blue catfish and Northern snakehead.
Current Actions:
The District Department of the Environment has an ongoing study examining stomach contents of the invasive blue catfish. To date, more than 500 blue catfish digestive tracts have been examined with no American shad observed. The opportunistic nature of the blue catfish still poses a potential impact to American shad populations within the District of Columbia.
Goals:
The District Department of the Environment has plans to continue this study to further understand the impacts that the blue catfish has on the resident and anadromous species within the District of Columbia.
Timeline:
The blue catfish stomach analysis study will continue until enough data has been gathered to determine the effects of this invasive species on the native and managed species of the District.


District of Columbia Shad Habitat
Peirce Mill
Rock Creek
Anacostia River
National Airport Runway Extension
Potomac River
Blue Plains Discharge
0 0.5 1 2 Miles
N
W
E
S

Potomac River Fisheries Commission

Habitat Plan for American Shad

Threat: Competition and Predation by Invasive and Managed Species

Action: Organize a Catfish Task Force with experts from the Chesapeake Bay region to integrate scientific data and current research on invasive catfish. Blue and flathead catfish are found in many areas of the Chesapeake Bay system. Blue catfish appear to be increasing in numbers and expanding their range throughout the Potomac River. The Catfish Task Force will develop a plan with management recommendations and strategies for the fisheries managers from the various jurisdictions to consider.

Regulatory Agencies/Contacts: Potomac River Fisheries Commission (PRFC), Maryland Department of Natural Resources (MD DNR), Virginia Marine Resources Commission (VMRC), Virginia Department of Game and Inland Fisheries (VDGIF), and D.C. Fisheries & Wildlife officials participate in the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (SFGIT), chaired by the director of the NOAA Chesapeake Bay Office.

Goal: convene a Catfish Task Force and develop an Invasive Catfish Action Plan

Progress: The SFGIT organized a Catfish Task Force in 2012, which has met several times. The Task Force acknowledges that eradication of invasive catfish is not feasible, so they are focusing on reducing abundance, mitigating spread, and promoting public awareness and communication. The Task Force is currently working on an Invasive Catfish Action Plan that will have management recommendations and strategies. Researchers from around the Bay were invited to brief the SFGIT on current studies related to invasive catfish from NOAA funded grants. A predation study on fishery resources by blue and flathead catfish is being conducted at VCU. A researcher at VIMS is exploring contaminants' impacts on the expansion of a fishery as a population control strategy. Another researcher at VIMS is conducting a tagging study to estimate population size and survival rates of blue catfish in the Chesapeake Bay tributaries. Trophic dynamics of blue catfish in Maryland are being investigated by researchers at the Smithsonian Environmental Research Center (SERC). The VDGIF is looking at catfish predation habits over broad spatial and temporal scales. Diet analysis of blue and flathead catfish are being investigated in Maryland (MD DNR).

Timeline: The Invasive Catfish Action Plan should be finalized in 2013. Some of the NOAA funded research projects are on either two or three year schedules to complete.

Commonwealth of Virginia
American Shad Habitat Plan

Prepared by:

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Virginia Marine Resources Commission

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Virginia Department of Game and Inland Fisheries

January 10, 2014

Agencies within the Commonwealth of Virginia with Regulatory Ability Related to American Shad or American Shad Habitat Management

Virginia Marine Resources Commission (VMRC). The VMRC is divided into three divisions: 1) Fisheries Management, which is charged with regulation of fisheries resources in tidal and marine environments, including collection of fisheries statistics, development of management plans, and promotion and development of recreational fishing activities; 2) Habitat Management, which manages and regulates the submerged bottom lands, tidal wetlands, sand dunes, and beaches; and 3) Law Enforcement, which enforces state and federal fisheries laws and regulations.

Virginia Department of Game and Inland Fisheries (VDGIF). The VDGIF manages and regulates inland fisheries, wildlife, and recreational boating for the Commonwealth of Virginia, and is responsible for enforcement of laws pertaining to wildlife and inland fisheries management.

Virginia Department of Environmental Quality (DEQ). The DEQ is charged with monitoring and regulating the quality of air and water resources in Virginia. DEQ is organized into many programs, including Air, Water, Land Protection and Revitalization, Renewable Energy, Coastal Zone Management, Enforcement, Environmental Impact Review, Environmental Information, and Pollution Prevention.

Habitat Assessment

In Virginia, American shad are found in the Chesapeake Bay and its major tributaries, including the Potomac, Rappahannock, York, and James rivers, as well as smaller tributaries and other coastal habitats (e.g., along the Delmarva peninsula) (Fig. 1). Additionally, American shad are found in certain rivers in Virginia that drain to North Carolina (Desfosse et al., 1994). Here we focus on the major western tributaries of the Chesapeake Bay as these areas have come to define the primary stocks in Virginia waters (the James, York, and Rappahannock stockes). Although certain spawning/rearing reaches are known for American shad for individual rivers (Bilcovic et al. 2002), the amount of habitat used by American shad for these life history stages at a river-wide scale is unknown for Virginia tributaries of the Chesapeake Bay. Several tidal portions of the three major Virginia tributaries of the Chesapeake Bay have been designated as high priority areas for living resources, and migratory fishes in particular (Figs. 2, 3).

James River System

The James River forms at the junction of Cowpasture and Jackson rivers (rkm 580), and its drainage is the largest watershed in Virginia, totaling 26,164 km^2 (Jenkins and Burkhead, 1994). Average annual spring discharge on the James River is 294.2 m^3/s (Tuckey 2009). Prior to damming, which began in the colonial period, shad and river herring were reported to reach these headwaters and far into the major tributaries of the James River (Loesch and Atran, 1994). The two primary tributaries of the James River below the fall line at Richmond are the Appomattox River, which joins at the city of Hopewell (rkm 112), and the Chickahominy River, which joins at rkm 65. The extent of salt water is variable, but brackish conditions are observed as far up as the mouth of the Chickahominy River on a seasonal basis. Tidal water reaches Boshers Dam in Richmond (rkm 182).

York River System

The York River system includes the Mattaponi and Pamunkey rivers, which merge at West Point, VA, to form the York River (53 rkm). This is the smallest of the three western tributary systems, with a watershed of 6,892 km^2 (Jenkins and Burkhead, 1994); the Pamunkey drainage is larger and has greater average spring discharge than that of the Mattaponi (3,768 km^2 and 47.5 m^3/s vs. 2,274 km^2; 27.2 m^3/s, Bilcovic 2000). Tidal propogation extends to approximately 67 rkm in the Mattaponi and 97 rkm in the Pamunkey (i.e., approximately 120 km and 150 km, respectively, from the mouth of the York River; Lin and Kuo, 2001). The extent of the salt intrusion varies by season, but moderate salinity values (>2 ppt) are often observed in lower portions of these rivers.

Rappahannock River System

The Rappahannock River, which is approximately 195 km in length (172 km is tidal; 118 is salt water), has its headwaters in the piedmont and is fed by the Rapidan River. The Rappahannock watershed encompasses a total of 7,032 km^2 (Jenkins and Burkhead, 1994), and the average annual discharge at the fall line is 45 m^3/s (O'Connell and Angermeier 1997). An estimated 125 tributaries of the Rappahannock River are potentially used by alosines (O'Connell and Angermeier 1997).

Threats Assessment and Habitat Restoration Programs

Rulifson (1994) identified the following river specific factors potentially involved in the decline of migratory alosines in Virginia, including American shad:

<u>Rappahannock River System:</u>
- System wide: dams, overfishing, turbidity, low oxygen

<u>York River System:</u>
- York River: industrial water intakes, industrial discharge locations, overfishing, chemical pollution, thermal effluents, low oxygen, sewage outfalls
- Mattaponi River: industrial discharge locations, overfishing, thermal effluents
- Pamunkey River: industrial discharge locations, overfishing, thermal effluents

<u>James River System:</u>
- James River: channelization, dredge and fill, dams, industrial water intakes, industrial discharge locations, overfishing, chemical pollution, thermal effluents, turbidity, sewage outfalls
- Nansemond River: dams
- Chickahominy River: dams, industrial discharge locations, overfishing.
- Appamattox River: dams
- Pagan River: turbidity, sewage outfalls

Further Rulifson (1994) identified the potential habitat management practices, or rather their effects, involved in the decline of migratory alosines in Virginia, including American shad:

Rappahannock River: inadequate fishways, reduced spawning habitat

York River System:
- York River: poor water quality
- Mattaponi River: poor water quality
- Pamunkey River: poor water quality

James River System:
- James River: inadequate fishways, reduced freshwater input to estuaries, reduced spawning habitat, poor water quality, water withdrawal
- Nansemond River: inadequate fishways, reduced freshwater input to estuaries, reduced spawning habitat, water withdrawal
- Chickahominy River: reduced freshwater input to estuaries, reduced spawning habitat, fishing on spawning area, water withdrawal
- Appomattox River: inadequate fishways, water releases from dams, reduced spawning habitat, water withdrawal
- Pagan River: turbidity, poor water quality

From the above threats assessment, two primary classes of threats and their associated repercussions are identified here in relation to American shad habitat needs and restoration in Virginia. These are discussed below. The threat of overfishing was addressed in 1994, when a harvest moratorium was put in place for all Virginia waters (a small bycatch fishery has been allowed in each river system since 2006).

Threat: Barrier to Migration (Dams). As an anadromous fish, American shad are negatively impacted by obstructions to migration from marine and estuarine habitats to the upstream freshwater spawning and rearing habitats. Here we provide a review of the primary obstructions found on the three Virginia tributaries of the Chesapeake Bay.

Rappahannock River: The main stem of the Rappahannock River was dammed until 2004-2005 when the Crib Dam (built in 1854) and the Embrey Dam (built in 1910) at Fredericksburg (rkm 250) were removed. Removal of the dam opened 170 km of potential habitat for migratory fishes, such as American shad and river herring (American shad and blueback herring have been collected 28 miles upstream of dam). The Embrey Dam was the last remaining dam on the Rappahannock main stem. There are dams in place on tributaries of the Rappahannock (e.g., the Rapidan River) that may impeded migration of American shad (although it is unknown if American shad used these reaches prior to dam installation). A fish passage was installed on the Orange Dam on the Rapidan River, a tributary of the Rappahannock (http://www.dgif.virginia.gov/fishing/fish-passage/) 10 miles upstream of Rapidan Mill Dam, which remains as a migration barrier.

York River System: The Mattaponi, Pamunkey, and York rivers are all completely undammed. There are few dams in place on some tributaries of these rivers (e.g., the Ashland Mill Dam on the South Anna River, a tributary of the Pamunkey).

James River: Numerous dams on the James River and its tributaries have historically blocked migration of fishes. Between 1989 and 1993 three dams in the fall zone were breached or notched, extending available habitat to the base of Boshers Dam. A fish passage was installed in Boshers Dam(built in 1823) in 1999, reopening 221 km of the upper James River and 322 km of its tributaries to American shad and other anadromous fishes; the next dam of the mainstem is at Lynchburg, VA (Weaver et al., 2003). The main stem of the Appomattox River is accessible to American shad (127 miles), with a fishway at Harvell Dam in Petersburg, VA (rkm 17; scheduled for removal in 2014; see below), and a fish lift on Brasfield Dam (Lake Chesdin), near Matoaca, VA. The first existing dam on the Chickahominy is Walkers Dam at rkm 35 (with a fish passage rebuilt in 1989, and replaced in 2013). A number of additional dam removal and fishway construction projects have occurred in the past on several smaller creeks and streams in the James River drainage as well (http://www.dgif.virginia.gov/fishing/fish-passage/).

Recommended Actions: Installation of fish passage systems, breaching and removal of dams as appropriate (see Fig. 4 for recent activities in Virginia and the Chesapeake Bay watershed generally). Continued monitoring of fish passage systems currently in place for effectiveness for American shad passage.

The remaining significant American shad habitat that is yet to be reopened in Virginia includes the South Anna River, a tributary of the Pamunkey River, upstream of the Ashland Mill Dam (this would open 37 miles of shad habitat). American shad are routinely collected during sampling below Ashland Mill Dam at Rt. 1. Removal of this dam was discussed as mitigation for the King William Reservoir, but it is still in place. This remains a high priority fish passage project site in Virginia, although no timeframe or immediate plans for its removal are set. In the James River, there remain seven dams spaced over 21 miles upstream of Lynchburg, VA, starting with Scott's Mill Dam (removal of these barriers or installation of adequate fish passage facilities would open a significant amount of additional habitat). Within the Rappahannock River system, removal or fish passage at the Rapidan Mills Dam (on the Rapidan River, a tributary of the Rappahannock) would open 33 miles of habitat because there is a Denil fishway on a water supply dam (Orange, VA) 10 miles upstream of Rapidan Mill Dam.

The Harvell Dam (Appomattox River) is scheduled to be removed in 2014. Although this dam has a fishway on it, this removal would provide American shad full access to upstream habitats of the Appomattox until they encounter the Brasfield Dam fishlift. An additional 121 miles of potential American shad habitat is available upstream of the Brasfield lift should that lift prove to be successful at passing American shad.

Agency or Agencies with Regulatory Authority: Licensing and relicensing of dams is regulated by FERC. Within Virginia, VDGIF oversees the Fish Passage Program. VMRC, VDGIF, and DEQ all may be involved with the permitting process, regulations and monitoring of aspects of fish passage systems, dam removals, and other environmental factors associated with these activities depending on position of the dam.

Goal: "The importance of migratory fish species was recognized in the 1987 Chesapeake Bay Agreement and re-affirmed in Chesapeake 2000. A commitment was endorsed to 'provide for fish passage at dams and remove stream blockages whenever necessary to restore natural passage for migratory and resident fish.' The Fish Passage Work Group of the Bay Program's Living Resource Subcommittee developed strategies (1988) and implemented plans (1989) to fulfill this commitment. In 2004, the original Fish Passage Goal of 1,357 miles (established in 1987) was exceeded. Chesapeake 2000 led to the establishment of a new Fish Passage Goal, set in 2004, committing signatory jurisdictions to the completion of 100 fish passage/dam removal projects," to re-open an additional 1,000 miles of high-quality habitat to migratory and resident fishes. [from VDGIF (http://www.dgif.virginia.gov/fishing/fish-passage/#background; accessed January

8, 2014)]. This increased the overall goal to 2,807 total miles for which Virginia is responsible for roughly one-third of the miles to be reopened. To date, the partners have reopened a grand total of 2,574.5 miles, which is 92% of the 2,807 mile goal. The proposed new fish passage goal in the new Chesapeake Bay Agreement will be to reopen an additional 1,000 miles by 2025 (this will include miles starting from 2011, which is about 200 to date).

Cost: N/A

Timeline: N/A. While there is no timeline set for dam removal and fish passage in Virginia, there is a meeting of the ASMFC Fish Passage Work Group scheduled for February 2014, during which a prioritization of projects, including those in Virginia, will be discussed. While not set for individual species (i.e., specific to American shad), this next phase in prioritizing will use the prioritization tools and other existing information to create a Virginia plan that could include breaking down habitat total goals and accomplishments per anadromous species.

Threat: Pressures from Land Use associated with Population Growth

Many of the non-barrier threats identified by Rulifson (1994) can be collectively viewed as the results of changes in land use associated with population growth. The population surrounding the three primary Virginia barriers is centered in Richmond (James River), with a significant population center in Fredericksburg (Rappahannock River); the remaining areas are rural (Fig. 5). According to the Chesapeake Bay Program, within Virginia land use pressure is highest along the James River at Richmond, with other significantly high vulnerability levels at the James River near the confluence of the Chickahominy River, and the peninsula separating the James River from the York River (Fig. 6). Land use surrounding rivers within the Chesapeake Bay watershed in Virginia likely is associated with contamination (significant levels throughout, principally PCBs, but also metals within the York River system; Fig. 7), sediment load (High in the Rappahannock, Low in the York River system, Chickahominy and Appomattox rivers, and Medium in the Upper James River; Fig. 8), and phosphorus yields (High in the Rappahannock, Medium in the Upper James River, and Low in the other rivers; Fig. 9); nitrogen yields are low in all three river systems (Fig. 10). Low summertime dissolved oxygen levels remains a threat in all portions of three rivers, except the upper Mattaponi and upper Pamunkey rivers (York River System), and the upper James River (Fig. 11).

Recommended Action: No specific actions can be identified related to mitigation against land use in Virginia as it relates to American shad habitat use. Indeed, it is difficult to identify specific actions to be taken in land use management that will affect American shad population status (Waldman and Gephard, 2011). However, further study of freshwater habitat use by American shad in Virginia is needed. Specifically, quantification and analysis of specific reaches of riverine habitats used by American shad during residency (adults during the spawning run, larvae, and juveniles) is needed to better manage and address habitat concerns of the species.

Agency or Agencies with Regulatory Authority: Land use regulations associated with water quality primarily are under the authority of DEQ, although both VMRC and VDGIF may be involved in the permitting process and other aspects of regulation for certain activities that will affect water quality.

Goal: No specific goal(s) are identified for protecting American shad from pressures associated with habitat alteration and other land use changes. Stocking of hatchery fishes (VDGIF) and enforcement of a moratorium on fisheries of American shad (VMRC; VDGIF) are aimed at curbing further declines.

Progress: The moratorium for American shad has been in place in Virginia since 1994. Stocking efforts are focused on the James River (since 1994) and more recently (since 2003) on the Rappahannock River. Significant levels of hatchery returns are seen on the James River (34% in 2012) and increasing levels on the Rappahannock (from 0% in 2007 and years before, to 6.8% in 2012). Although it is suspected that the James River stock is dependent on hatchery inputs (Hilton et al. 2013), the stocking program has decreased in recent years due to decreasing funds.

Cost: N/A

Timeline: N/A

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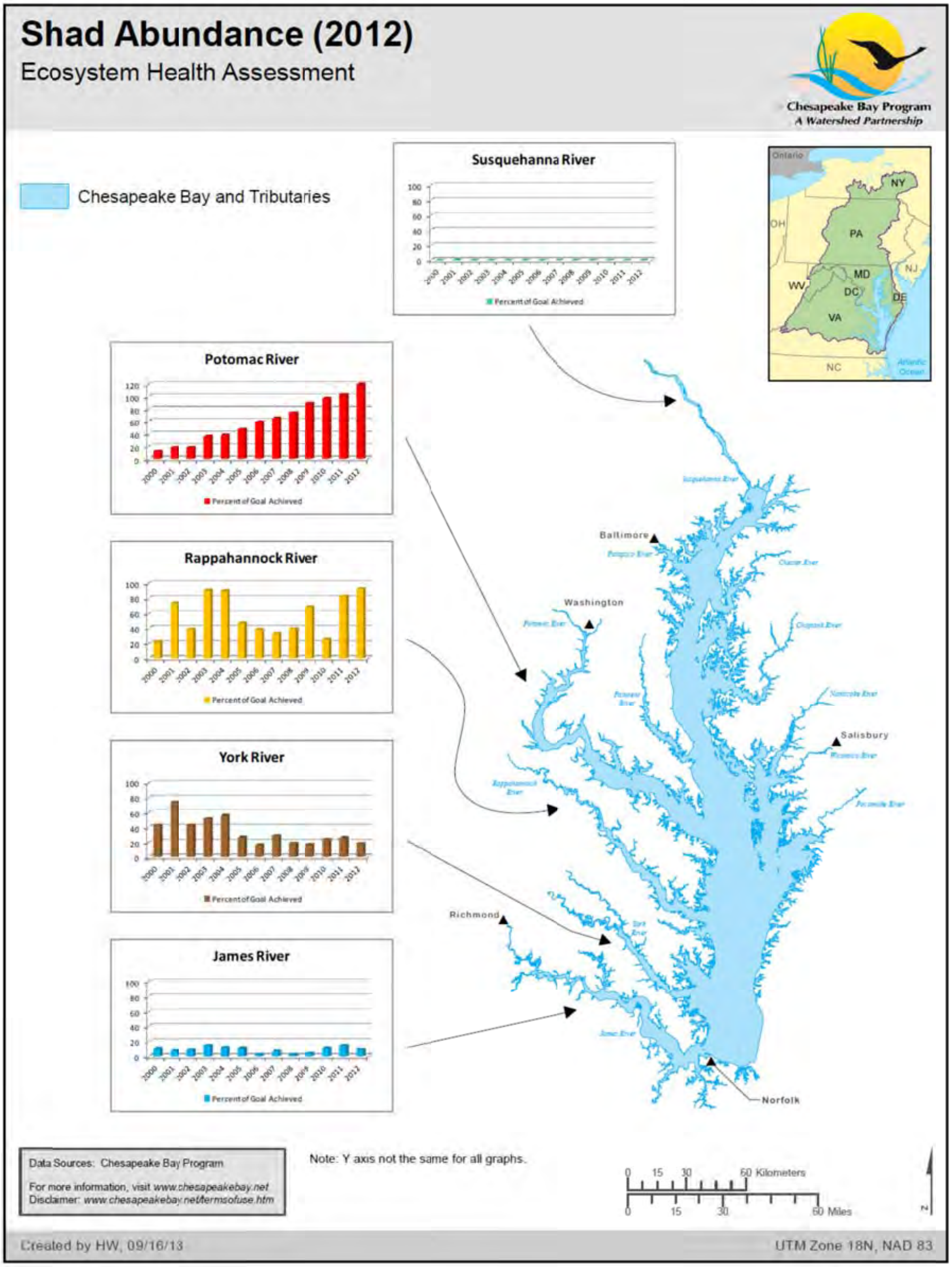

Figure 1. Shad distribution and abundance in the Chesapeake Bay. (Source: Chesapeake Bay Program)

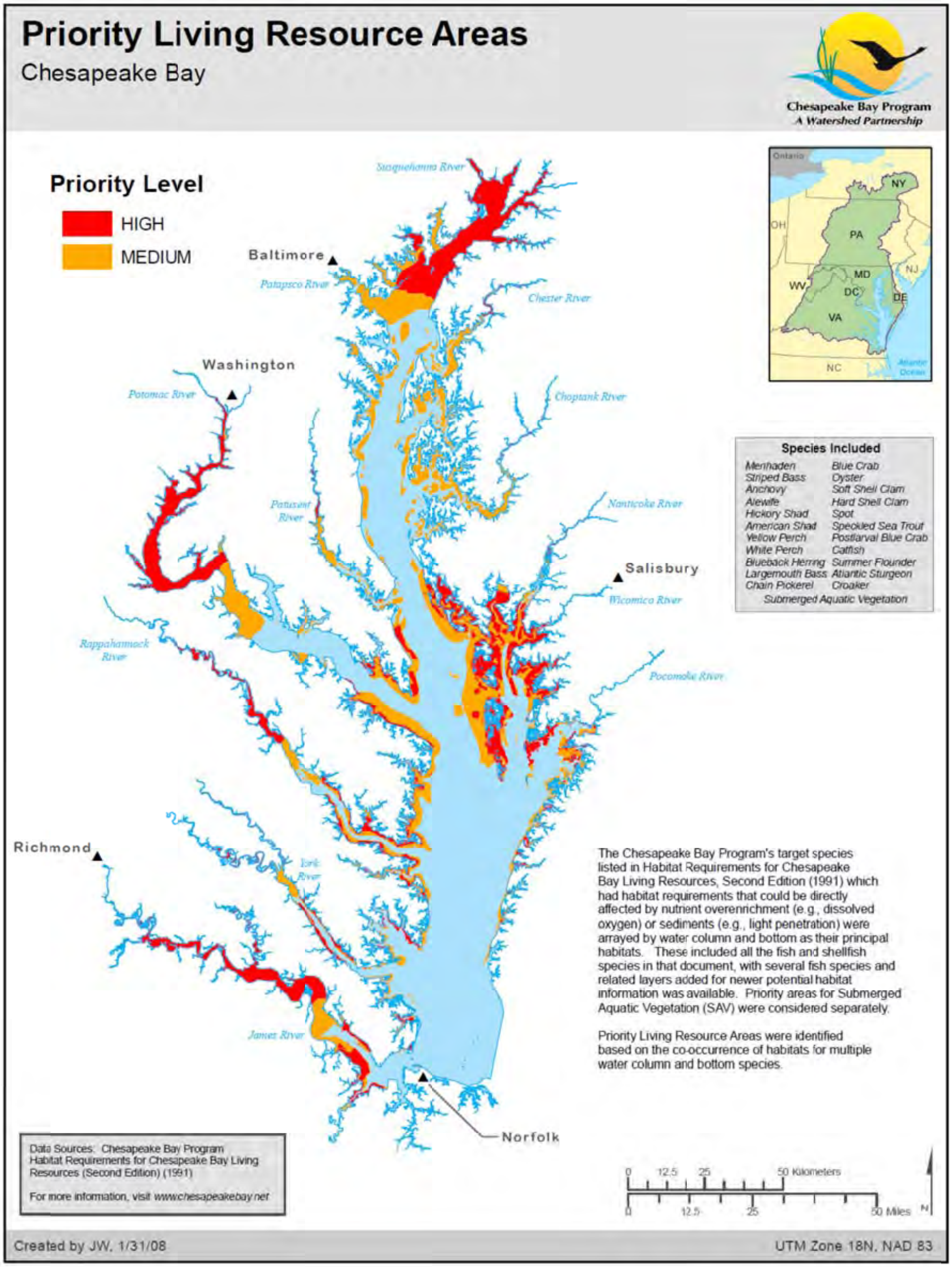

Figure 2. Priority living resource areas of the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

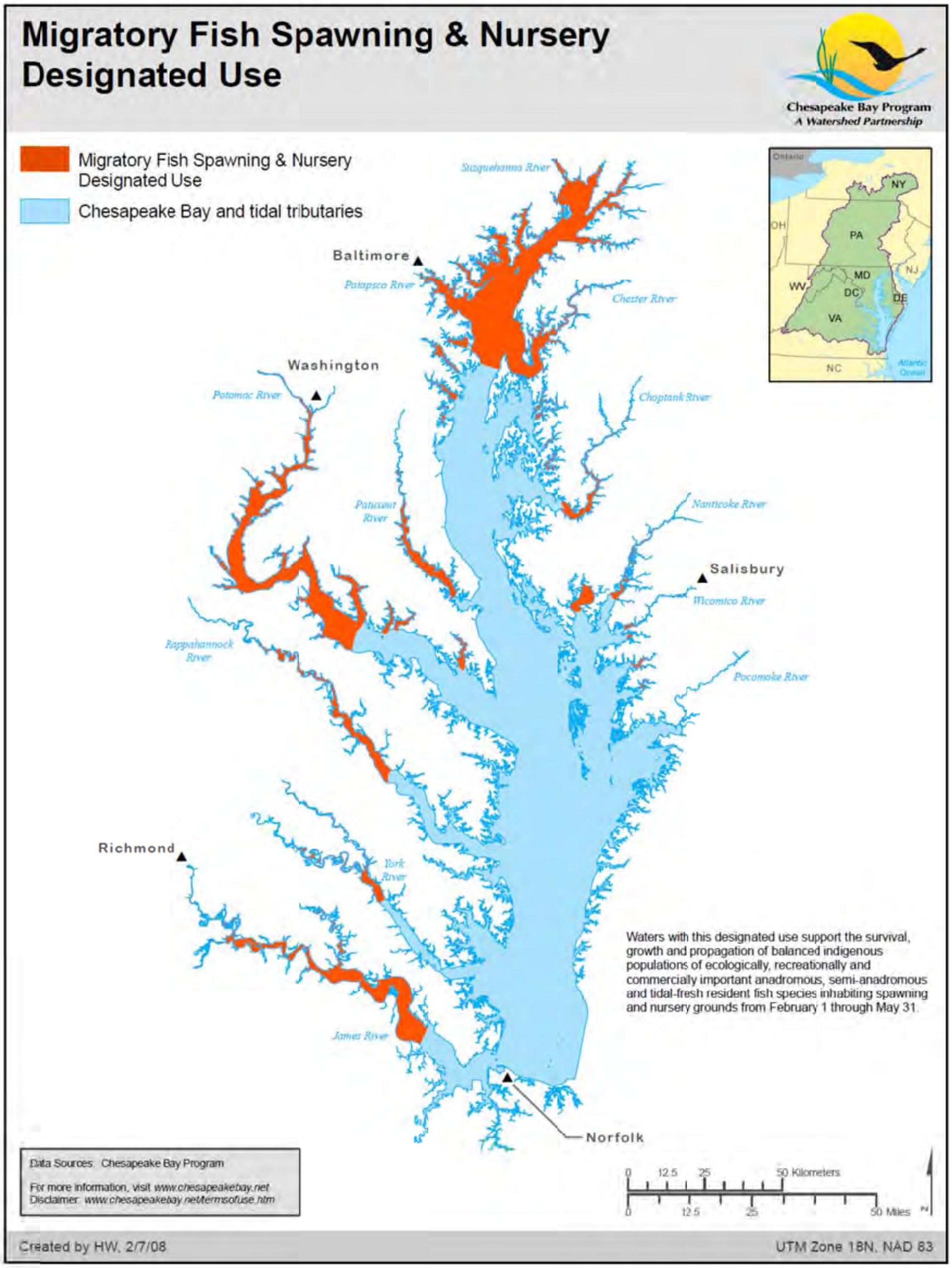

Figure 3. Migratory fish use of the Chesapeake Bay watershed (Source: Chesapeake Bay Program)

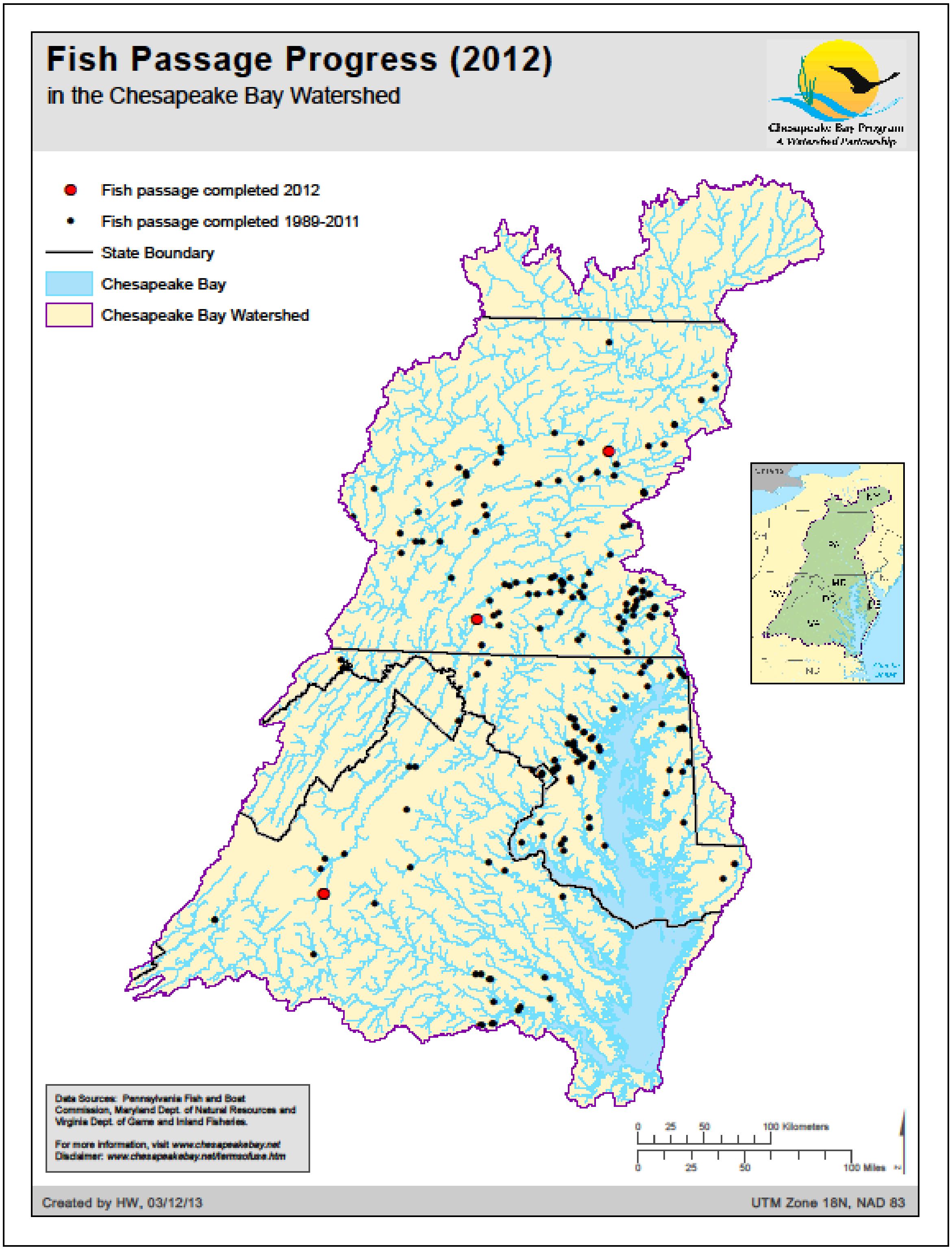

Figure 4. Fish passage projects in the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

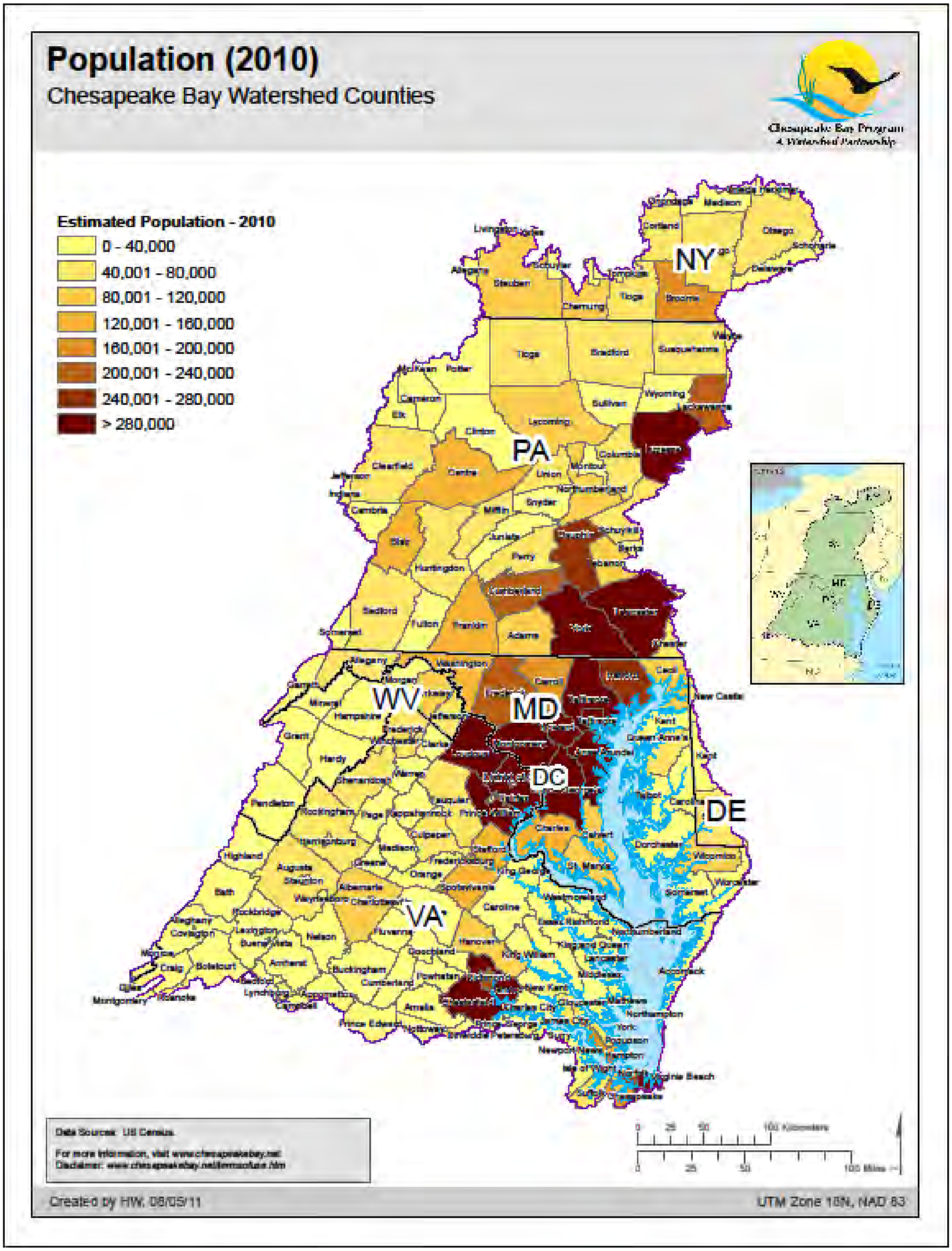

Figure 5. Population levels of the Chesapeake Bay region. (Source: Chesapeake Bay Program)

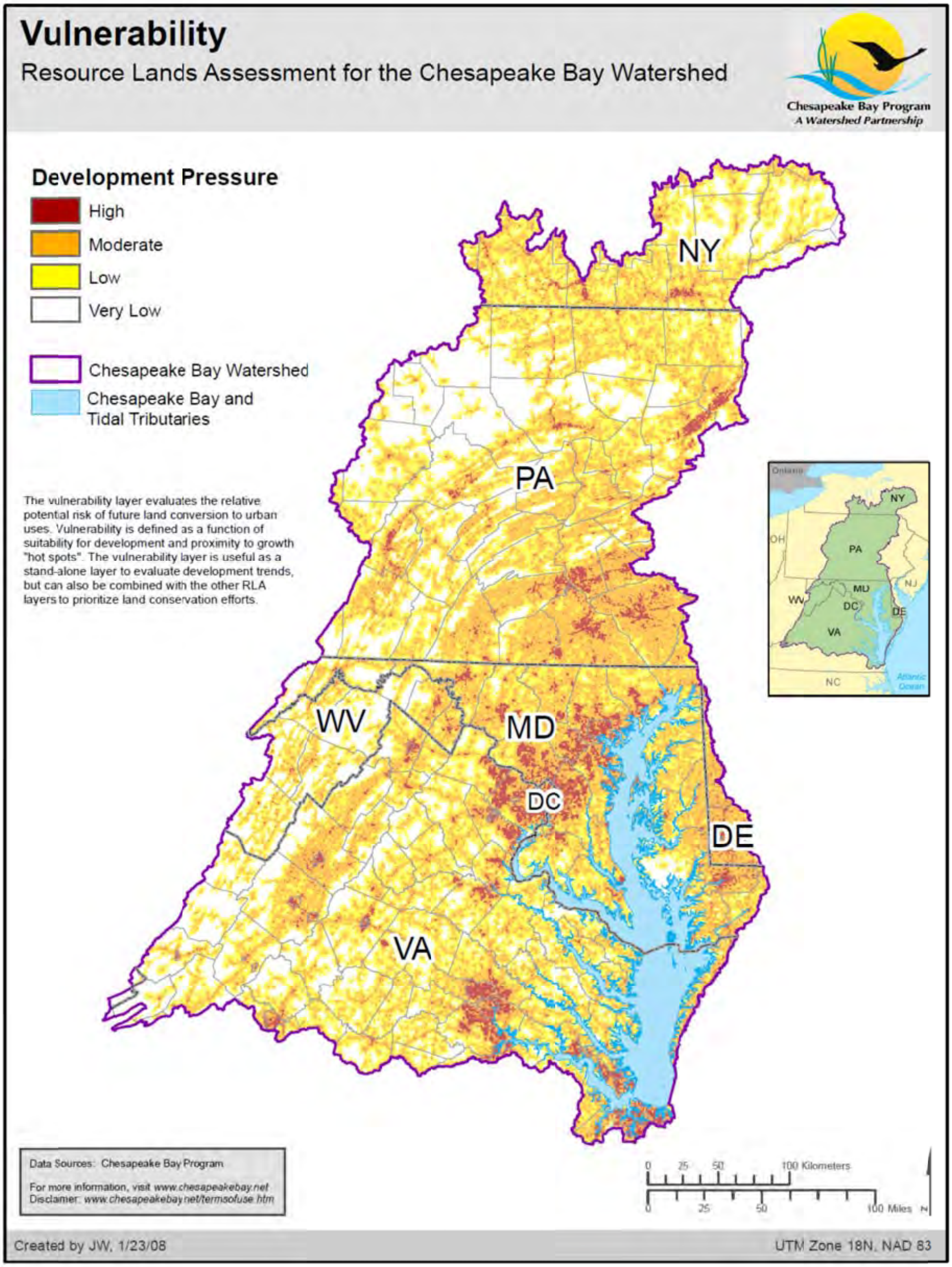

Figure 6. Potential for lands to become urban, representing significant land use changes and impacts. (Source: Chesapeake Bay Program)

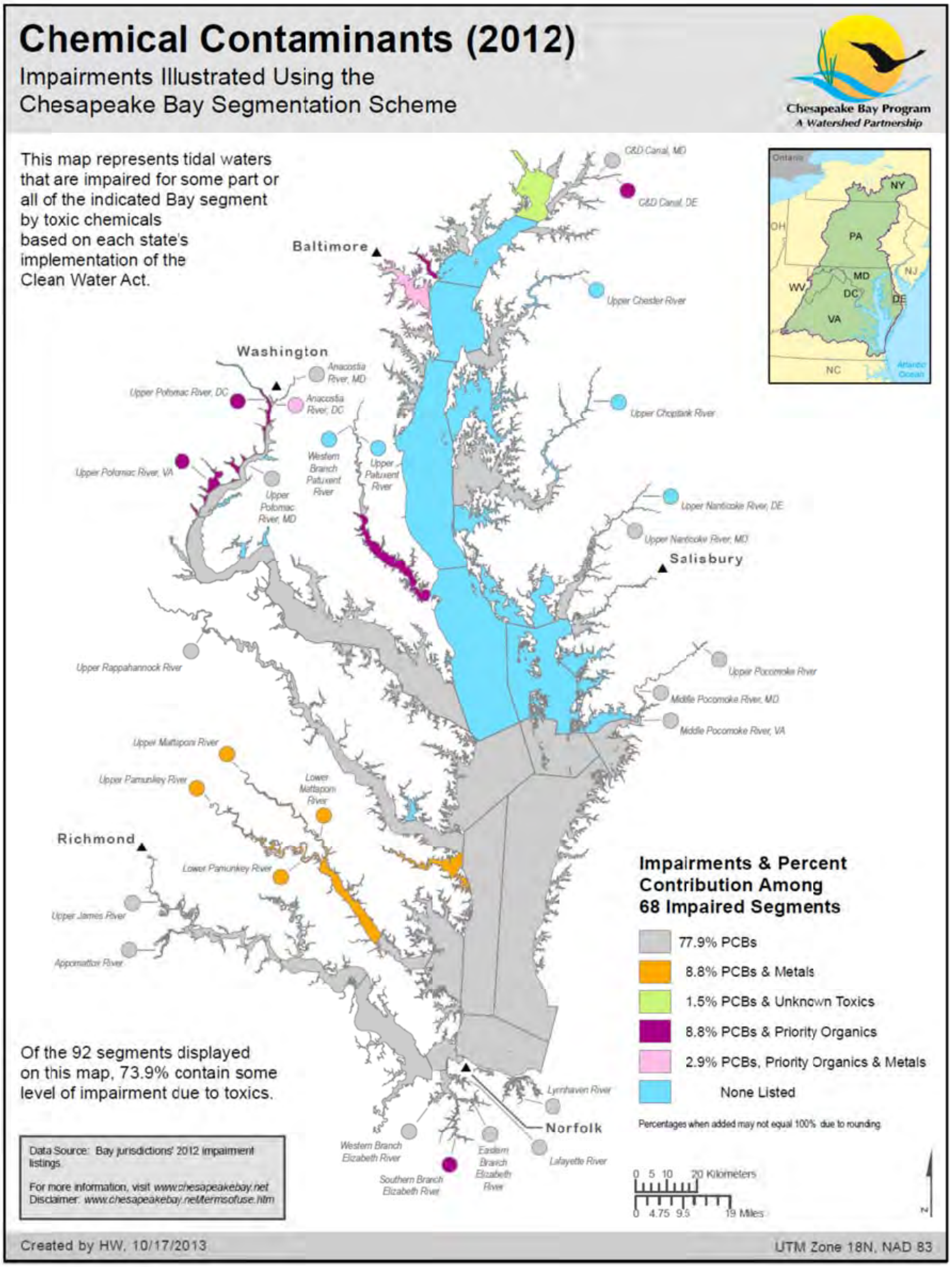

Figure 7. Chemical contaminants in the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

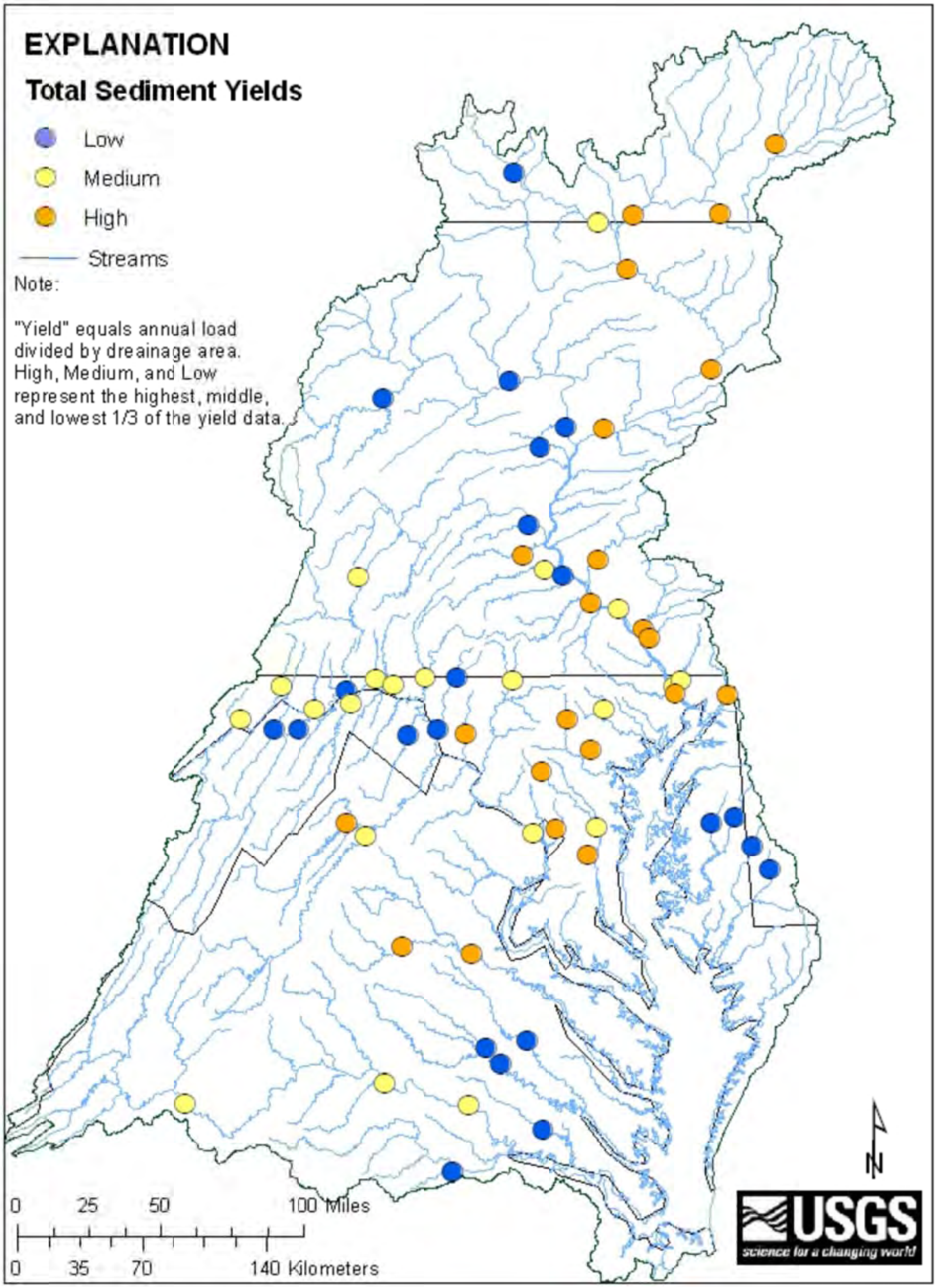

Figure 8. Sedimentation yields in the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

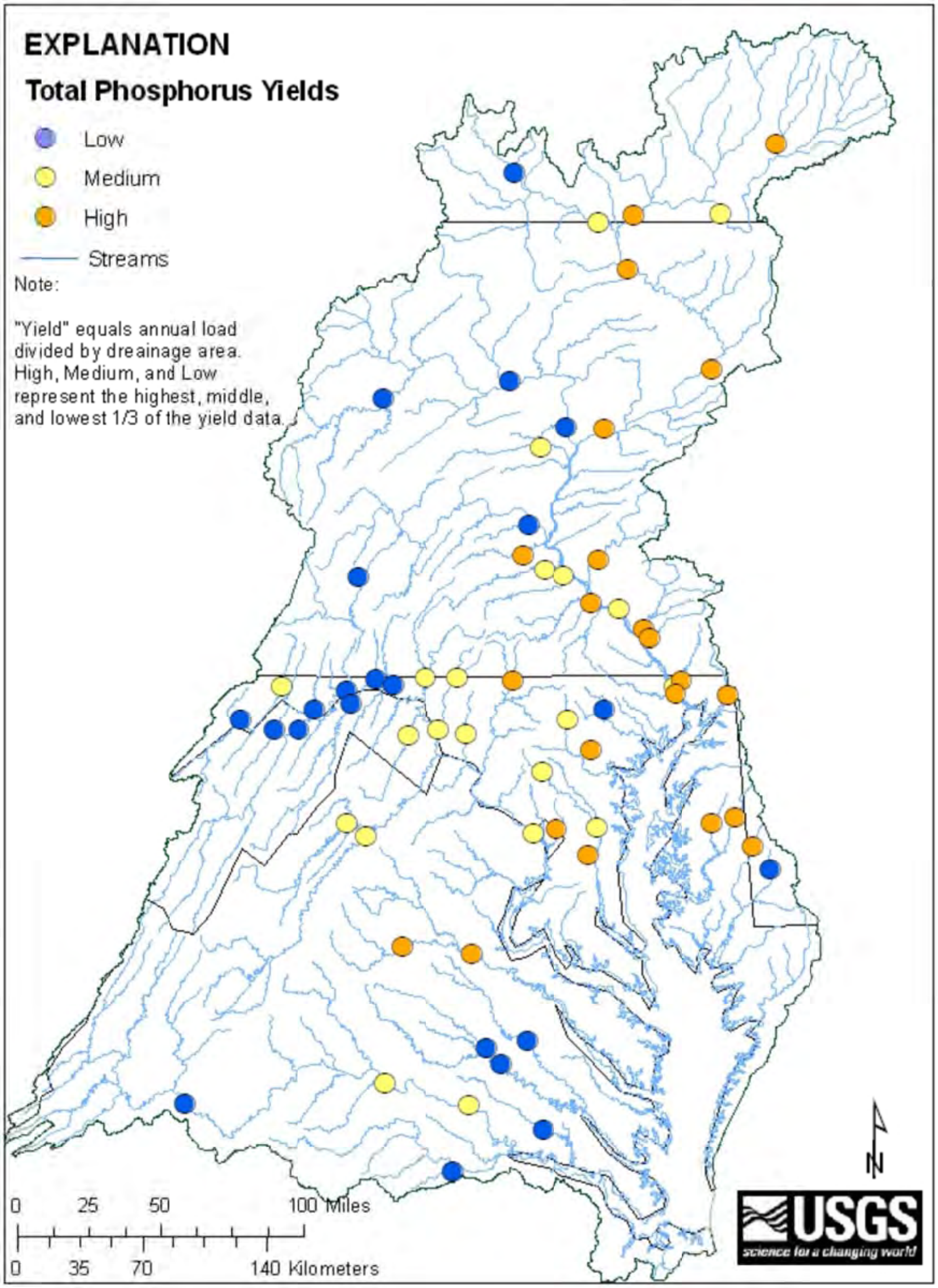

Figure 9. Total phosphorus yields in the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

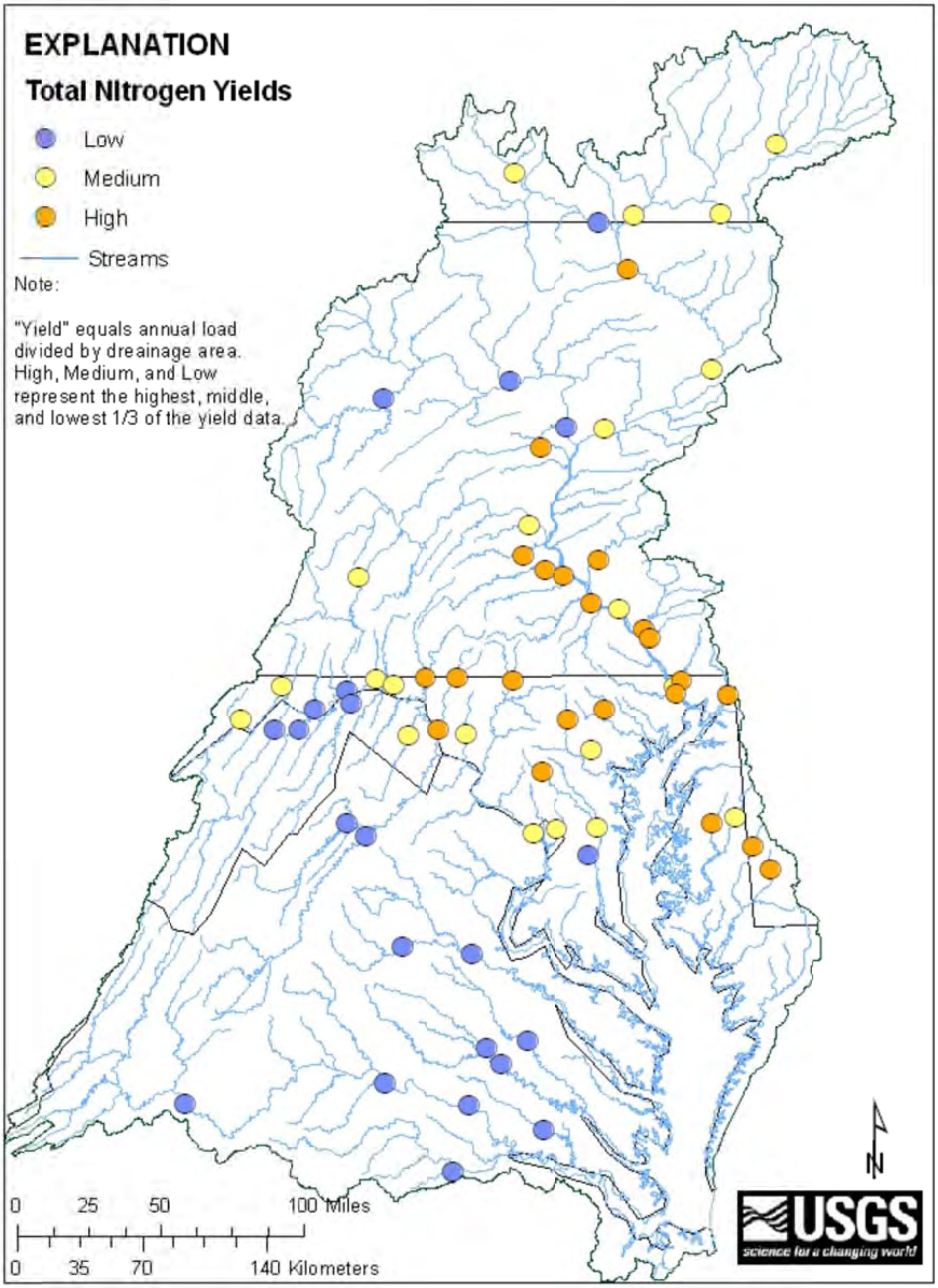

Figure 10. Total nitrogen yields in the Chesapeake Bay watershed (Source: Chesapeake Bay Program)

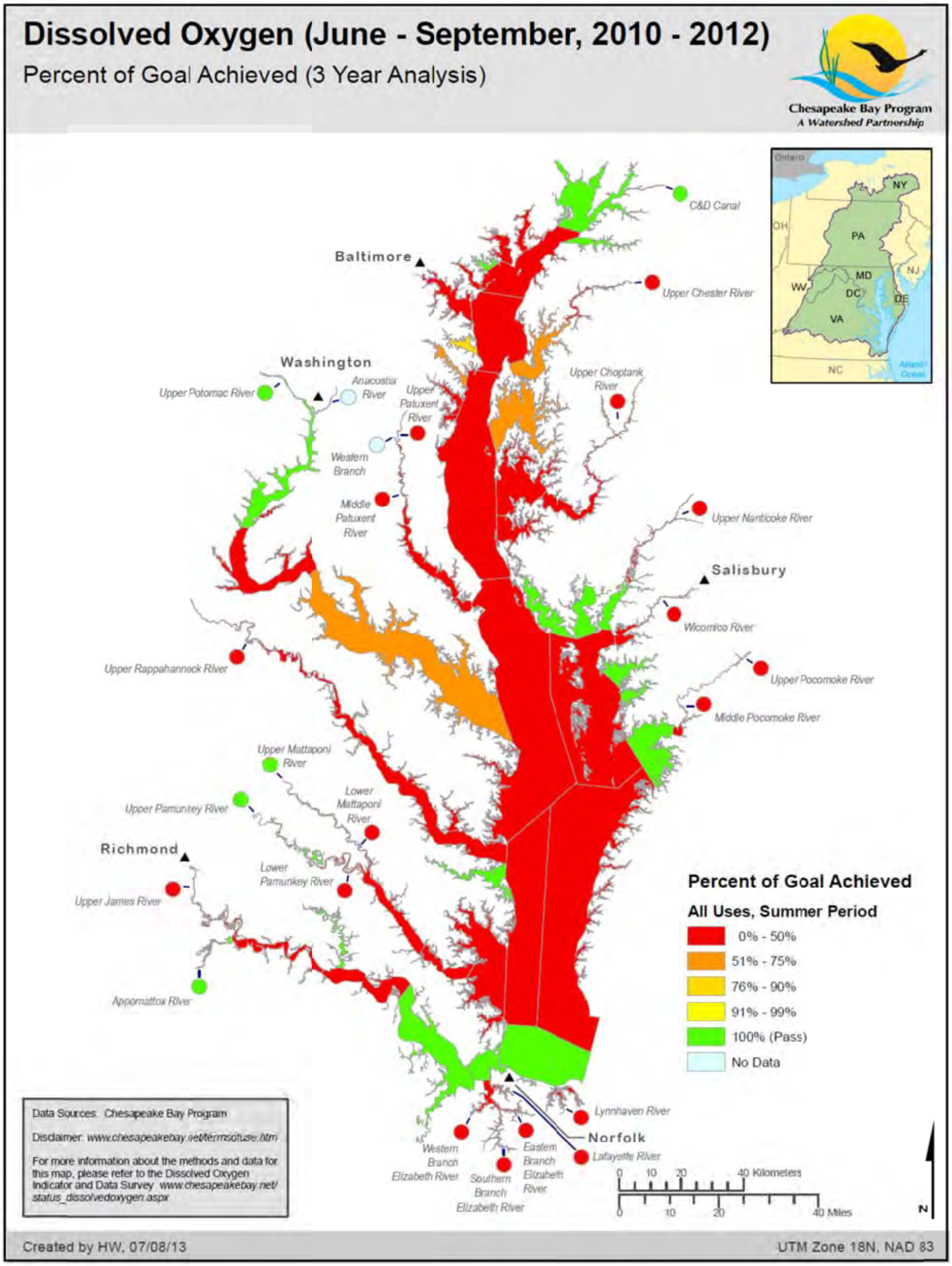

Figure 11. Dissolved oxygen in the Chesapeake Bay watershed. (Source: Chesapeake Bay Program)

NORTH CAROLINA AMERICAN SHAD HABITAT PLAN

North Carolina Division of Marine Fisheries
North Carolina Wildlife Resources Commission

January 2014

Introduction

Amendment 3 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Fishery Management Plan required all states and jurisdictions to develop an Implementation Plan, which consists of two components: 1) a Sustainable Fishery Plan (for jurisdictions wishing to keep fisheries open) and 2) a Habitat Plan. The requirement for a Habitat Plan was in recognition of the fact that much of the decline in American shad stocks along the Atlantic coast is related to degradation of spawning and juvenile habitat from anthropogenic impacts such as upland development, stormwater runoff, and sewer discharges, as well as barriers to migration from dam construction and culverts. Restoration, protection and enhancement of American shad habitat is a key component of rebuilding populations of this species to levels that will support their ecological, economic and cultural roles.

The purpose of the Habitat Plan is to collate information regarding the status of and threats to American shad spawning, nursery and juvenile habitats specific to a particular state or jurisdiction, and to develop restoration programs to address such threats. This document serves as North Carolina's American Shad Habitat Plan and as detailed below, draws heavily upon existing documents and efforts.

North Carolina Coastal Habitat Protection Plan (CHPP)

In recognition of the fact that protecting habitat was equally as important as preventing overfishing, the North Carolina General Assembly passed the Fisheries Reform Act in 1997. This law established the requirement to develop a Coastal Habitat Protection Plan to protect and enhance important coastal fisheries habitats. It also contains a directive to three major rulemaking commissions (Environmental Management Commission, Coastal Resources Commission and Marine Fisheries Commission) to cooperate in the development and implementation of the plan. The NC Division of Marine Fisheries (NCDMF) was charged with writing the plan.

The initial version of the CHPP was approved by all three commissions in December 2004, and detailed the status, trends and threats to six major fisheries habitats: the water column, submerged aquatic vegetation, wetlands, shell bottom, soft bottom and ocean hard bottom. A Steering Committee comprised of two commissioners from each of the three rulemaking commissions provided guidance and policy oversight, while NCDMF staff wrote the plan with assistance of the CHPP Development Team – staff from the Divisions of Water Quality, Coastal Management, Environmental Health and the Wildlife Resources Commission (NCWRC). A number of state and federal agency staff external to the development of the CHPP provided review of the individual chapters of the plan. Additionally, two-year Implementation Plans were developed to guide agency activities and progress towards the goals, objectives and recommendations of the CHPP.

The CHPP is reviewed and updated on a five-year schedule, with the last update completed in 2010. A process similar to that described above was employed in the review and update of information, goals, objectives and recommendations. During this update, two commissioners from the NCWRC were added to the Steering Committee in recognition of the increasing role of this commission in Implementation Plan items. Because of the breadth and depth of data and information contained in the document, both state and federal agency staff have come to rely on the CHPP as a resource. Recommendations from the CHPP have been incorporated into several programs within state government as funding priorities.

In an effort to minimize duplication, the NC American Shad Habitat Plan (hereafter "Habitat Plan") relies heavily upon the extensive body of information and recommendations contained within the CHPP. As such, various sections of the CHPP are referred to in the sections of the Habitat Plan for more detailed and specific information. Because the CHPP is 638 pages (including appendices), it is not included as an appendix to this Habitat Plan (Deaton et al 2010).

Individual chapters of the CHPP (both 2004 and 2010 versions) as well as Implementation Plans and all documents related to Strategic Habitat Areas (referred to in the Habitat Assessment below) can be found within the CHPP document (Deaton et al 2010).

The Habitat Plan follows the suggested outline contained in Amendment 3, consisting of a Habitat Assessment, Threats Assessment, and Habitat Restoration Program.

Section 1: Habitat Assessment

American Shad Spawning and Nursery Area Habitat

American shad are an anadromous, pelagic, highly migratory schooling species (Colette and Klein-MacPhee 2002). They utilize a variety of habitats with variations in habitat preference due to location, season, and ontogenetic stage.

American shad are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including: water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, hard bottom, and shell bottom (Deaton et al. 2010). Each habitat is part of a larger habitat mosaic, which plays a vital role in the overall productivity and health of the coastal ecosystem. Although American shad are found in all of these habitats, the usage varies by habitat. Additionally, these habitats provide the appropriate physicochemical and biological conditions necessary to maintain and enhance the American shad population. Limburg and Waldman (2009) have shown that the loss of habitat contributes to the decline in anadromous fish stocks throughout the world. Therefore the protection of each habitat type is critical to the sustainability of the American shad stock.

American shad ascend all coastal rivers in North Carolina and are most abundant in the Roanoke, Chowan, Tar-Pamlico, Neuse, Northeast Cape Fear, and Cape Fear rivers as well as Albemarle and Pamlico sounds (Street *et al*. 1975; Marshall 1976; Sholar 1977; Fischer 1980; Hawkins 1980; Johnson *et al*. 1981; Winslow *et al*. 1983; Winslow *et al*. 1985) (Figure 1).

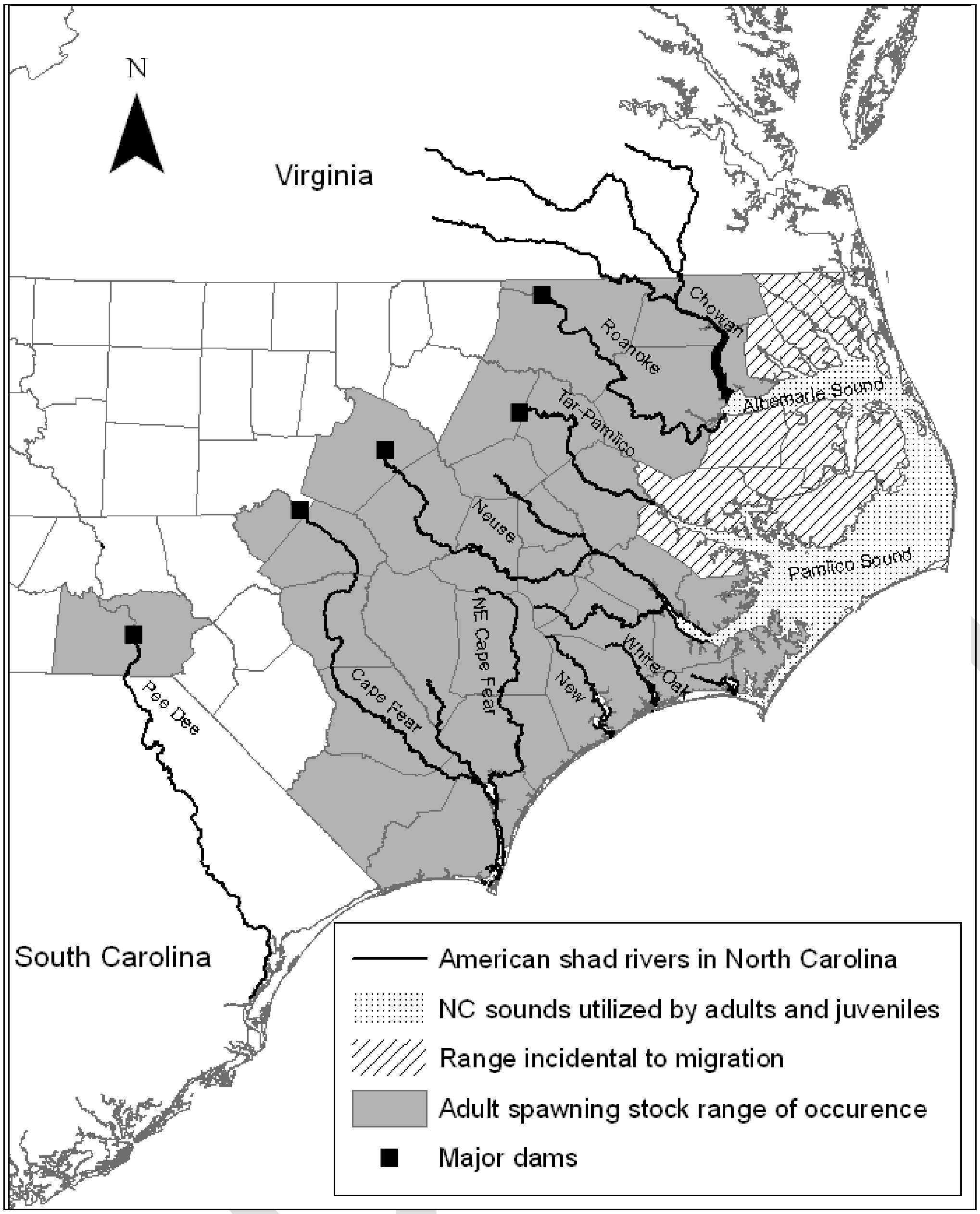

Figure 1. North Carolina river systems depicting the extent of American shad occurrence and habitat use.

The NCDMF conducted American shad spawning area surveys between 1973 and 1984 in the major coastal tributaries. Physical characteristics of the spawning grounds vary somewhat between systems. Shad may spawn anywhere within a given spawning area but prefer shallow flats composed of sand, gravel, or a combination of the two bordering the rivers (Smith 1907; Walburg and Nichols 1967; Beasley and Hightower 2000; Hightower and Sparks 2003). Water conditions may vary from clear to very turbid, water depth ranges from 3 to 30 ft, and temperatures may range from 8 to 26°C (Walburg and Nichols 1967; Winslow 1990).
Shad eggs are non-adhesive and slightly heavier than water, so they gradually sink and are carried along by currents (Ulrich *et al.* 1979). Sufficient water current is required to keep eggs suspended in the water column for successful development (Cheek 1968; Sholar 1977). .

Current velocity, increasing light and temperature are all important cues for anadromous spawning activity (Klauda et al. 1991; Orth and White 1993). Successful spawning of American shad coincides with water velocities between 2 and 3 ft/s (61-91 cm/s) (Fay et al. 1983; Mackenzie et al. 1985; Hill et al. 1989). This requirement may explain why American shad spawning was found only in the Nottoway, Blackwater, Meherrin, Roanoke, Tar, Neuse and Cape Fear rivers, all of which have relatively strong currents compared to other coastal rivers in the state. During their spawning migration, anadromous fish actively avoid waters with low dissolved oxygen and extremely high turbidity (Steel 1991). All American shad spawning areas have been documented either by capture of eggs or larvae, or direct observation of spawning.

Nursery habitat for anadromous fishes is generally downstream from spawning locations but still within the freshwater low-salinity system. Juvenile American shad use the same general nursery areas as river herring, but the young shad prefer deeper pools away from the shoreline and occasionally move into shallow riffles (Funderburk et al. 1991). During summer, juvenile shad migrate from the bottom during the day to the surface at night (Loesch and Kriete 1984). A decrease in temperature during the fall and slight increases in river flow seem to trigger downstream movement of American shad (Funderburk et al. 1991). Nursery area surveys conducted by NCDMF noted decreased catch of juvenile shad in October on the Cape Fear River, Neuse River, and Albemarle Sound (Winslow 1990).

Albemarle Sound

The Albemarle Sound area includes Albemarle Sound, all of its tributaries, Currituck, Roanoke, and Croatan sounds, and all of their tributaries. Albemarle Sound, located in the northeastern portion of North Carolina, is a shallow estuary extending 88.5 km in an east-west direction averaging 11.3 km wide and .9–6.1 m deep. Ten rivers drain into Albemarle Sound, which joins Pamlico Sound through Croatan and Roanoke sounds, and in turn, empties into the Atlantic Ocean via Oregon Inlet. Currituck Sound joins Albemarle Sound from the northeast. Although the headwaters of the Roanoke River are located in the Appalachian foothills of Virginia, most of the tributaries to the Sound originate in extensive coastal swamps. The Roanoke and Chowan Rivers are the principal tributaries, and areas of these rivers are known to function as American shad spawning areas (Street *et al*. 1975; Johnson *et al*. 1981; Winslow *et al*. 1983; Winslow *et al*. 1985; Hightower and Sparks 2003). American shad spawning occurs in the Chowan River system in Virginia where the River divides into the Blackwater and Nottoway Rivers. The upper Meherrin River, a tributary of the Chowan River, also functions as a spawning area in North Carolina and Virginia. Spawning also occurs in the Roanoke River near Weldon and Roanoke Rapids.

Roanoke River

The Roanoke River is a relatively narrow stream that follows a winding course to its mouth below Plymouth, where it enters western Albemarle Sound. The Roanoke River watershed arises in the mountains of Virginia and covers 25,035 square km (8,893 square miles); only 9,081 square km (3,506 square miles) of the basin lies within North Carolina (NCDWQ 2001). Fifteen counties and 42 large municipalities (e.g., Greensboro, Winston-Salem, High Point, Roanoke Rapids, Williamston, Plymouth) are represented within the North Carolina portion of the basin. Near the North Carolina-Virginia border, John H. Kerr Reservoir, Lake Gaston, and Roanoke Rapids Lake impound the Roanoke River. The U.S. Army Corps of Engineers (USACOE) and Dominion/NC Power Company operate these reservoirs for flood control and hydropower generation. A dam was constructed in 1955 on the River at Roanoke Rapids, North Carolina, 220.6 km (137 miles) from the mouth (Carnes 1965). This dam does not have facilities for fish passage and is therefore the upper limit of migration. Recent studies have shown that American shad accumulate in the Roanoke Rapids area, and newly-spawned American shad eggs have been collected there (Knutzen 1997; Hightower and Sparks 2003; Kornegay and Thomas 2004; Harris and Hightower 2007). Downstream of Roanoke Rapids Lake, flows in the Roanoke River are highly regulated by discharges from the dams. From the Roanoke Rapids Dam, the Roanoke River flows 221 km (137 miles) through an expansive area of bottomland hardwood wetlands to its confluence with Albemarle Sound. Major tributaries of this lower section of the Roanoke River include Broad Creek, Devil's Gut, Broad Neck Swamp, Conoho Neck Swamp, and the Cashie River.

Tar-Pamlico River

The Tar-Pamlico watershed is the fourth largest in North Carolina encompassing 14,090 square km (5,440 square miles). From its headwaters in Person County, the Tar-Pamlico watershed is drained by 3,790 km (2,355 miles) of tributaries along its 290 km (180 mile) main-channel length to Pamlico Sound near the confluence of the Pungo River (NCDWQ 1999). River reaches upstream of the City of Washington are designated as the Tar River and are primarily freshwater, while the reach below Washington, referred to as the Pamlico River, has characteristics of an upper estuary. Sixteen counties and six large municipalities (Greenville, Henderson, Oxford, Rocky Mount, Tarboro, and Washington) are represented within the basin. Major tributaries to the river include Fishing, Swift, and Tranters creeks, Cokey Swamp, and the Pungo River. Main stem headwater reaches and tributaries are located within the outer piedmont physiographic region and are characterized by low flows during dry seasons due to minimal groundwater discharge (NCDWQ 1999). However, since the majority of the basin is located within the coastal plain, these waters are largely characterized by slow flowing, low gradient, brown and blackwater streams with extensive floodplains often comprised of bottomland hardwood forests and marshes.

Neuse River

The Neuse River is formed by the confluence of the Eno and Flat Rivers in the Piedmont region of North Carolina and flows in a southeasterly direction through the coastal lowlands discharging into Pamlico Sound 430 km (267 miles) from its origin (Hawkins 1980b; McMahon and Lloyd 1995). Through the Piedmont, the Neuse River has a relatively high gradient, and substrates tend to be rocky (McMahon and Lloyd 1995). As the river passes through the fall line into the coastal lowlands, it widens and slows with the reduced gradient. Downstream of the fall line, substrate is dominated by sand and silt (McMahon and Lloyd 1995). The Neuse River resides entirely within North Carolina and drains approximately 14,500 square km (5,598 square miles) of land, which is composed of approximately 48% forest, 30% agriculture, 9% wetlands, 6% developed lands, and 5% water (Hawkins 1980b; McMahon and Lloyd 1995). Flow regimes in the Neuse River downstream of Raleigh, North Carolina are controlled by Falls Lake Dam (river km 370; river mile 230), which was built in 1983 by the USACOE to create an impoundment for flood control, water supply, water quality, and recreational purposes. Spawning of American shad has been documented in the main stem Neuse River up to the first dam near Raleigh and in several tributaries: Contentnea Creek, Mill Creek, Little River, Swift Creek, and Crabtree Creek (Burdick and Hightower 2006).

Cape Fear River

The Cape Fear River, the largest river system in the state, forms at the confluence of the Deep and Haw rivers in the Piedmont region of North Carolina and flows southeasterly for approximately 274 km where it discharges into the Atlantic Ocean at Cape Fear, near Southport, North Carolina (Figure 13.1). The basin lies entirely within the state, includes portions of 27 counties and 114 municipalities, and encompasses 9,984 km of freshwater streams and rivers, 36 lakes and reservoirs, and 15,864 ha of estuarine waters (NCDWQ 1995).

Major tributaries include the Upper and Lower Little Rivers in Harnett County, the Black River in Bladen, Pender, and Sampson counties, and the Northeast Cape Fear River in Duplin, Pender, and New Hanover counties.

Habitat Designations

There are several different existing designations used in North Carolina that identify, delineate, and designate functionally important habitat areas Some of the key designations for anadromous species are nursery areas, anadromous fish spawning areas and strategic habitat areas. These designations are presented below and discussed in the 2010 NCDMF CHPP.

Nursery areas: Those areas in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season [NCMFC rule 15A NCAC 03N .0102 (a)].

Primary nursery area (PNA): Those areas of the estuarine system where initial post-larval development takes place. These areas are located in the uppermost sections of a system where populations are uniformly very early juveniles [NCMFC rule 15A NCAC 03N .0102 (b)].

Secondary nursery areas (SNA): Those areas of the estuarine system where later juvenile development takes place. Populations are usually composed of developing sub-adults of similar size which have migrated from upstream primary nursery areas to the secondary nursery area located in the middle portion of the estuarine system [NCMFC rule 15A NCAC 03N .0102 (c)].

[Inland] primary nursery areas (IPNA): Those [inland] areas inhabited by the embryonic, larval, or juvenile life stages of marine or estuarine fish or crustacean species due to favorable physical, chemical or biological factors [NCWRC rule 15A NCAC 10C.0502].

Anadromous fish spawning areas (AFSA): Those areas where evidence of spawning of anadromous fish has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae [NCMFC rule 15A NCAC 03I .0101 (b) (20) (C)].

Anadromous fish nursery areas: Those areas in the riverine and estuarine systems utilized by post-larvae and later juvenile anadromous fish [NCMFC rule 15A NCAC 03I .0101 (b) (20) (D)].

Anadromous Fish Spawning Areas (AFSAs). Anadromous fish spawning areas are defined in NCMFC rule 15A NCAC 03N .0106 and NCWRC rule 15A 10C .0602 as those areas where evidence of spawning of anadromous fish has been documented through direct observation of spawning, capture of running ripe females or capture of eggs or early larvae (Figures 2 and 3). The areas are delineated in NCMFC rule 15A NCAC 03R .0115 and NCWRC rule 15A 10C .0603. Anadromous fish spawning areas cover 17% and 10% of streams/shorelines and water bodies, respectively, in coastal plain portions of CHPP regions. Most AFSAs are located in the Albemarle region (70%) and include the mainstem Roanoke River, Chowan River, Alligator River, and Phelps Lake.

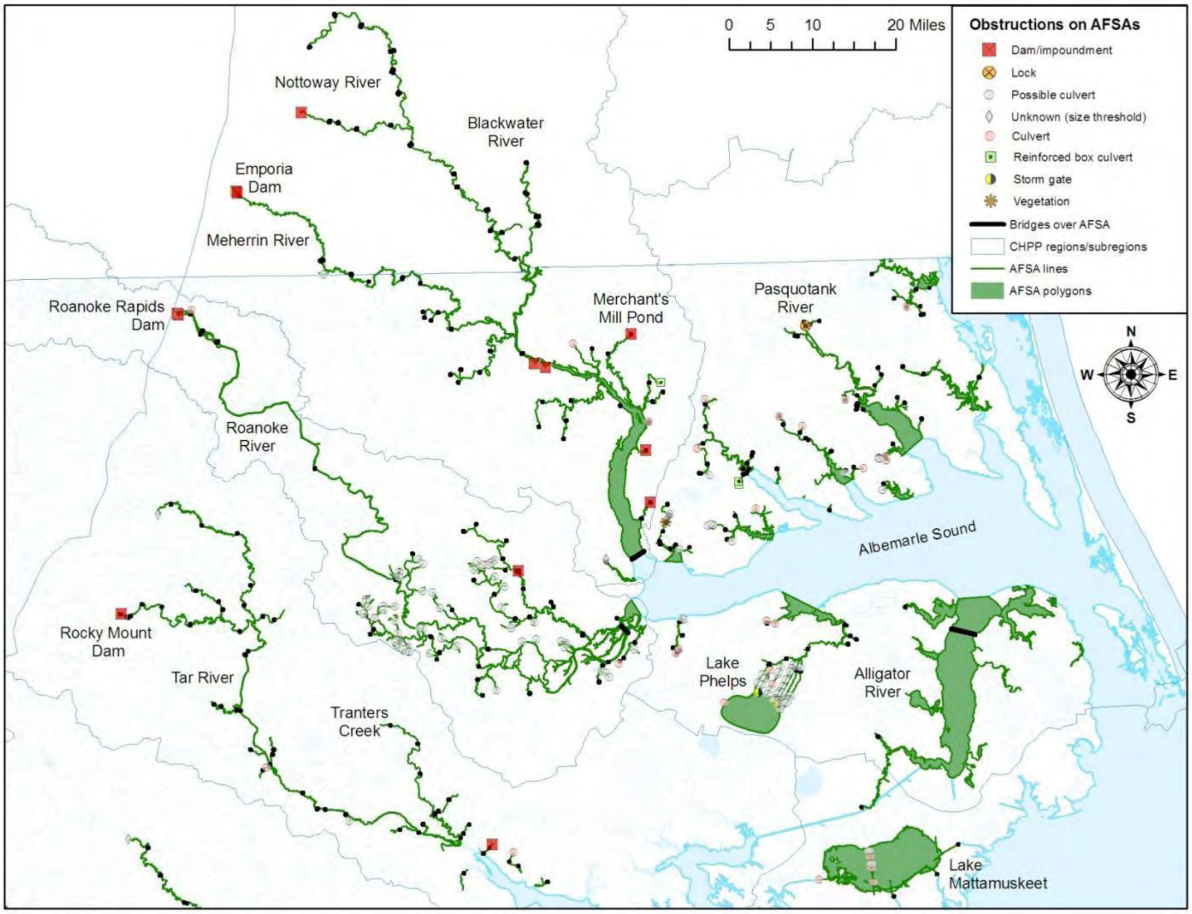

Figure 2. Anadromous fish spawning areas in the Albemarle Sound and Tar River areas.

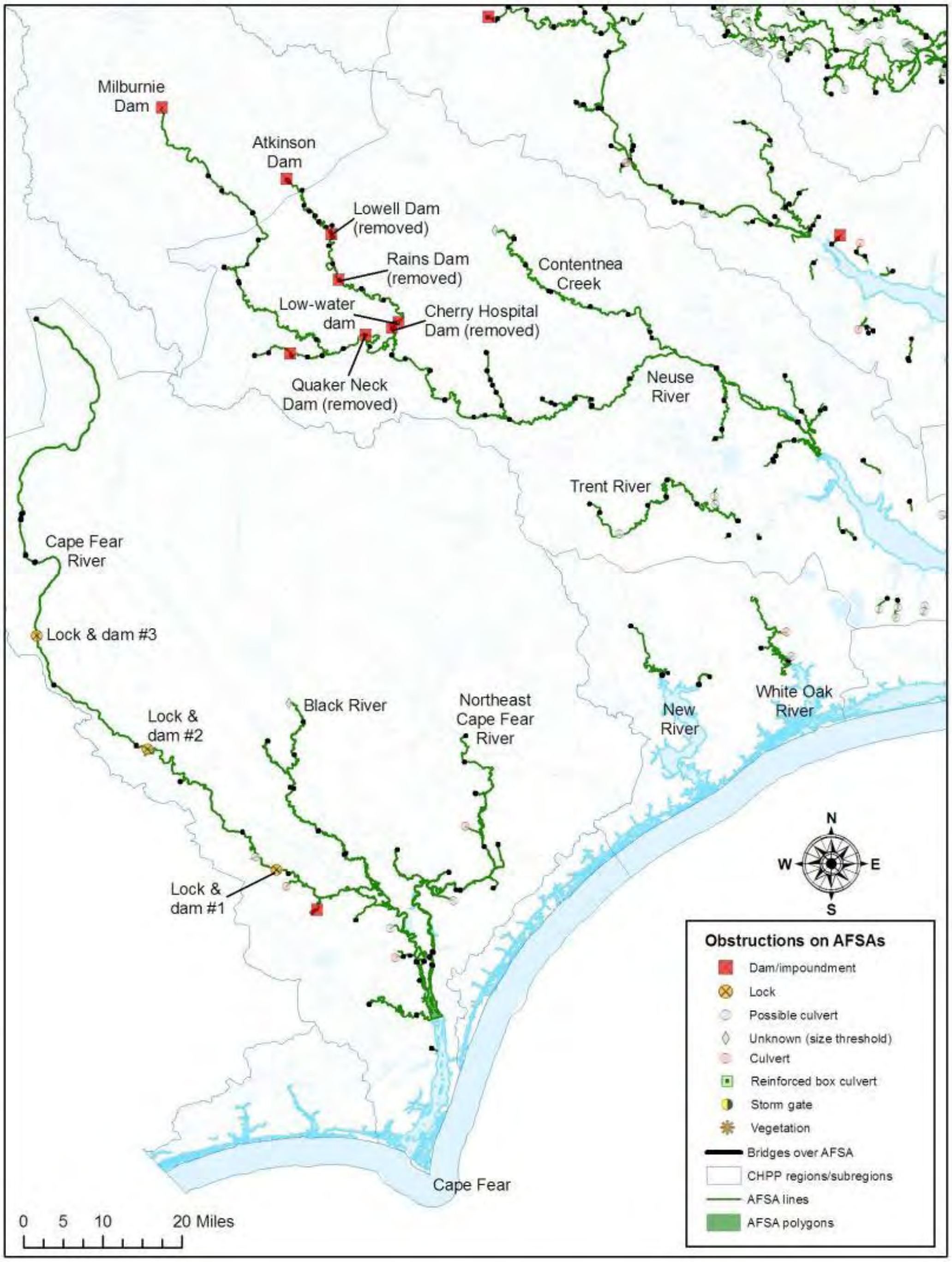

Figure 3. Anadromous fish spawning areas in the Neuse River and Cape Fear River areas.

Nursery Areas

North Carolina Primary Nursery Areas, first designated by the NCMFC in 1977, are similar in concept to Federal Habitat Areas of Particular Concern (HPAC). However, the NMFS has designated very few HAPCs (none in North Carolina), while the NCMFC/NCDMF and NCWRC have designated tens of thousands of acres as nursery areas in North Carolina (see below).

The state designations are well accepted by the various state and federal regulatory and permitting agencies, as well as by the public.

The NCMFC and NCWRC have designated nursery areas since 1977 and 1990, respectively, based on field sampling (Figures 4 and 5). Approximately 162,000 acres of Coastal Fishing Waters are currently designated by the NCMFC as Primary, Secondary, and Special Secondary Nursery Areas. About 10,000 acres of Inland Fishing Waters in the coastal area are designated as Inland Primary Nursery Areas, as well as the following areas of the four main rivers draining to North Carolina's coast:

- Roanoke River, U.S. 258 bridge to Roanoke Rapids Dam (35.5 stream miles, 57.1 km)
- Tar-Pamlico River, railroad bridge at Washington to Rocky Mount Mill Dam (90.2 stream miles, 145.2 km)
- Neuse River, Pitchkettle Creek to Milburnie Dam (160.6 stream miles, 258.4 km)
- Cape Fear River, Lock and Dam #1 to Buckhorn Dam (126.7 stream miles, 203.9 km).

There are specific protections for designated nursery areas included in the rules of the NC Environmental Management, Coastal Resources and Marine Fisheries commissions. There are relatively few PNAs in the Albemarle/Roanoke region, but a relatively large number of IPNAs. There are approximately 162,000 acres of PNA and SNAs (Permanent and Special) in North Carolina Coastal Fishing Waters (including both water and wetlands).

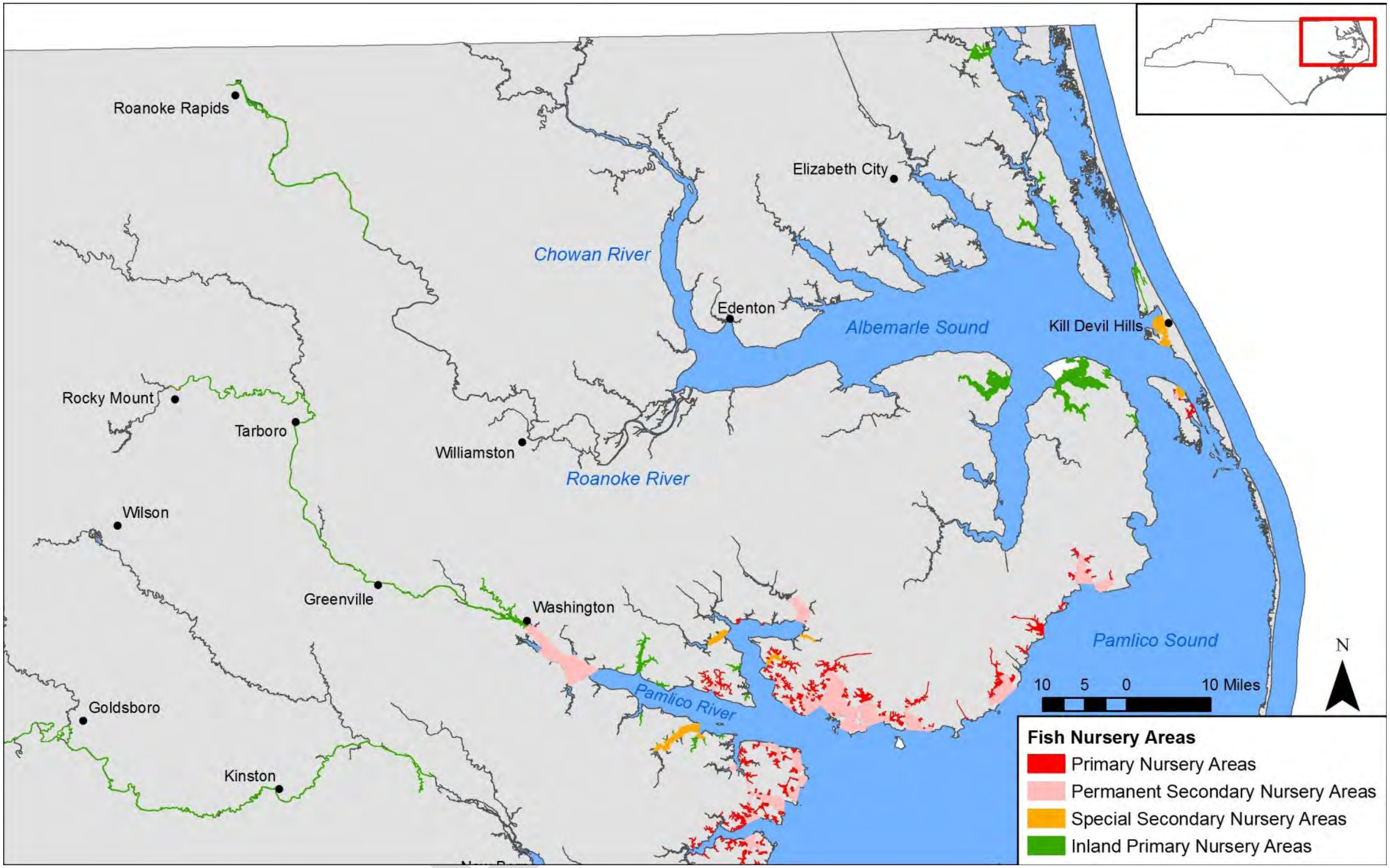

Figure 4. Nursery area designations in the Albemarle Sound and Pamlico River areas.

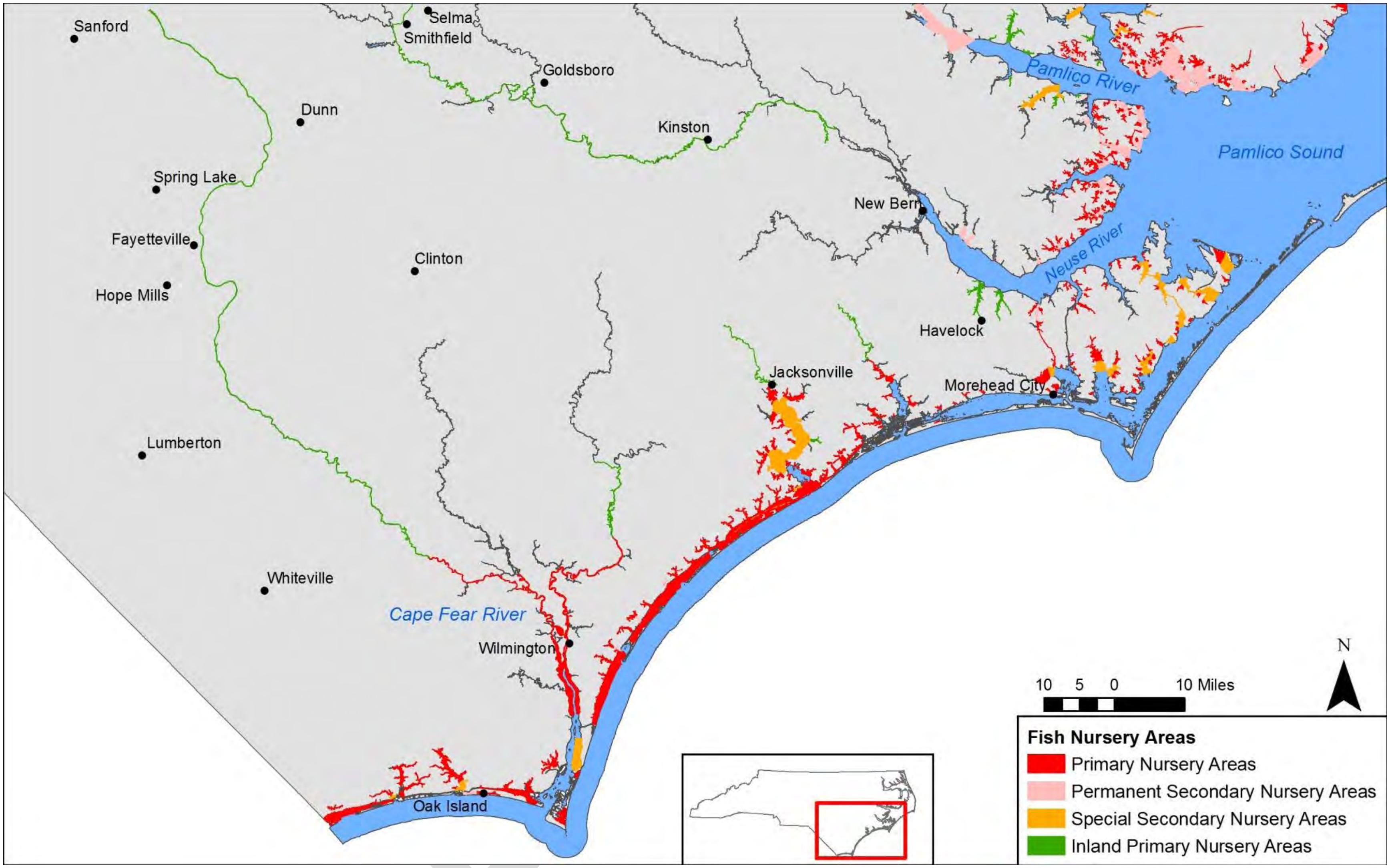

Figure 5. Nursery area designations in the Neuse River and Cape Fear River areas.

Strategic Habitat Areas (SHAs) - CHPP Chapter 8

The identification and designation of Strategic Habitat Areas (SHAs) for marine and coastal fishery species is a critical component in the implementation of North Carolina's approved CHPP. Strategic Habitat Areas were defined in the CHPP as, "specific locations of individual fish habitat or systems of habitats that have been identified to provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity" (Street et al. 2005). Criteria for identifying SHAs were developed by an advisory committee of the Marine Fisheries Commission established in summer 2005. The committee developed a scientifically based process for identifying candidate areas for designation using biological data and the consensus of a regional expert panel (regional advisory committee).

The identification of existing SHAs was conducted in a two step process: 1) using GIS-based habitat and alteration data in a computerized site-selection analysis, and 2) verifying and modifying information based on input from a scientific advisory committee. Staff and advisory committee specified representation levels for 42 habitat types, or natural resource targets. There were also 18 alteration factors that were represented geospatially (e.g., hydrologic alterations, water quality degradation). The site selection program MARXAN was used to select areas that met representation levels while also minimizing alteration. The scientific advisory committee then modified the computer results based on their unique knowledge and experience. The SHAs were corroborated with biological data, ecological designations, and specific knowledge of the area. The SHA nominations will be incorporated into conservation and restoration planning efforts.

SHA designations are based on regional analyses that identify optimally placed habitat areas of various ecological condition (exceptional or at risk). SHAs may include areas that have already been protected by other designations, as well as areas not currently recognized in any way. A network of designated SHAs providing habitat connections throughout North Carolina's coastal waters should ensure that the complex life history needs of all species are met. Once SHAs are designated in rule, resource managers may address gaps in existing management and take steps to prevent further alteration of the system as a whole. Thus, the necessary protections may go above and beyond current measures designed to protect habitat. Even before designation in rule, conservation agencies may incorporate candidate SHAs in their site selection process for acquisition, enhancement or restoration projects.

Four regions have been delineated for analysis and development of SHAs (Figure 6). SHAs have been identified in Region 1 and 2 (Figures 7 and 8, respectively). SHA identification is currently underway for Region 3.

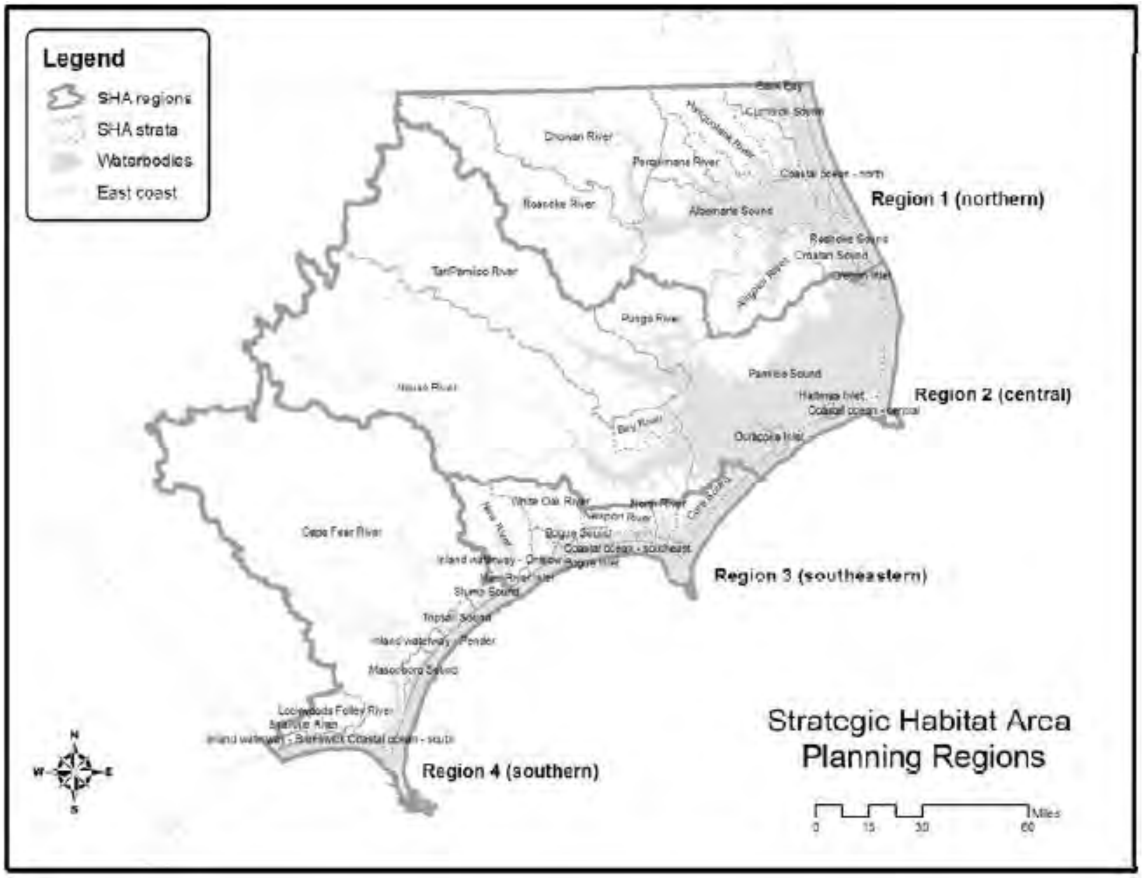

Figure 6. Geographic areas for Strategic Habitat Area (SHA) analysis.

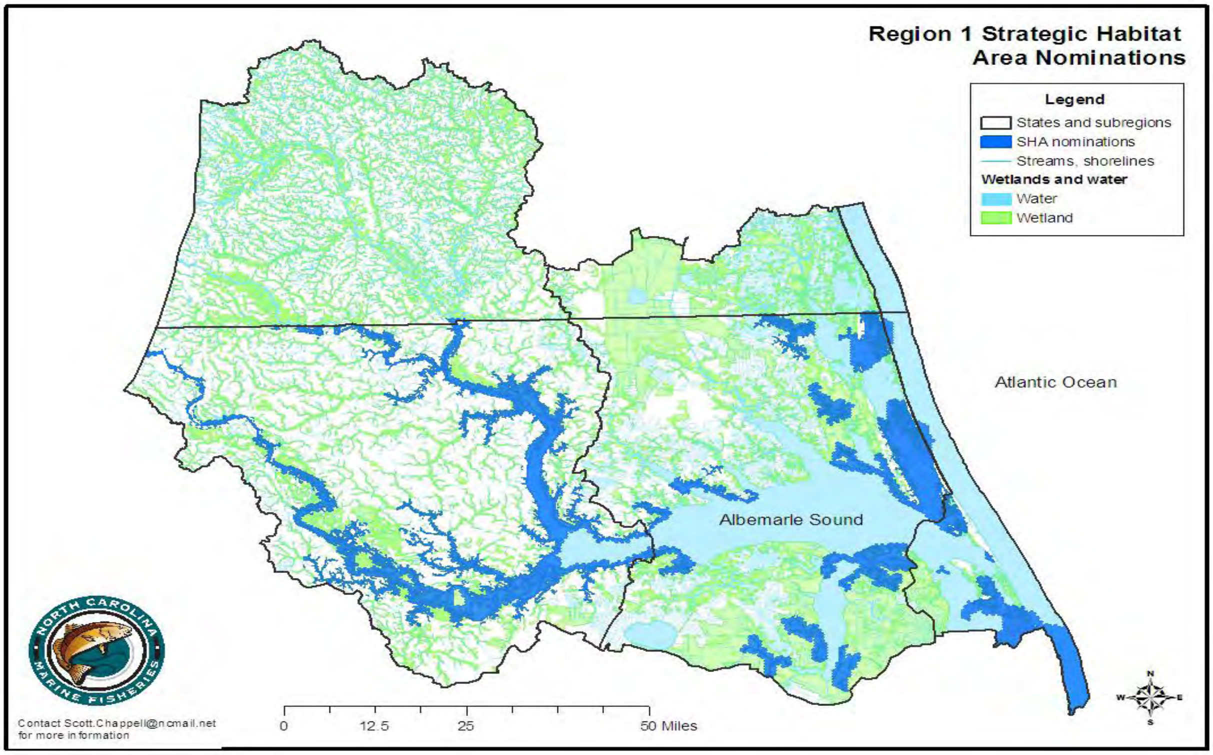

Figure 7. Region 1 strategic habitat area nominations.

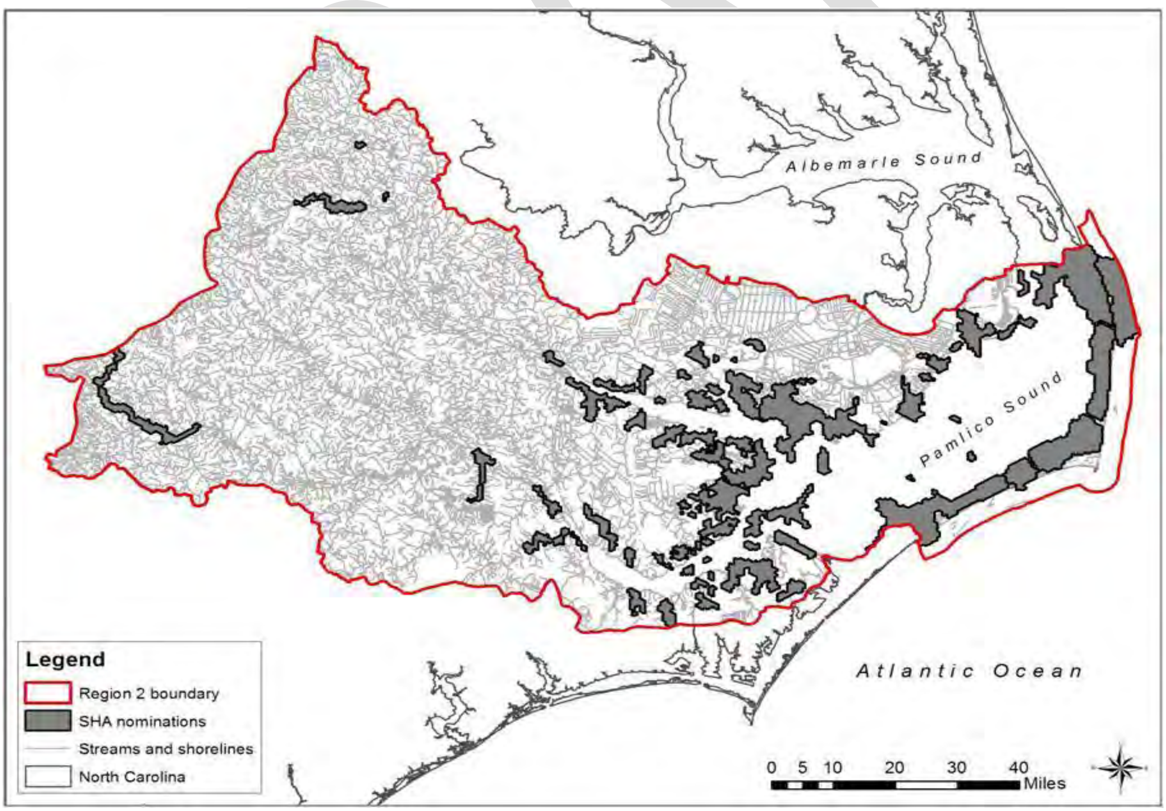

Figure 8. Region 2 strategic habitat area nominations.

Section 2: Threats Assessment

Barriers to Migration Inventory and Assessment

Dams- CHPP section 2.4.1.1

The majority of dams in North Carolina occur in the upstream portions of estuaries, rivers, and streams. In the coastal plain, dams are most abundant in the upper reaches of the Cape Fear, Neuse, Tar-Pamlico, Roanoke, and Chowan watersheds. These structures primarily impact anadromous fish and the catadromous American eel spawning migrations, maps 2.5a-b in the CHPP (Deaton et al 2010). Eggs and larvae are less likely to survive if passage to their historical spawning areas is obstructed by dams or other alterations (Moser and Terra 1999).

In the coastal plains portion of CHPP Region 1, approximately 18% (2,369 miles) of National Hydrologic Dataset (NHD) streams (13,070 miles) appear blocked by an impoundment, based on SHA Assessment results (see “Ecosystem management and Strategic Habitat Areas” chapter for more information; Pg. 446). The Chowan subregion of Region 1 had the largest percent of dam-obstructed streams at 38%. CHPP Table 2.21 tallies the number of dams, locks, and culverts in CHPP regions and subregions.

Other Physical Structures- CHPP section 2.4.1.2;5.4.1.5

Based on analysis of NC DENR and NC DOT records, it has been estimated that the state loses, on average, about 500 acres of wetlands per year, mostly from road construction (see “Status and trends” section of the Wetlands chapter for more information). Road construction over rivers, streams, or wetlands often involves blockage of a portion of the original stream channel and floodplain. Bridges may cross over the water or culverts may be constructed under the road, depending on the size of stream and associated wetlands. In the past, bridges were constructed by filling the adjoining wetlands and creating a narrow channel for water passage.

Altered Water Quality and Quantity- CHPP section 2.4.2

Besides degrading water quality, modifications to normal flow conditions (e.g., stream blockages, water withdrawals, droughts, or discharges) can negatively impact anadromous fish migrations, including American shad.

Water Withdrawals Inventory and Assessment - CHPP Section 2.4.1.1

Water is withdrawn from surface and ground waters for multiple purposes. Surface water is withdrawn for industrial uses (such as cooling water for nuclear and fossil fuel power plants), municipal water supply, crop irrigation, and other uses. Thermoelectric power generation accounts for the greatest amount of surface water withdrawals (Table 2.22). Documented water use in the state has risen from 9,286 to 10,863mgd from 1995-2008 (an increase of 1,577 mgd in 13 years).

Specific information regarding the type and quantity of water withdrawals for each basin is catalogued by the NC Division of Water Resources (NCDWR 2001).

Toxic and Thermal Discharges Inventory and Assessment - CHPP Section 2.4.2.1; 2.4.2.3;4.4.2.2

Both direct (point source) and indirect (non-point source) discharges occur in the river systems that support American shad, and can contain a variety of stressors that are generally dependent on adjacent land use. Common stressors contained in both point and non-point discharges are nutrients and toxins (e.g., chlorinated hydrocarbons).

Several of these major rivers flow into estuarine environments that are characterized by slowly moving, poorly flushed waters with high level of nutrients, which offer ideal conditions for various algae, fungi, and bacteria to thrive. Toxins can exist in the water column as well as adhere to bottom sediments. General information regarding discharges of nutrients and toxins is presented in the CHPP with specifics for each river basin.

Channelization and Dredging Inventory and Assessment - CHPP Section 2.4.1.3; 2.4.1.4; 4.4.1.1;5.4.1.4

Water Column, wetlands, SAV, and soft bottom, all of which are critical to American shad stocks, are directly threatened by dredging and channelization. Not only will dredging directly affect American shad stocks, the sedimentation and turbidity associated with it will have adverse impacts on American shad.

Much of NC's estuarine waters are shallow and these shallow waters are where most structured habitats like wetlands, SAV, and shell bottom occur. Dredging can consist of deepening existing shallow water habitat or creating new waters from upland in the form of canals, boat basins, marinas, or ditches. This is generally done for the purpose of navigation or drainage for flood or mosquito control. The latter is no longer permitted.

Land Use Inventory and Assessment - CHPP Section 1.5.1; 2.4.2.3

Land use and land cover vary from North Carolina's oceanfront shoreline to the freshwater upstream limit of American shad in coastal river systems. Statewide the dominant land cover is forest, followed by agriculture, and developed land (Figure 1). In the flat and relatively low elevation of the coastal plain, marsh and forested wetlands are very abundant. Forest land can be upland or wetland, and can be managed (silvaculture) or natural (undisturbed). Forestry and agriculture are the biggest industries in terms of land cover in the coastal plain.

Land cover and water quality within a watershed are closely linked. The impact of land uses on fish habitat and water quality depends on the location of the land uses in the watershed as well as local weather conditions (rainfall, winds etc.).

Atmospheric Deposition Inventory and Assessment - CHPP Section 2.4.3.3

The effect of atmospheric deposition on water quality is difficult to trace. Sources of atmospheric pollutants include vehicle exhaust, industrial emissions, and waste from animal operations (Walker et al. 2000; USGS 2003). Atmospheric deposition was the source implicated in 7.9% of impaired coastal draining streams in North Carolina (NCDWQ 2006). The greatest number of streams impaired from atmospheric deposition occurred in the Roanoke River Basin. A significant portion of nutrient pollution has also been attributed to atmospheric deposition .

Climate Change Inventory and Assessment - CHPP Section 2.4.5;4.4.5;5.4.4

Rising sea level is a major threat to coastal and riparian wetlands in North Carolina. Analyses of data from tide gauge stations in Hampton, Virginia, and Charleston, South Carolina, from 1921 to 2000 (Riggs 2001), show sea level rising along the Atlantic coast by about 3.35 mm per year (1.1 ft per 100 years). Gauge data specific to North Carolina are available only for 20 years, but suggest a slightly greater rate of approximately 4.57 mm per year (1.5 ft per 100 years).

The specific effects of climate change, including warming water, increased drought severity, and loss of flood plain spawning habitat should be further investigated.

Competition and Predation by Invasive and Managed Species Inventory and Assessment - CHPP 2.4.4; 4.4.3;5.4.3

There is widespread documentation that some non-native species can out-compete native species, altering the established ecosystem, habitat, and eventually water quality (Mallin et al. 2001, Burkholder et al. 2007).

For aquatic plants the most troublesome species in low-salinity estuarine waters are Eurasian water milfoil and hydrilla. It is possible for water milfoil and hydrilla to become thick dense beds that will out compete native SAV species. The presence of these two species may remove critical habitat by "choking" out native species or fish kills may arise due to low DO levels. Weed control activities in coastal waters are primarily focused on these species. Control activities target areas where native species are not the dominant species based on site assessments (R. Emens DWR, personal communication 2009).

Both the blue catfish (*Ictalurus furcatus*) and flathead catfish (*Pylodictis olivaris*) are nonnative catfish species in coastal North Carolina that are known to prey on native fishes including river herring and American shad. In North Carolina flathead catfish do not target native species, but they are opportunistic feeders eating whatever becomes available (Pine *et al.* 2005) but both species have been documented to consume river herring (Schloesser et al. 2011). At the current time, the blue catfish population is expanding in the Albemarle Sound and its tributaries but the extent of its effect on river herring is unknown. Flathead catfish do not appear to be an issue in the Albemarle Sound region but they have been collected by NCDMF throughout coastal waters (NCDMF unpublished data). The NCDMF has no regulations for the taking of invasive catfish in NC. With no regulations present it will help to keep these catfish populations low.

Section 3: Habitat Restoration Program

Barrier Removal and Fish Passage Program

Chowan Watershed

In the Chowan watershed, there is one hydropower dam on the Meherrin River, and one on the Nottaway River (Baskerville Mill dam), both in Virginia. In addition to dams found on mainstem rivers, numerous smaller mill dams are found on creeks throughout eastern North Carolina. For example, Collier and Odom (1989) reported three such dams within the Chowan River basin on Bennetts, Indian, and Rockyhock creeks (Figure 9.4). The dams on mainstem and tributary portions of the Chowan drainage basin form the upstream boundaries of some documented anadromous fish spawning habitat in North Carolina and Virginia. Although there is a fish passage structure, the upstream boundaries include the Emporia Dam on the Meherrin River in Virginia (Collier and Odom 1989). The structure on at the dam does not effectively pass fish upstream. Removing or bypassing these dams would open access to many miles of potential spawning habitat. Recent fish passage in the Chowan watershed includes only the Bennett's Creek dam creating Merchant's Mill Pond (Mike Wicker USFWS, personal communication, 2005). The effectiveness of dam removal/bypassing in river herring recovery will depend on whether the runs have been extirpated from the entire stream reach impounded.

Roanoke River

Currently, numerous large and small dams are present in the Roanoke River Basin. Roanoke Rapids Dam at river mile 137 is the lowermost dam on the mainstem of the river. Roanoke Rapids Dam impounds the river to Gaston Dam at river mile 145. Gaston Dam impounds the river to river mile 170, below Kerr Dam at river mile 179. Kerr Dam impounds the river up the Dan River to river mile 206, and up the Staunton River to river mile 212. Currently the Mid-East Resource Conservation and Development Council are working with APNEP and the NCWRC to restore river herring passage and habitat at the Hoggard Mill Pond in the headwaters of the Cashie River (J. Hawhee, APNEP, personal communication 2013).

Tar/Pamlico River

The Rocky Mount Mills Dam is the lowermost dam on the Tar River that obstructs migration of striped bass, American shad, Atlantic sturgeon, hickory shad, and blueback herring (Collier and Odom 1989). The Rocky Mount Mills Dam is a small hydro-dam that conducts peaking operations to produce electricity. Removal of the dam is unlikely due to the fact that the City of Rocky Mount has a water supply intake just above the dam and the dam is listed as a state historical site. However, discussions with the current owner, Capitol Broadcasting, Inc., are ongoing regarding the possibility of improving water flows downstream, and providing upstream passage for American shad. If water flows can be improved, this would be beneficial for all species using the Tar River, including river herring. Two other Tar River dams further upstream are considered to be within the range of anadromous fish migration, but are not currently accessible (Collier and Odom 1989).

Neuse River

The first blockage in the Neuse River is Milburnie Dam at river mile 183. The next obstruction is Falls of Neuse Dam at river mile 195. A substantial amount of mainstem habitat was restored in 1998 with the removal of the Quaker Neck Dam near Goldsboro (Bowman and Hightower 2001).

Removal of Milburnie Dam would allow the United States Army Corps of Engineers (USACE) some latitude to provide a stable flow regime for the Neuse and provide access to another 10-20 miles of riverine habitat for spawning. The owner of the dam has expressed an interest in removing the dam. The NCDWQ has expressed concern over removal of Milburnie Dam, due to possible loss of wetlands associated with the dam. In March 2010, the USACE received a prospectus to utilize the 29,000 linear feet of the Neuse River above the Milburnie Dam as a mitigation bank for state and federal permits. The applicant hopes to begin a phased removal of the dam in the fall 2013.

Little River, a Neuse River tributary, has had three low-head dams removed since 1998. Cherry Hospital Dam, Rain Mills Dam, and Lowell Mill Dam have been removed and have reconnected 51 river miles of Little River to the Neuse River and 147 river miles including Little River tributaries. Near Goldsboro there is the water withdrawal and treatment structure but it has been breached. This structure may still impede striped bass migrations during low flow years (W. Laney, USFWS, personal communication 2010). Full removal of this dam is not an option since it is the City of Goldsboro back up water intake structure so American Rivers has been working with the City to develop fish passage at this location.

The highest priorities for dam removal are Milburnie Dam on the mainstem Neuse River and the remaining dam on the Little River near Goldsboro (Atkinson Mill Dam), in the Neuse subregion (M. Wicker/USFWS, pers. com., March 2010).

Cape Fear River

In the Cape Fear River, the lowermost obstructions to migration are the three locks and dams located within the Coastal Plain operated by the USACE. The Cape Fear River may provide the best opportunity for remediation of obstructions. The Corps constructed a rock ramp fish passage for the lower most lock and dam, and is in discussions with resource agencies to design and construct fish passages on the other two locks and dams. There are water supply intakes above all three dams which prevents them from being removed.

Hatchery Product Supplementation Program

State and federal fisheries management agencies in North Carolina and Virginia finalized negotiations with Dominion/N.C. Power with regards to relicensing of the Gaston and Roanoke Rapids lakes hydroelectric dams through the Federal Energy Regulatory Commission (FERC). Among the mitigative measures required by relicensing was a long-term, well-funded, and coordinated program to restore American shad in the Roanoke River basin. Measures outlined in this effort included improvements in hatchery production of fry, continued intensive monitoring of fry stocking success upstream and downstream of the mainstem reservoirs, and an assessment of American shad population size, using hydroacoustic techniques, as it pertains to providing upstream passage facilities.

American shad fry reared at the USFWS Edenton National Fish Hatchery (ENFH) and at the NCWRC Watha State Fish Hatchery have been stocked annually into the Roanoke River since 1998. This restoration project was initiated by NCWRC and funded by the North Carolina Department of Transportation as mitigation for aquatic habitat damages resulting from highway bridge construction on the Roanoke River. Annual production and stocking information can be found in North Carolina's annual Shad and River Herring Compliance reports.

Water Quality Improvement Program

As noted in the Introduction, two-year Implementation Plans are developed by the staffs of the NC Division of Water Quality, NC Division of Coastal Management, NCDMF and NC WRC, in conjunction with the CHPP Steering Committee, detailing specific steps towards achieving CHPP goals and objectives. One of the four major goals of the CHPP is "Protect and enhance water quality" and significant cooperation among agencies has occurred in pursuit of this goal. Appendix 1 contains the most recent Implementation Plan (2011-2013), and outlines specific items regarding water quality, while Appendix 2 contains the most recent CHPP Annual Report, which details progress on items contained in the Implementation Plan.

The North Carolina General Assembly also recognized the importance of water quality to habitat integrity, as illustrated by its creation of the Clean Water Management Trust Fund (CWMTF) in 1996. The original purpose of the fund was to provide grant assistance for projects and land purchases that would specifically improve water quality. Previously, the CWMTF had a budget of up to $100,000,000, but in the past two years (2011 and 2012), the budget has been dramatically reduced to less than $50,000,000.

In 2010, the North Carolina General Assembly directed the NCDENR to develop hydrologic models for each river basin in N.C. An important part of this bill requires the department to determine the flows needed to maintain ecological integrity in surface waters. The bill further authorized the creation of a Science Advisory Board (SAB) to assist the department in assessing these ecological flows. Members of the SAB include staff from the NCDMF, NCWRC, USGS, and NMFS as well as several other government agencies and non-government organizations. The SAB is expected to make their recommendations by the end of 2013.

Habitat Improvement Program

Similar to the Water Quality Improvement Program, the CHPP Implementation Plan fills the role of a Habitat Improvement Program. Two of the four major CHPP goals are directly related to habitat protection and improvement: "Identify, designate and protect strategic habitat areas" and "Enhance habitat and protect it from physical impacts." The documents contained in Appendices 1 and 2 detail the components of and progress towards several efforts aimed at improving fisheries habitat in North Carolina.

In addition to the water quality goals noted in the previous section, the CWMTF has monies available to buy existing dams or have them opened for fish passage. The CWMTF receives input from both NCDMF and NCWRC on where fisheries priorities exist in the state. In 2010, American Rivers initiated a dam removal program in North Carolina. This organization has been working with state and federal agencies to prioritize which dams should and can be removed. While creating this list, American Rivers has been actively trying to obtain funding to remove dams. The Southeast Aquatic Resources Partnership is partnering with the Nature Conservancy to perform a GIS assessment that will prioritize barriers to aquatic resources movement for removal. This assessment, the Southeast Aquatic Connectivity Assessment Project, will prioritize on both the regional and state scales. Researchers at East Carolina University (R. Rulifson and J.P. Walsh) are in the process of estimating the acreage of habitat gained by the removal of the first and second obstructions on North Carolina coastal rivers.

Additionally, staffs from NCDMF and NCWRC, as well as other federal and state agencies participate in several cooperative efforts to improve fish passage, including the ASMFC Fish Passage workgroup.

Project Permit/Licensing Review and Minimization Programs

NCDMF participates in an extensive permit review process that is coordinated by the NC Division of Coastal Management on behalf of15 federal and state agencies. NCDMF is specifically authorized by state statute to review and comment on permits that may impact public trust resources, and has established a set of internal guidelines for staff in order to maintain a consistent review process. Dedicated staff conduct reviews on permits related to coastal development, while programmatic fisheries staff take the lead in reviewing federal permits for particular species.

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SOUTH CAROLINA HABITAT PLAN FOR AMERICAN SHAD

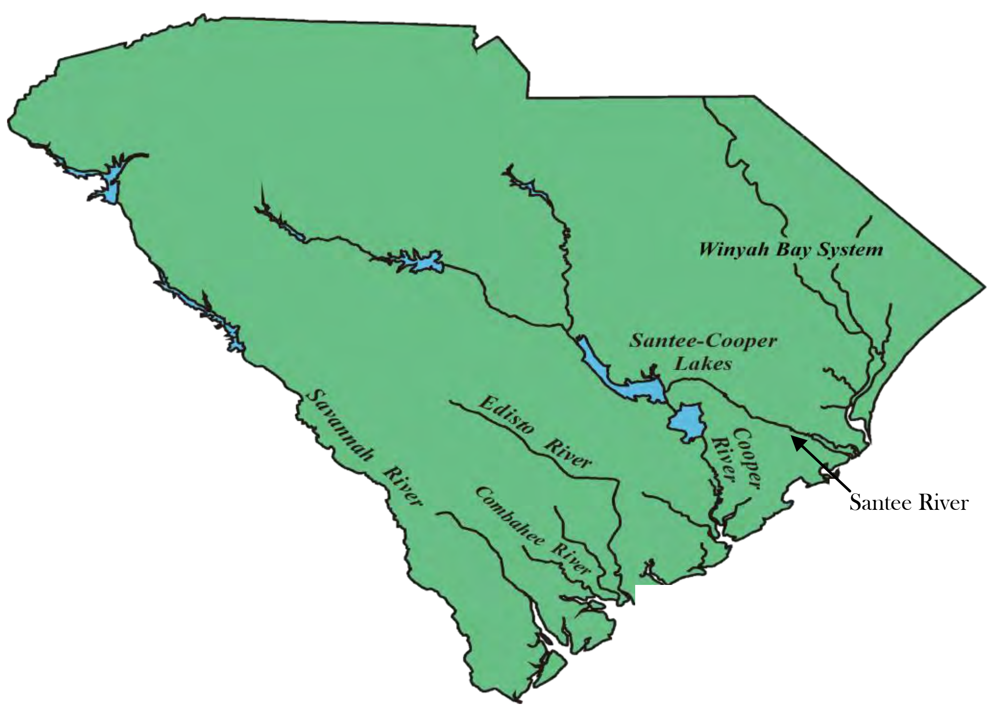
South Carolina Department of Natural Resources

September 2013

Introduction:

The purpose of this Habitat Plan is to briefly document existing conditions in rivers with American shad runs, identify potential threats, and propose action to mitigate such threats. American shad (*Alosa sapidissima*) are found in at least 19 rivers of South Carolina (Waccamaw, Great Pee Dee, Little Pee Dee, Lynches, Black, Sampit, Bull Creek, Santee, Cooper, Wateree, Congaree, Broad, Wando, Ashley, Ashepoo, Combahee, Edisto, Coosawhatchie, and Savannah Rivers). Many have historically supported a commercial fishery, a recreational fishery, or both. Currently, commercial fisheries exist in Winyah Bay, Waccamaw, Pee Dee, Black, Santee, Edisto, Combahee, and Savannah Rivers, while the Sampit, Ashepoo, Ashley, and Cooper rivers no longer support commercial fisheries. With the closure of the ocean-intercept fishery beginning in 2005, the Santee River and Winyah Bay complex comprise the largest commercial shad fisheries in South Carolina. Recreational fisheries still exist in the Cooper, Savannah, Edisto, and Combahee Rivers, as well as the Santee River Rediversion Canal. For the purposes of this plan, systems have been identified which, in some cases, include several rivers. Only river systems with active shad runs were included in this plan, these include the Pee Dee River run in the Winyah Bay System (primarily the Waccamaw and Great Pee Dee Rivers), the Santee-Cooper system (Santee and Cooper Rivers with the inclusion of Lakes Moultrie and Marion), and the ACE Basin (Edisto and Combahee Rivers). A joint plan with Georgia will be submitted for the Savannah River. (Figure 1).

Figure 1. Map of major South Carolina drainage basins and river systems with American shad (*Alosa sapidissima*) fisheries or historical American shad runs.



Pee Dee River System

Habitat Assessment

The Pee Dee River watershed encompasses parts of North Carolina and South Carolina. Beginning in North Carolina in the Appalachian Mountains, tributaries flow out across the piedmont and at the confluence of the Yadkin and Uwharrie Rivers the Great Pee Dee River begins. From there it flows 90 km in North Carolina, and 280 km in South Carolina before emptying into Winyah Bay. The Great Pee Dee River flows unimpeded for its entire length in South Carolina.

Historical Habitat

American shad inhabited all of the Great Pee Dee River (280 km) and had access to all main stem tributaries throughout the 22,258 km^2 watershed within South Carolina (SCDHEC), including Little Pee Dee River (187 km), Lynches River (225 km), Black River (243 km), and Waccamaw River (225 km) in both South Carolina and North Carolina. Stevenson (1899) reported American shad utilized the Pee Dee River throughout its entire length in South Carolina. He also reported American shad were taken 161 km up the Waccamaw River, 210 km up the Black River, and "considerable numbers" were taken 200 km up the Lynches River. Welch (2000), found contradicting reports on the historical presence of American shad in the Little Pee Dee River. A published letter to the U.S. Fish Commissioner from 1887 talked of shad in the Little Pee Dee River (Burns 1887); whereas Stevenson (1899) found no record of American shad caught in large numbers.

Current Useable Habitat

Spawning – American shad have access to all adequate habitats, there are no barriers to migration throughout the South Carolina portion of the watershed. Suitable freshwater riverine channel habitat for spawning occurs ~48 km inland and continues throughout the entire river portion of the Great Pee Dee River in South Carolina and all main stem tributaries.

Rearing - Suitable rearing habitats are similar to the listed waterways for suitable spawning habitat with the addition of 18,158 ha of estuary in the Pee Dee River basin (SCDHEC 2013).

Threats Assessment

a. Barriers to migration inventory and assessment

The Blewett Falls Dam is the furthest downstream dam on the Great Pee Dee River located at km 302. It is a North Carolina facility, however since it affects the spawning run of shad in the Pee Dee River System, it is mentioned briefly in this plan.

Action: Develop a plan for establishing fish passage at barriers in the Pee Dee River System.

Regulatory Agencies/Contacts: USFWS, NMFS, FERC, USACE, South Carolina Department of Natural Resources (SCDNR), North Caroina Wildlife Resources Commission (NCWRC), dam owners and operators, and federal and state legislators.

Goal/Target: Establish fish passage at dams in the Yadkin-Pee Dee River basin, where passage is determined to be feasible.

Progress: As part of the Federal Energy Regulation Commission (FERC) licensing process, hydroelectric facilities in the Yadkin-Pee Dee River Basin (in particular Blewett Falls Dam) are required to implement trap and truck operations by the forth spawning season following the issuance of the license. This phased approach also requires modification of the trap facility and installation of a fish exit flume, allowing direct passage of fish over Blewett Falls by 2020. In addition, mandated flow requirements associated with the issuance of the license should greatly improve water quality in the system.

Cost: Unknown at this time.

Timeline: 2020

b. The following is a list of point source, nonpoint source, and water withdrawals that occur in the Pee Dee River System:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*	*Receiving Stream*
INTERNATIONAL PAPER CO./GEORGETOWN	MAJOR INDUSTRIAL	SC0000868	03040207-01	(Sampit River)	SAMPIT RIVER
3V, INC.	MAJOR INDUSTRIAL	SC0036111	03040207-01	(Sampit River)	SAMPIT RIVER
CITY OF GEORGETOWN WWTP	MAJOR DOMESTIC	SC0040029	03040207-01	(Sampit River)	SAMPIT RIVER
CITY OF GEORGETOWN/WTP	MINOR INDUSTRIAL	SCG645013	03040207-01	(Sampit River)	SAMPIT RIVER
ISG GEORGETOWN INC.	MAJOR INDUSTRIAL	SC0001431	03040207-01	(Sampit River)	SAMPIT RIVER
SCPSA/WINYAH STEAM STATION	MAJOR INDUSTRIAL	SC0022471	03040207-01	(Sampit River)	TURKEY CREEK
INTERNATIONAL PAPER CO./SANTEE	MINOR DOMESTIC	SC0042960	03040207-01	(Sampit River)	TURKEY CREEK TRIBUTARY
CWS/WHITES CREEK-LINCOLNSHIRE SD	MINOR DOMESTIC	SC0030732	03040207-01	(Sampit River)	WHITES CREEK
GCSD/DEEP CREEK ELEM SCHOOL	MINOR DOMESTIC	SC0039195	03040207-02	(Great Pee Dee River/Winyah Bay)	BOSER SWAMP
GCSD/PLEASANT HILL ELEM SCHOOL	MINOR DOMESTIC	SC0039101	03040207-02	(Great Pee Dee River/Winyah Bay)	FLAT RUN SWAMP
CAROLINA SAND INC./BRITTONS NECK	MINOR INDUSTRIAL	SCG730043	03040207-02	(Great Pee Dee River/Winyah Bay)	MAPLE SWAMP
JAYCO/CANNONS LAKE MINE	MINOR INDUSTRIAL	SCG730538	03040207-02	(Great Pee Dee River/Winyah Bay)	MAPLE SWAMP
GCW&SD/PLANTERSVILLE EDR	MINOR DOMESTIC	SCG645051	03040207-02	(Great Pee Dee River/Winyah Bay)	CHAPEL CREEK TRIBUTARY
TOWN OF HEMINGWAY/WWTP	MINOR DOMESTIC	SC0039934	03040207-02	(Great Pee Dee River/Winyah Bay)	CLARK CREEK
DELTA MILLS INC./CYPRESS PLANT	MINOR INDUSTRIAL	SCG250151	03040201-12	(Great Pee Dee River)	GREAT PEE DEE RIVER

CAROLINA SAND/GRESHAM PIT	MINOR INDUSTRIAL	SCG730181	03040201-12	(Great Pee Dee River)	GREAT PEE DEE RIVER TRIBUTARY
DELTA MILLS INC./PAMPLICO PLANT	MINOR INDUSTRIAL	SCG250150	03040201-12	(Great Pee Dee River)	MILL BRANCH
TOWN OF PAMPLICO	MINOR DOMESTIC	SC0021351	03040201-12	(Great Pee Dee River)	GREAT PEE DEE RIVER
CITY OF MARION/S. MAIN ST. WWTP	MAJOR DOMESTIC	SC0046230	03040201-10	(Great Pee Dee River)	GREAT PEE DEE RIVER
DUPONT TEIJIN FILMS/FLORENCE PLANT	MAJOR INDUSTRIAL	SC0002917	03040201-10	(Great Pee Dee River)	GREAT PEE DEE RIVER
STONE CONTAINER CORP	MAJOR INDUSTRIAL	SC0000876	03040201-10	(Great Pee Dee River)	GREAT PEE DEE RIVER
MARION CERAMICS, INC./PEE DEE MINE	MINOR INDUSTRIAL	SCG730219	03040201-10	(Great Pee Dee River)	TOBYS CREEK
MOHAWK IND./OAK RIVER PLANT	MINOR INDUSTRIAL	SC0001996	03040201-08	(Great Pee Dee River)	GREAT PEE DEE RIVER
WALKER CONSTR./WALKER BORROW PIT	MINOR INDUSTRIAL	SCG730234	03040201-08	(Great Pee Dee River)	CARTERS BRANCH
DARLINGTON COUNTY/RUSSELL 2 MINE	MINOR INDUSTRIAL	SCG730515	03040201-08	(Great Pee Dee River)	BUCKHOLTZ CREEK TRIBUTARY
HANSON AGGREGATES SE/BROWNSVILLE	MINOR INDUSTRIAL	SCG730468	03040201-08	(Great Pee Dee River)	ROGERS CREEK TRIBUTARY
HANSON AGGREGATES SE/BLENHEIM	MINOR INDUSTRIAL	SCG730039	03040201-08	(Great Pee Dee River)	RIGGINS BRANCH
US CONSTRUCTORS/HANSON PIT	MINOR INDUSTRIAL	CG730435	03040201-08	(Great Pee Dee River)	GREAT PEE DEE RIVER TRIBUTARY
TOWN OF CLIO WWTF	MINOR DOMESTIC	SC0040606	03040201-08	(Great Pee Dee River)	HAGINS PRONG
TOWN OF CHERAW WWTP	MAJOR DOMESTIC	SC0020249	03040201-05	(Great Pee Dee River)	GREAT PEE DEE RIVER
DOMTAR PAPER CO.LLC/MARLBORO MILL	MAJOR INDUSTRIAL	SC0042188	03040201-05	(Great Pee Dee River)	GREAT PEE DEE RIVER
DELTA MILLS INC.	MAJOR INDUSTRIAL	SC0002151	03040201-05	(Great Pee Dee River)	GREAT PEE DEE RIVER
GALEY & LORD, INC./SOCIETY HILL	MAJOR INDUSTRIAL	SC0002704	03040201-05	(Great Pee Dee River)	GREAT PEE DEE RIVER
HANSON AGGREGATES SE/CASH MINE	MINOR INDUSTRIAL	SCG730467	03040201-05	(Great Pee Dee River)	PEE DEE RIVER TRIBUTARY
HANSON AGGREGATES SE/MARLBORO	MINOR INDUSTRIAL	SCG730359	03040201-05	(Great Pee Dee River)	CROOKED CREEK
CITY OF BENNETTSVILLE WWTP	MAJOR DOMESTIC	SC0025178	03040201-05	(Great Pee Dee River)	CROOKED CREEK
US CONSTRUCTION/BERMUDA PIT	MINOR INDUSTRIAL	SCG730472	03040201-05	(Great Pee Dee River)	CROOKED CREEK
MOREE FARMS/PARADISE PIT	MINOR INDUSTRIAL	SCG730558	03040201-05	(Great Pee Dee River)	SPOT MILL CREEK TRIBUTARY
SCHAEFFLER GROUP USA, INC	MINOR INDUSTRIAL	SCG250163	03040201-05	(Great Pee Dee River)	WILSON BRANCH TRIBUTARY
PALMETTO BRICK/IRBY MINE	MINOR INDUSTRIAL	SCG730240	03040201-05	(Great Pee Dee River)	PHILS CREEK
PALMETTO BRICK/ROBERTS MINE	MINOR INDUSTRIAL	SCG730573	03040201-05	(Great Pee Dee River)	PHILS CREEK TRIBUTARY
PALMETTO BRICK/WINBURN MINE	MINOR INDUSTRIAL	SCG730241	03040201-05	(Great Pee Dee River)	CEDAR CREEK
MARLBORO COUNTY/COUNTY PIT	MINOR INDUSTRIAL	SCG730158	03040201-05	(Great Pee Dee River)	BEVERLY CREEK
PALMETTO BRICK/CLINKSCALE MINE	MINOR INDUSTRIAL	SCG730443	03040201-05	(Great Pee Dee River)	BEAVERDAM CREEK TRIBUTARY
PALMETTO BRICK/PEFUES MINE	MINOR INDUSTRIAL	SCG730434	03040201-03	(Great Pee Dee River)	MARKS CREEK
OLD CASTLE STONE/ESKRIDGE MINE	MINOR INDUSTRIAL	SCG730475	03040201-03	(Great Pee Dee River)	GREAT PEE DEE RIVER TRIBUTARY
MARION CERAMICS/PAVER MINE	MINOR INDUSTRIAL	SCG730218	03040201-03	(Great Pee Dee River)	GREAT PEE DEE RIVER TRIBUTARY

Water Quantity					
Water User	***Regulated Cap. (MGD)***	***Pumping Cap. (MGD)***	***Section Number***	***Section Name***	***Stream***
CITY OF GEORGETOWN	5.2	10.5	03040207-02	(Great Pee Dee River/Winyah Bay)	GREAT PEE DEE RIVER
GSW&SA/BULL CREEK REGIONAL WTP	50.87	60.42	03040207-02	(Great Pee Dee River/Winyah Bay)	BULL CREEK
TOWN OF CHERAW	4.5	11.5	03040201-05	(Great Pee Dee River)	GREAT PEE DEE RIVER
CITY OF BENNETTSVILLE	4	6	03040201-05	(Great Pee Dee River)	LAKE WALLACE

All point source, nonpoint source, and water withdrawals that occur in the Pee Dee River System are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). All discharges are held to water quality standards for the state. Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat. In addition, all programs are currently undergoing cooling water intake structures rules (40 CFR 122 and 125) analysis to assess the likelihood of impingement or entrainment in efforts to ensure compliance with the proposed EPA 316(b).

c. Toxic and thermal discharge inventory and assessment-none

d. Channelization and dredging

The following is a list of historic dredging programs that occurred in the Pee Dee River System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
8/20/1993	Pee Dee	SAC-1993-12414	NWP	WATERFORD PLANTATION CANAL	Georgetown	33.428610	-79.194440
7/13/1994	Pee Dee	SAC-1994-10314	LOP	CANAL MAINTENANCE EXCAVATION	Darlington	34.352990	-79.691980
8/9/1994	Pee Dee	SAC-1994-22612	NWP	DREDGING	Georgetown	33.305700	-79.292900
12/2/1994	Pee Dee	SAC-1994-15178	NWP	SAMPIT SHIPARD	Georgetown	33.353890	-79.306670
5/9/1995	Pee Dee	SAC-1995-10620	SP	STATE PIER #32 DREDGING	Georgetown	33.366570	-79.290710
7/17/1996	Pee Dee	SAC-1996-10887	SP	EMERGENCY CANAL DREDGE	Georgetown	33.701700	-79.258600
5/26/1998	Pee Dee	SAC-1998-11458	SP	SANDBAR REMOVAL	Chesterfield	34.707220	-79.876110
11/19/1999	Pee Dee	SAC-1999-11854	SP	GEORGETOWN LANDING MARINA US HWY 17	Georgetown	33.366600	-79.268360
1/3/2003	Pee Dee	SAC-2003-13032	SP	BELLE ISLE MARINA	Georgetown	33.306220	-79.292630
5/13/2008	Pee Dee	SAC-1985-08234-4NJ	NWP	SCWMRD	Horry	33.664130	-79.135730
12/7/2012	Pee Dee	SAC-2000-11969	SP	BELLE ISLE MARINA DREDGING	Georgetown	33.304400	-79.293100

In addition, the shipping channel near Georgetown, SC is 28.8 km long and authorized to 8.2 m. However, funding is rarely available to maintain it. Currently, it is significantly shallower than 8.2 m in some areas (Appendix 1).

It is highly unlikely current or past dredging operations are having impacts on adult American shad migration and utilization of historic habitat.

e. The following is a list of land use and mining activities that occur in the Pee Dee River System:

Nonpoint Source Management Program				
Landfill Facilities	***Status***	***Permit #***	***Section Number***	***Section Name***
INTERNATIONAL PAPER, INC. LANDFILL	ACTIVE	222435-1601	03040207-01	(Sampit River)
INTERNATIONAL PAPER, INC. LANDFILL	ACTIVE	222654-8001	03040207-01	(Sampit River)
INTERNATIONAL PAPER, INC. LANDFILL	ACTIVE	222654-8002	03040207-01	(Sampit River)
FRASIER COMPOSTING SITE	ACTIVE	222679-3001	03040207-01	(Sampit River)
MCKENZIE WOOD CHIPPING	ACTIVE	222732-3001	03040207-01	(Sampit River)
MILLER WOOD PROCESSING FACILITY	ACTIVE	222763-3001	03040207-01	(Sampit River)
TOWN OF HEMMINWAY COMPOSTING SITE	ACTIVE	451003-3001	03040207-02	(Great Pee Dee River/Winyah Bay)
THOMPSONS LAND CLEARING	ACTIVE	222678-3001	03040207-02	(Great Pee Dee River/Winyah Bay)

SMURFIT STONE CONTAINER CORP.	ACTIVE	213310-1601	03040201-10	(Great Pee Dee River)
FLORENCE COUNTY C&D LANDFILL	ACTIVE	211001-1201	03040201-10	(Great Pee Dee River)
CITY OF BENNETTSVILLE TRANSFER STA.	ACTIVE	351002-6001	03040201-08	(Great Pee Dee River)
MARLBORO COUNTY COMPOSTING FACILITY	ACTIVE	351001-3001	03040201-08	(Great Pee Dee River)
PALMETTO BRICK CO.	ACTIVE	353324-1601	03040201-05	(Great Pee Dee River)
FURR FACILITY C&D LANDFILL	ACTIVE	132670-1201	03040201-05	(Great Pee Dee River)
MCDUFFIE & SON COMPOSTING	ACTIVE	352691-3001	03040201-05	(Great Pee Dee River)
WEYERHAEUSER COMPANY	ACTIVE	353301-1601	03040201-05	(Great Pee Dee River)
WEYERHAEUSER COMPANY	ACTIVE	353301-8001	03040201-05	(Great Pee Dee River)
CHESTERFIELD COUNTY LANDFILL	ACTIVE	131001-1601	03040201-05	(Great Pee Dee River)

Mining Activities	***Mineral***	***Permit #***	***Section Number***	***Section Name***
SAMPIT MINE	SAND	1639-43	03040207-01	(Sampit River)
HARMONY TOWNSHIP LAKES 1&2	SAND	1655-43	03040207-01	(Sampit River)
GRESHAM MINE NECK SAND MINE #2	SAND	0899-67	03040207-02	(Great Pee Dee River/Winyah Bay)
BACCHUS LAKE MINE	SAND	1682-67	03040207-02	(Great Pee Dee River/Winyah Bay)
CANNONS LAKE MINE	SAND	1552-67	03040207-02	(Great Pee Dee River/Winyah Bay)
WHITE HALL SAND MINE	SAND	1675-67	03040207-02	(Great Pee Dee River/Winyah Bay)
RICHARDSON MINE	SAND/GRAVEL	1765-67	03040207-02	(Great Pee Dee River/Winyah Bay)
JOHNSON ROAD MINE	SAND	1704-67	03040207-02	(Great Pee Dee River/Winyah Bay)
CHARLIE RICHARDSONS LAKE MINE	SAND	1776-67	03040207-02	(Great Pee Dee River/Winyah Bay)
PEE DEE CERAMICS MINE	CLAY	0050-67	03040201-10	(Great Pee Dee River)
BAKER BROTHERS OF GRESHAM INC	SAND; SAND/CLAY	0959-31	03040201-08	(Great Pee Dee River)
RUSSELL MINE #2	SAND/CLAY	0967-31	03040201-08	(Great Pee Dee River)
WALKER BORROW PIT	SAND	1195-69	03040201-08	(Great Pee Dee River)
BROWNSVILLE PLANT	SAND/GRAVEL	0090-69	03040201-08	(Great Pee Dee River)
CLINKSCALE	SAND	1528-69	03040201-05	(Great Pee Dee River)
MARLBORO PIT	CLAY	0171-69	03040201-05	(Great Pee Dee River)
ROBERTS MINE	SAND	1559-69	03040201-05	(Great Pee Dee River)
CASH PLANT	SAND/GRAVEL	0092-25	03040201-05	(Great Pee Dee River)
PEE DEE MINE	SAND/GRAVEL	0466-25	03040201-05	(Great Pee Dee River)
MARLBORO COUNTY PIT	SAND/CLAY	0280-69	03040201-05	(Great Pee Dee River)
BURNT FACTORY MINE	SAND/CLAY	1716-69	03040201-05	(Great Pee Dee River)
MARLBORO PLANT	SAND/GRAVEL	0095-69	03040201-05	(Great Pee Dee River)
MARLBORO FIELD PLANT	SAND/GRAVEL	0096-69	03040201-05	(Great Pee Dee River)
WINBURN	KAOLIN	0997-25	03040201-05	(Great Pee Dee River)
PEGUES MINE	SHALE	1485-69	03040201-03	(Great Pee Dee River)
MARLBORO COUNTY MINE	SAND	0726-69	03040201-03	(Great Pee Dee River)
MARION CERAMICS INC. - PAVER MINE	SHALE	0550-69	03040201-03	(Great Pee Dee River)

All land use and mining activities that occur in the Pee Dee River System are closely monitored by the South Carolina Deparment of Health Environmental Control (DHEC). Therefore, it is highly unlikely these programs impact adultAmerican shad migration and utilization of historic habitat.

f. Atmospheric deposition

Atmospheric deposition is measured as a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies as part of the National Atmospheric Deposition Program (NADP). This organization uses many networks (NTN, AIRMoN, MDN, AMNet, and AMNoN) to monitor methyl mercury, ammonia, etc. Detailed information concerning atmospheric deposition in SC can be found at the following website: http://nadp.sws.uiuc.edu/data/annualmaps.aspx

It does not appear that current levels of atmospheric deposition are impacting American shad migrations or utilization of historic habitat.

g. Climate change assessment

A changing climate will present water-related challenges for American shad in several areas including: water quality, water quantity and changes in sea level. Current climate models predict continued warming across the southeast, with the greatest temperature increases projected in summer. Average annual temperatures are projected to rise 4.5°F by the 2080s under a lower emissions scenario and 9°F under a higher emissions scenario with a 10.5°F increase in summer. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration. Drought conditions could potentially impact American shad recruitment and long duration drought could negatively impact multiple year classes. Sea level rise is of concern because of the expected change in location of the saltwater/freshwater interface. As sea level rises, saltwater will move further up the river systems of the state thus reducing the amount freshwater spawning habitat available. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. A changing climate will impact the water resources of South Carolina and will present challenges for American shad management.

Action: Develop a climate change plan.

Regulatory Agencies/Contacts: SC Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address climate change.

Progress: A “draft” plan has been developed and is still under review (Appendix 2)

Cost: Unknown at this time.

Timeline: Unknown

h. Competition and predation by invasive and managed species assessment

Aquatic invasive species occur throughout South Carolina's coastal rivers, and non-native ictalurids are some of the most ubiquitous invasive species. Flathead catfish (*Pylodictis olivaris*) and blue catfish (*Ictalurus furcatus*) were introduced into South Carolina in 1964 and are now found in all of South Carolina's coastal rivers. A significant portion of blue catfish and especially flathead catfish diet is comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad. Ictalurid population information is currently unavailable for South Carolina's coastal rivers; however current studies are occurring in South Carolina and other neighboring states to assess the potential impacts of non-native catfish on American shad.

Action: Develop an invasive species plan.

Regulatory Agencies/Contacts: SC Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address invasive species.

Progress: SCDNR programs are currently monitoring catch rates of invasive catfish as part of non-targeting sampling and any flat head catfish captured during these activities are being removed from the system. In addition, current eradication programs, such as those on the Satilla River, GA, are being reviewed by SCDNR staff to determine if such programs are feasible for SC Rivers.

Cost: Unknown at this time.

Timeline: Unknown

Santee-Cooper System

Habitat Assessment

Watersheds in the Santee River basin begin in the foothills of the Blue Ridge Mountains, flow across the piedmont and coastal plain before emptying in the Atlantic Ocean. Santee River basin is the second largest watershed on the Atlantic coast of the United States, and through the works of man in the 1940's the Santee River was directly connected to the Cooper River. The connection was made by building Santee (Wilson) Dam on the Santee River at ~km 145 creating Lake Marion, then Lake Moultrie was constructed by diking and the two lakes were connected via a canal. Pinopolis Dam was constructed on Lake Moultrie and a ~7 km tailrace canal was dug to deliver the majority of the Santee River flow into Cooper River. Prior to the diversion of the Santee River, the Cooper River was a coastal plain, tidally influenced tributary to Charleston Harbor. In 1985, a 18.5 km rediversion canal and St. Stephens Dam were completed that rerouted a majority of the Santee River flow back to the historical Santee River channel at ~rkm 85.

Historical Habitat

Prior to dam construction, American shad inhabited many major rivers with suitable spawning and rearing habitat throughout a 27,454 km^2 watershed in South Carolina and a 13,726 km^2 watershed in North Carolina, these included the Santee River (230 km), and its major tributaries the Wateree River (120 km), Congaree River (76 km), Broad River (241 km), and the Catawba River (350 km) located in South Carolina and North Carolina. Although the complete distribution of American shad is unknown there were also historical records from smaller tributaries of the Broad River; such as Saluda River, Enoree River, Tyger River, and Pacolet River (Welch, 2000). The Cooper River also provided 67 km of suitable habitat.

Current Useable Habitat

Spawning – American shad begin spawning in tidal freshwater near rkm 48, and have about 105 km of suitable riverine channel habitat for spawning in the Santee River below the Santee-Cooper Dams and an additional 40km in the Cooper River (McCord 2003). Two of the three dams of the Santee-Cooper reservoir project provide American shad passage. A boat lock at Pinopolis Dam is operated for anadromous fish passage on the Cooper River, and a fish lift operates for anadromous fish passage at St. Stephens Dam on the rediversion canal. These passage facilities provide American shad access to areas of suitable spawning habitat such as Lake Marion (44,515 ha), Upper Santee River (above Lake Marion) (9.5 km), Wateree River to the base of Wateree Dam (121 km), Congaree River (76 km), and Broad River to the Columbia Diversion Dam (4 km). An additional fishway at Columbia Diversion Dam provides passage for American shad in the Broad River to the base of Parr Dam (39 km). Adult American shad are annually encountered in all currently available habitats.

Rearing-Suitable rearing habitats are similar to the listed waterways for suitable spawning habitat with the addition of Lake Moultrie (24,281 ha), and the estuaries of the Santee River basin (7,420 ha) and Charleston Harbor (18,518 ha) (SCDHEC 2013).

Threats Assessment

a. Barriers to migration inventory and assessment

The following are a list of dams on the Santee Cooper River System:

Name	Pupose	Owner	Height (ft.)	Width (ft.)	Length (ft.)	Impoundment size (ha)	Water storage capacity (acre/ft.)	Location	River Kilometer	Fish Passage	Method
Jefferies Dam	Hydro	Santee-Cooper	~85	~60	11,500	38,400	1,129,480	33°14'40.78"N/79°59'28.95"W	77	Yes	Lock
Santee Dam	Hydro	Santee-Cooper	48	~30	40,940	24,000	1,180,800	33°27'13.59"N/ 80° 9'50.30"W	140	No	
St. Stephen Dam	Hydro	Santee-Cooper	128	~156	965	38,400	1,129,480	33°25'36.19"N/79°55'51.57"W	84	Yes	Fish Lock

Action: Develop a plan for establishing fish passage at barriers in the Santee Cooper River System.

Regulatory Agencies/Contacts: USFWS, NMFS, FERC, USACE, South Carolina Department of Natural Resources (SCDNR), dam owners and operators, and federal and state legislators.

Goal/Target: Establish fish passage at dams in the Santee Cooper River River basin, where passage is determined to be feasible.

Progress: As part of the Federal Energy Regulation Commission (FERC) licensing process, hydroelectric facilities in the Santee Cooper River Basin (in particular Santee Dam) are required provide upstream and downstream passage for anadromous fishes following the issuance of the license. This will require construction of a fishway at the Santee Dam and modifications at the Jefferies Dam (Pinopolis Lock). In addition, mandated flow requirements associated with the issuance of the license should greatly improve water quality in the system. Currently, FERC is awaiting a Biological Opinion for Atlantic and shortnose sturgeon from NMFS before any decisions can be made.

Cost: Unknown at this time.

Timeline: unknown

b. The following is a list of point source and nonpoint sources that occur in the Santee River:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*	*Receiving Stream*
GCW&SD NORTH SANTEE WWTP	MINOR DOMESTIC	SC0042439	03050112-060	(North Santee River/South Santee River)	NORTH SANTEE RIVER
SCPSA/WINYAH STEAM	MAJOR INDUSTRIAL	SC0022471	03050112-060	(North Santee River/South Santee River)	NORTH SANTEE RIVER
TOWN OF ST STEPHEN	MINOR DOMESTIC	SC0025259	03050112-030	(Santee River)	SANTEE RIVER
CHARGEURS WOOL (USA), INC.	MAJOR INDUSTRIAL	SC0000990	03050112-030	(Santee River)	SANTEE RIVER
MARTIN MARIETTA/GEORGETOWN II (SOUTHERN AGGR.)	MINOR INDUSTRIAL	SCG730059	03050112-030	(Santee River)	DUTART CREEK
US ARMY/ST. STEPHEN POWER PLANT	MINOR INDUSTRIAL	SC0047937	03050112-020	(Rediversion Canal)	REDIVERSION CANAL
GA PACIFIC RESINS/RUSSELVILLE/CHEM	MINOR INDUSTRIAL	SCG250181	03050112-020	(Rediversion Canal)	REDIVERSION CANAL
GA PACIFIC CORP./RUSSELVILLE/PARTICLE	MINOR INDUSTRIAL	SCG250179	03050112-020	(Rediversion Canal)	REDIVERSION CANAL
ALBANY INTNL/PRESS FABRIC	MINOR INDUSTRIAL	SC0002569	03050112-020	(Rediversion Canal)	CURRIBOO BRANCH
WILLIAMSBURG CO. W&SA/SANTEE RIVER WWTP	MINOR DOMESTIC	SC0048097	03050112-010	(Santee River)	SANTEE RIVER
PINEWOOD SITE-HILLS/LABRUCE MINE	MINOR INDUSTRIAL	SCG730026	03050111-010	(Santee River)	LAKE MARION
PINEWOOD CUSTODIAL TRUST	MINOR INDUSTRIAL	SC0042170	03050111-010	(Santee River)	LAKE MARION
MARTIN MARIETTA/BERKELEY QUARRY	MINOR INDUSTRIAL	SCG730058	03050111-010	(Santee River)	LAKE MARION TRIBUTARY
TOWN OF PINEWOOD WWTP	MINOR DOMESTIC	SC0046868	03050111-010	(Santee River)	BALLARD CREEK

Nonpoint Source Management Program				
Landfill Facilities	*Status*	*Permit #*	*Section Number*	*Section Name*
GA PACIFIC CORP. CHEM.	ACTIVE	083304-1601 (IWP-078, CWP-026)	03050112-020	(Rediversion Canal)

DUKE POWER CO.	ACTIVE	463303-1601 (IWP-192, IWP-128)	03050111-010	(Santee River)
JF CLECKLEY & CO./PLT #4		IWP-025, IWP-023	03050111-010	(Santee River)
JF CLECKLEY & CO./PLT #6		IWP-060	03050111-010	(Santee River)
LAIDLAW ENVIR. SERVICES	ACTIVE	IWP-145	03050111-010	(Santee River)

The following is a list of point source and nonpoint sources that occur in the Cooper River:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*	*Receiving Stream*
MEAD WESTVACO SC	MAJOR INDUSTRIAL	SC0001759	03050201-050	(Cooper River)	COOPER RIVER
AMERADA HESS/VIRGINIA AVE. N.	MINOR INDUSTRIAL	SC0002852	03050201-050	(Cooper River)	COOPER RIVER
AMERADA HESS/VIRGINIA AVE. S.	MINOR INDUSTRIAL	SC0002861	03050201-050	(Cooper River)	COOPER RIVER
ALLIED TERMINALS/CHARLESTON	MINOR INDUSTRIAL	SC0001350	03050201-050	(Cooper River)	COOPER RIVER
SOPUS PRODUCTS/CHAS	MINOR INDUSTRIAL	SC0003026	03050201-050	(Cooper River)	COOPER RIVER
SUN CHEMICAL CORP.	MAJOR DOMESTIC	SC0003441	03050201-050	(Cooper River)	COOPER RIVER
US NAVY/WEAPONS STATION	MINOR INDUSTRIAL	SC0043206	03050201-050	(Cooper River)	COOPER RIVER
NCSD/FELIX DAVIS WWTP	MAJOR DOMESTIC	SC0024783	03050201-050	(Cooper River)	COOPER RIVER
OAK AMERICAS LLC/COOPER RIVER PLT.	MAJOR INDUSTRIAL	SC0026506	03050201-050	(Cooper River)	COOPER RIVER
BP AMOCO CHEMICALS/COOPER RIVER	MAJOR INDUSTRIAL	SC0028584	03050201-050	(Cooper River)	COOPER RIVER
BCW&SA/LOWER BERKELEY WWTP	MAJOR DOMESTIC	SC0046060	03050201-050	(Cooper River)	COOPER RIVER
NUCOR STEEL/BERKELEY PLT	MAJOR INDUSTRIAL	SC0047392	03050201-050	(Cooper River)	COOPER RIVER
MT PLEASANT WATER PLANT #2	MINOR DOMESTIC	SC0043273	03050201-050	(Cooper River)	COOPER RIVER
EVENING POST PUBLISHING CO.	MINOR INDUSTRIAL	SCG250040	03050201-050	(Cooper River)	COOPER RIVER TRIBUTARY
CHARLESTON CPW/DANIEL ISLAND	MINOR DOMESTIC	SC0047074	03050201-050	(Cooper River)	TIDAL CREEK TO COOPER RIVER
SCE&G/WILLIAMS STATION	MAJOR INDUSTRIAL	SC0003883	03050201-050	(Cooper River)	TIDAL CREEK TO COOPER RIVER
DEFENSE FUEL SUPPORT PT/CHAS	MINOR INDUSTRIAL	SCG340022	03050201-050	(Cooper River)	FILBIN CREEK
MEAD WESTVACO CORP/CHAS	MAJOR INDUSTRIAL	SC0001759	03050201-050	(Cooper River)	FILBIN CREEK
KINDER MORGAN BULK TERM./N. CHAS	MINOR INDUSTRIAL	SCG340015	03050201-050	(Cooper River)	FILBIN CREEK
KINDER MORGAN BULK TERM./SHIPYARD RIV. TERM	MINOR INDUSTRIAL	SC0048046	03050201-050	(Cooper River)	SHIPYARD CREEK
MONTENAY CHARLESTON/RESOURCE RECOVERY	MINOR INDUSTRIAL	SC0041173	03050201-050	(Cooper River)	SHIPYARD CREEK
TOWN OF MONCKS CORNER WWTP	MAJOR DOMESTIC	SC0021598	03050201-030	(West Branch Cooper River)	WEST BRANCH COOPER RIVER
BCW&SA/CENTRAL BERKELEY WWTP	MINOR DOMESTIC	SC0039764	03050201-030	(West Branch Cooper River)	WEST BRANCH COOPER RIVER
SCE&G/WILLIAMS ASH DISP	MINOR INDUSTRIAL	SC0046175	03050201-030	(West Branch Cooper River)	WAPPOOLA SWAMP
SCE&G/WILLIAMS LANDFILL	MINOR INDUSTRIAL	SC0039535	03050201-030	(West Branch Cooper River)	MOLLY BRANCH
OAKLEY MAINTENANCE FACILITY MINOR DOMESTIC	MINOR DOMESTIC	SC0026867	03050201-030	(West Branch Cooper River)	MOLLY BRANCH TRIBUTARY
D&A PARTNERSHIP/DANGERFIELD MINE	MINOR INDUSTRIAL	SCG730125	03050201-030	(West Branch Cooper River)	MOLLY BRANCH
SCPSA/CROSS GENERATING STATION	MAJOR INDUSTRIAL	SC0037401	03050201-010	(Lake Moultrie)	DIVERSION CANAL
US NAVY/SHORT STAY REC. FAC.	MINOR INDUSTRIAL	SC0024708	03050201-010	(Lake Moultrie)	LAKE MOULTRIE
BERKELEY COUNTY/CROSS HIGH SCHOOL	MINOR DOMESTIC	SC0027103	03050201-010	(Lake Moultrie)	LAKE MOULTRIE
SCPSA/JEFFERIES GENERATING STATION	MAJOR INDUSTRIAL	SC0001091	03050201-010	(Lake Moultrie)	TAIL RACE CANAL
C.R. BARD, INC.	MAJOR INDUSTRIAL	SC0035190	03050201-010	(Lake Moultrie)	TAIL RACE CANAL
SCPSA/MONCKS CORNER WTP	MINOR DOMESTIC	SCG641011	03050201-010	(Lake Moultrie)	TAIL RACE CANAL

BERKELEY COUNTY/CROSS ELEM SCHOOL	MINOR DOMESTIC	SC0034479	03050201-010	(Lake Moultrie)	DUCK POND CREEK

Nonpoint Source Management Program				
Landfill Facilities	***Status***	***Permit #***	***Section Number***	***Section Name***
WESTVACO LANDFILL	ACTIVE	IWP-177, IWP-090, IWP-150	03050201-050	(Cooper River)
SCE&G/WILLIAMS STATION	ACTIVE	083320-1601 (IWP-191)	03050201-030	(West Branch Cooper River)
SCE&G/GENCO/WILLIAMS STATION	ACTIVE	083309-1601	03050201-030	(West Branch Cooper River)
BERKELEY COUNTY LANDFILL	ACTIVE	081001-1101	03050201-030	(West Branch Cooper River)
SCPSA/CROSS GENERATING STATION	ACTIVE	085801-1601	03050201-010	(Lake Moultrie)
C&D LANDFILL	--------	083322-1201	03050201-010	(Lake Moultrie)

All point source and nonpoint sources that occur in the Santee Cooper River System are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). All discharges are held to water quality standards for the state. Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat. In addition, all programs are currently undergoing Cooling Water Intake Structures Rules (40 CFR 122 and 125) analysis to assess the likelihood of impingement or entrainment in efforts to ensure compliance with the proposed EPA 316(b).

c. Toxic and thermal discharge inventory and assessment-none

d. Channelization and dredging

The following is a list of historic dredging programs that occurred in the Cooper River System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
9/9/1993	Cooper	SAC-1993-10092	SP	MAINTENANCE EXCAVATION	Berkeley	33.210830	-79.976110
9/2/1994	Cooper	SAC-1994-10386	SP	TAIL RACE CANAL DUCT SYSTEM	Berkeley	33.212300	-79.974540
4/10/1995	Cooper	SAC-1995-10597	SP	MARITIME CENTER	Charleston	32.787740	-79.926830
7/20/1995	Cooper	SAC-1995-10659	SP	MAINTENANCE DREDGING	Charleston	32.882200	-79.964600
11/24/1995	Cooper	SAC-1995-10730	SP	REISSUE 854D324 DREDGING	Charleston	32.883330	-79.966670
8/29/1995	Cooper	SAC-1995-12639	NWP	YACHT BASIN DREDGING	Charleston	32.772790	-79.926430
2/8/1996	Cooper	SAC-1996-10773	SP	MAINTENANCE DREDGING NAVY BASE	Charleston	32.883330	-79.966670
8/20/1996	Cooper	SAC-1996-10943	SP	DREDGING AT PIER P	Charleston	32.851390	-79.945830
9/22/1997	Cooper	SAC-1997-11257	SP	PIERS TANGO & SIERRA	Charleston	32.849720	-79.938330
8/7/1997	Cooper	SAC-1997-13631	NWP	METAL TRADES INC PIER H	Charleston	32.859530	-79.959140
6/23/1997	Cooper	SAC-1997-22569	NWP	SILTING NAVIGATION PROBLEMS	Berkeley	33.181100	-79.976900
6/18/1997	Cooper	SAC-1997-22633	NWP	DREDGE CANAL	Berkeley	33.180500	-79.975000
3/19/1998	Cooper	SAC-1998-11402	SP	BETWEEN PIER TANGO AND PIER SIERRA	Charleston	32.849720	-79.938330
1/29/1999	Cooper	SAC-1999-11623	SP	STATE PIER 8 MAINTENANCE DREDGING	Charleston	32.798620	-79.930090
4/30/1999	Cooper	SAC-1999-11708	SP	ATF MAINTENANCE DREDGING	Charleston	32.829440	-79.937780
8/6/1999	Cooper	SAC-1999-11777	SP	MAINTENANCE DREDGING LOP	Charleston	32.829440	-79.937780
7/5/2000	Cooper	SAC-2000-11971	SP	MAINTENANCE DREDGING STATE PIER 15	Charleston	32.902700	-79.959400
7/5/2000	Cooper	SAC-2000-11972	SP	UNION PIER TERMINAL STATE PIER 2	Charleston	32.781390	-79.923610
4/11/2001	Cooper	SAC-2001-12267	SP	CHARLESTON NAVAL COMPLEX DREDGING	Charleston	32.863700	-79.963200
4/11/2001	Cooper	SAC-2001-12268	SP	MAINTENANCE DREDGING PIERS Z M & N	Charleston	32.852200	-79.947400
4/11/2001	Cooper	SAC-2001-12269	SP	MAINTENANCE DREDING PIER P	Charleston	32.883330	-79.966670
10/2/2001	Cooper	SAC-2001-12429	SP	BERTH MAINTENANCE DREDGING	Charleston	32.883010	-79.967970

7/8/2002	Cooper	SAC-2002-12823	SP	COOPER RIVER MARINA EXPANSION	Charleston	32.831750	-79.935020
1/2/2003	Cooper	SAC-2003-13026	SP	UNION PIER TERMINAL STATE PIER 2	Charleston	32.783900	-79.924400
3/12/2003	Cooper	SAC-2003-13099	SP	COLUMBUS STREET TERMINAL	Charleston	32.793790	-79.926260
4/22/2005	Cooper	SAC-2005-15947	NWP	BIGGINS LANDING - MINOR DREDGING	Berkeley	33.212190	-79.973770
11/16/2006	Cooper	SAC-2006-03557	SP	BERTH MAINTENANCE DREDGING	Charleston	32.881390	-79.967500
12/14/2006	Cooper	SAC-2006-03772	SP	BIGGINS LANDING DREDGING (SANTEE COOPER)	Berkeley	33.212950	-79.973900

The following is a list of historic dredging programs that occurred in the Santee Cooper Lakes System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
4/19/1993	Santee Cooper Lakes	SAC-1993-17035	NWP	SANTEE LAKES	Calhoun	33.541020	-80.509260
11/5/1993	Santee Cooper Lakes	SAC-1993-18242	NWP	MAINTENANCE DREDGING CROSS S/D	Berkeley	33.328000	-80.146000
11/1/1993	Santee Cooper Lakes	SAC-1993-18243	NWP	MAINTENANCE EXCAVATION	Orangeburg	33.500000	-80.452780
1/11/1994	Santee Cooper Lakes	SAC-1994-10173	SP	BOAT SLIP EXCAVATION	Clarendon	33.481940	-80.374440
4/21/1994	Santee Cooper Lakes	SAC-1994-12510	NWP	STUMP HOLE LANDIANG DREDGE	Clarendon	33.570000	-80.503330
11/15/1994	Santee Cooper Lakes	SAC-1994-18248	NWP	MAINTENANCE DREDGING	Berkeley	33.230870	-80.018930
7/31/1996	Santee Cooper Lakes	SAC-1996-10902	SP	LAND O PINES S/D CANAL DREDGE	Berkeley	33.219200	-80.047100
8/5/1996	Santee Cooper Lakes	SAC-1996-10917	SP	FRANCIS MARION S/D DREDGING	Clarendon	33.481900	-80.380600
1/9/1997	Santee Cooper Lakes	SAC-1997-11060	SP	POLLYS LANDING MARINA	Clarendon	33.509700	-80.423600
11/7/1997	Santee Cooper Lakes	SAC-1997-12902	NWP	JACK'S HOLE CANAL MAINTENANCE	Berkeley	33.333500	-79.994640
8/30/1999	Santee Cooper Lakes	SAC-1999-11801	SP	COVE 1 MAINTENANCE EXCAVATION	Clarendon	33.496180	-80.412270
3/10/1999	Santee Cooper Lakes	SAC-1999-15973	NWP	EXCAVATION	Clarendon	33.482450	-80.386920
2/17/1999	Santee Cooper Lakes	SAC-1999-22910	NWP	EXCAVATION NEAR SPIERS LANDING	Berkeley	33.384900	-80.181700
1/10/2000	Santee Cooper Lakes	SAC-2000-11876	SP	CANAL EXCAVATION JACKS HOLE	Berkeley	33.333540	-79.994640
10/19/2000	Santee Cooper Lakes	SAC-2000-15941	NWP	MAINTENACE EXCAVATION	Berkeley	33.341700	-80.123000
10/1/2001	Santee Cooper Lakes	SAC-2001-11358	NWP	127 Waterfront Drive CHANNEL EXCAVATION	Orangeburg	33.416230	-80.323940
4/17/2001	Santee Cooper Lakes	SAC-2001-12271	SP	DIVERSION CANAL S/D MAINTENANCE EXCAVAT	Berkeley	33.387070	-80.144170
6/6/2002	Santee Cooper Lakes	SAC-2002-15847	NWP	DREDGING FILL	Berkeley	33.315700	-79.999000
11/3/2003	Santee Cooper Lakes	SAC-2003-14167	NWP	CANAL UPGRADE	Berkeley	33.384300	-80.139200
1/10/2007	Santee Cooper Lakes	SAC-2007-00073	SP	JACK'S HOLE DREDGING (SANTEE COOPER)	Berkeley	33.366800	-79.996760
11/26/2007	Santee Cooper Lakes	SAC-2007-02647	SP	MAINTENANCE SAND REMOVAL AT COVE ENTRANCE	Orangeburg	33.487700	-80.447900
1/2/2008	Santee Cooper Lakes	SAC-2008-00088	SP	DIVERSION CANAL DREDGING	Berkeley	33.347520	-80.100190

In addition, the shipping channel near Charleston, SC is currently authorized to a depth of 45 feet (47-foot deep entrance channel) plus 2 feet of advanced maintenance and 2 feet of allowable overdepth for a total potential dredging depth of 49 feet. More information is contained in Appendix 3.

It is highly unlikely current dredging operations are having impacts on adult American shad migration and utilization of historic habitat.

e. The following is a list of land use and mining activities that occur in the Santee River System:

Land Application Sites	*Type*	*ND #*	*Section Number*	*Section Name*
TOWN OF ELLOREE	DOMESTIC	ND0067628	03050111-010	(Santee River)
LAKE MARION RESORT & MARINA	DOMESTIC	ND0067610	03050111-010	(Santee River)
SANTEE PSD	DOMESTIC	ND0065676	03050111-010	(Santee River)
SANTEE RESORT HOTEL WWTP	DOMESTIC	ND0067652	03050111-010	(Santee River)
SANTEE LAKES CAMPGROUND	DOMESTIC	ND0067326	03050111-010	(Santee River)

CYPRESS POINT CONDO	DOMESTIC	ND0062227	03050111-010	(Santee River)
SCDPRT/SANTEE STATE PARK	DOMESTIC	ND0067920	03050111-010	(Santee River)

Mining Activities	*Mineral*	*Permit #*	*Section Number*	*Section Name*
MCKENZIE MINE	SAND	1240-19	03050112-060	(North Santee River/South Santee River)
CHARLES CLARK MINE	SAND	1531-19	03050112-060	(North Santee River/South Santee River)
TAYLOR POND MINE	SAND	1544-43	03050112-060	(North Santee River/South Santee River)
GEORGETOWN II QUARRY	LIMESTONE	0885-15	03050112-030	(Santee River)
OLD FIELD MINE	SAND/CLAY	0929-15	03050112-020	(Rediversion Canal)
MINGO MINE #4	CLAY	0712-27	03050111-010	(Santee River)
HILLS-LABRUCE	CLAY	1014-27	03050111-010	(Santee River)
MCCURRY PIT	CLAY	1069-17	03050111-010	(Santee River)

The following is a list of land use and mining activities that occur in the Cooper River System:

Mining Activities	*Mineral*	*Permit #*	*Section Number*	*Section Name*
PRIMUS TRACT	SAND/CLAY	0962-15	03050201-050	(Cooper River)
WILLIAMS ASH DISPOSAL	SAND	0964-15	03050201-030	(West Branch Cooper River)
JOHN R. CUMBIE MINE	SAND	0747-15	03050201-010	(Lake Moultrie)
WEEKS MINE	SAND	1488-15	03050201-010	(Lake Moultrie)

Water Quantity				
Water User	*Regulated Cap. (MGD)*	*Pumping Cap. (MGD)*	*Section Number*	*Section Name*
SANTEE COOPER REG. WTR. AUTH.	36	38	03050201-010	(Lake Moultrie)

All land use, mining activities, and water withdrawals that occur in the Santee Cooper River System are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat.

f. Atmospheric deposition assessment

Atmospheric deposition is measured as a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies as part of the National Atmospheric Deposition Program (NADP). This organization uses many networks (NTN, AIRMoN, MDN, AMNet, and AMNoN) to monitor methyl mercury, ammonia, etc. Detailed information concerning atmospheric deposition in SC can be found at the following website: http://nadp.sws.uiuc.edu/data/annualmaps.aspx

It does not appear that current levels of atmospheric deposition are impacting American shad migrations or utilization of historic habitat.

g. Climate change assessment

A changing climate will present water-related challenges for American shad in several areas including: water quality, water quantity and changes in sea level. Current climate models predict continued warming across the southeast, with the greatest temperature increases projected in summer. Average annual temperatures are projected to rise 4.5°F by the 2080s under a lower emissions scenario and 9°F under a higher emissions scenario with a 10.5°F increase in summer. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration. Drought conditions could potentially impact American shad recruitment and long duration drought could negatively impact multiple year classes. Sea level rise is of concern because of the expected change in location of the saltwater/freshwater interface. As sea level rises, saltwater will move further up the river systems of the state thus reducing the amount freshwater spawning habitat available. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. A changing climate will impact the water resources of South Carolina and will present challenges for American shad management.

Action: Develop a climate change plan.

Regulatory Agencies/Contacts: South Carolina Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address climate change.

Progress: A “draft” plan has been developed and is still under review (Appendix 2)

Cost: Unknown at this time.

Timeline: Unknown

h. Competition and predation by invasive and managed species assessment

Aquatic invasive species occur throughout South Carolina’s coastal rivers, and non-native ictalurids are some of the most ubiquitous invasive species. Flathead catfish and blue catfish were introduced into South Carolina in 1964 and are now found in all of South Carolina’s coastal rivers. A significant portion of blue catfish and especially flathead catfish diet is comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad. Ictalurid population information is currently unavailable for South Carolina’s coastal rivers; however current studies are occurring in South Carolina and other neighboring states to assess the potential impacts of non-native catfish on American shad.

Action: Develop an invasive species plan.

Regulatory Agencies/Contacts: South Carolina Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address invasive species.

Progress: SCDNR programs are currently monitoring catch rates of invasive catfish as part of non-targeting sampling and any flat head catfish captured during these activities are being removed from the system. In addition, current eradication programs, such as those on the Satilla River, GA, are being reviewed by SCDNR staff to determine if such programs are feasible for SC Rivers.

Cost: Unknown at this time.

Timeline: Unknown

Edisto River

Habitat Assessment

Two main tributaries of the Edisto River, the North Fork and South Fork begin just south of the piedmont fall line. The main stem river and its two major tributaries amble for 400 km through the Atlantic coastal plain as the longest free flowing black river in South Carolina. During excessive rainy seasons the river inundates lowlands and swamps and the flow basin increases to a mile wide or more.

Historic Habitat

American shad inhabited all of the Edisto River and its major tributaries throughout the 8,161 km^2 watershed (SCDHEC 2013). According to Stevenson (1899), American shad utilized the entire length of both the North and South Fork of the Edisto River, with the reported inland limit to be “sources 300 miles from the coast”.

Current Useable Habitat

Spawning - American shad have access to all adequate habitats in the watershed as there are no barriers to migration. Suitable freshwater riverine channel habitat for spawning in the Edisto River begins approximately at rkm 48 and continues for 143 km to the confluence of the North Fork and South Fork Edisto Rivers. Additionally, McCord (2003) stated that American shad are found for 16 km in the North Fork Edisto River and 48 km of South Fork Edisto River.

Rearing - Suitable rearing habitats are similar to the listed waterways for suitable spawning habitat with the addition of 8,432 ha of estuary in the Edisto River basin (SCDHEC 2013).

Threats Assessment

a. Barriers to migration inventory and assessment

There are no dams on the Edisto River.

b. The following is a list of point source, nonpoint source, mining activities, and water withdrawals that occur in the Edisto River:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*	*Receiving Stream*
TOWN OF BRANCHVILLE	MINOR DOMESTIC	SC0047333	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER
R. WHALEY DURR/HARTZOG PIT	MINOR INDUSTRIAL	SCG730091	03050206-01	(Edisto River - Headwaters)	CATTLE CREEK
SCE&G/CANADYS STATION	MAJOR INDUSTRIAL	SC0002020	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER
NORTH AMERICAN CONTAINER CORP.	MINOR INDUSTRIAL	SCG250191	03050206-01	(Edisto River - Headwaters)	BETTY BRANCH TRIBUTARY
PETER R. STOKES IV MINE	MINOR INDUSTRIAL	SCG731112	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER
JAY & J CONSTRUCTION INC./BRANCHVILLE PIT MINE	MINOR INDUSTRIAL	SCG731107	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER
REA CONTRACTING LLC/CARROLL PIT #9	MINOR INDUSTRIAL	SCG730656	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER TRIBUTARY
CIRCLE C TRUCK STOP	MINOR INDUSTRIAL	SCG730003	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER
SCDOT/GROVER PIT	MINOR INDUSTRIAL	SCG730517	03050206-01	(Edisto River - Headwaters)	EDISTO RIVER TRIBUTARY
ARGOS CEMENT LLC/HARLEYVILLE CEMENT PLT	MINOR INDUSTRIAL	SC0022586	03050206-02	(Indian Field Swamp)	TOM AND KATE BRANCH
TOWN OF HARLEYVILLE	MINOR DOMESTIC	SC0038504	03050206-02	(Indian Field Swamp)	TOM AND KATE BRANCH
DORCHESTER CO./UPPER DORCHESTER CO. WWTP	MINOR DOMESTIC	SC0025844	03050206-02	(Indian Field Swamp)	POLK SWAMP
SC MINERALS/SANDY RUN MINE	MINOR INDUSTRIAL	SCG730261	03050206-03	(Edisto River/South Edisto River)	SANDY RUN TRIBUTARY
MEM LLC/MIXSON MINE	MINOR INDUSTRIAL	SCG730385	03050206-03	(Edisto River/South Edisto River)	POORLY BRANCH
MURRAY MINES INC./PRINCIP MINE	MINOR INDUSTRIAL	SCG730773	03050206-03	(Edisto River/South Edisto River)	EDISTO RIVER TRIBUTARY
GLOVER REAL ESTATE LLC/COTTAGEVILLE MINE	MINOR INDUSTRIAL	SCG731055	03050206-03	(Edisto River/South Edisto River)	BOSTON BRANCH
SEAFREE EDISTO INC./GOOD HOPE MINE	MINOR INDUSTRIAL	SCG731086	03050206-03	(Edisto River/South Edisto River)	SANDY RUN
DANNY LEE CONSTRUCTION/PIT SAND HILL MINE	MINOR INDUSTRIAL	SCG730976	03050206-03	(Edisto River/South Edisto River)	EDISTO RIVER TRIBUTARY
PALMETTO SAND CO. INC./BINLAW HWY 17A	MINOR INDUSTRIAL	SCG730408	03050206-03	(Edisto River/South Edisto River)	SPOOLER SWAMP
ROGERS & SONS CONSTR. INC./SULLIVANS LANDING	MINOR INDUSTRIAL	SCG730643	03050206-03	(Edisto River/South Edisto River)	SPOOLER SWAMP
JOE WEEKS/DEEP SOUTH MINE	MINOR INDUSTRIAL	SCG731049	03050206-03	(Edisto River/South Edisto River)	ADAMS RUN TRIBUTARY
WEST BANK CONSTR. CO., INC./RED HOUSE POND	MINOR INDUSTRIAL	SCG730657	03050206-03	(Edisto River/South Edisto River)	SANDY RUN
MALPHRUS CONSTR.CO./CRYSTAL LAKES MINE	MINOR INDUSTRIAL	SCG730990	03050206-03	(Edisto River/South Edisto River)	EDISTO RIVER TRIBUTARY
CHARLES HILLS/NICHOLS POND MINE	MINOR INDUSTRIAL	SCG731064	03050206-04	(North Edisto River)	BOHICKET CREEK TRIBUTARY
BEARS BLUFF NATIONAL FISH HATCHERY	MINOR INDUSTRIAL	SC0047848	03050206-04	(North Edisto River)	WEE CREEK
LCP MINING CO. LLC/LEGARE CREEK PLANTATION MINE	MINOR INDUSTRIAL	SC0048488	03050206-04	(North Edisto River)	NORTH EDISTO RIVER
ISLAND CONSTR. CO./TREMONT MINE	MINOR INDUSTRIAL	SCG730128	03050206-04	(North Edisto River)	CHURCH CREEK TRIBUTARY
DIRT SUPPLY LLC/BLUEMEL MINE	MINOR INDUSTRIAL	SCG731001	03050206-04	(North Edisto River)	CHURCH CREEK TRIBUTARY
L. DEAN WEAVER/VANNESS MINE	MINOR INDUSTRIAL	SCG730436	03050206-04	(North Edisto River)	LOWER TOOGOODOO CREEK
RENTZ LANDCLEARING/RENTZ MINE	MINOR INDUSTRIAL	SCG730114	03050206-04	(North Edisto River)	LOWER TOOGOODOO CREEK TRIBUTARY

Nonpoint Source Management Program				
Landfill Facilities	***Status***	***Permit #***	***Section Number***	***Section Name***
HARTZOG PIT	SAND; SAND/CLAY	0412-35	03050206-01	(Edisto River - Headwaters)
P&M MINE	SAND	0950-35	03050206-02	(Indian Field Swamp)
HARLEYVILLE QUARRY	LIME	0110-35	03050206-02	(Indian Field Swamp)
CAW CAW BURROW	SAND	1447-19	03050206-03	(Edisto River/South Edisto River)
RED HOUSE POND	SAND	1568-19	03050206-03	(Edisto River/South Edisto River)
EDINGSVILLE ONE	SAND/CLAY	1090-19	03050206-03	(Edisto River/South Edisto River)
MAD DOG #3 MINE	SAND	1105-35	03050206-03	(Edisto River/South Edisto River)
EDISTO #1	SAND; TOPSOIL	1615-35	03050206-03	(Edisto River/South Edisto River)
DURANT SHELL HOUSE ROAD MINE	SAND; TOPSOIL	1705-19	03050206-03	(Edisto River/South Edisto River)
ADAMS RUN #1 MINE	SAND; TOPSOIL	1770-19	03050206-03	(Edisto River/South Edisto River)
MIXSON MINE	SAND/CLAY	1398-35	03050206-03	(Edisto River/South Edisto River)
HPT BINLAW MINE	SAND; S/CLAY; TOPSOIL	1492-35	03050206-03	(Edisto River/South Edisto River)
PETER J KUHNS		1539-29	03050206-03	(Edisto River/South Edisto River)
SULLIVANS LANDING MINE #2	SAND; SAND/CLAY	1556-35	03050206-03	(Edisto River/South Edisto River)
PRINCIP MINE	SAND; SAND/CLAY	1620-29	03050206-03	(Edisto River/South Edisto River)
PINE BLUFF MINE	SAND/CLAY	1654-35	03050206-03	(Edisto River/South Edisto River)
JOHNS ISLAND #1 MINE	SAND	0122-19	03050206-04	(North Edisto River)
RENTZ MINE	SAND; SAND/CLAY	0994-19	03050206-04	(North Edisto River)
JAMISON MINE	CLAY	0206-19	03050206-04	(North Edisto River)
CEDAR HILL MINE	SAND/TOP SOIL	1694-19	03050206-04	(North Edisto River)
BED ROCK II MINE	SAND/CLAY	1644-19	03050206-04	(North Edisto River)
SHEPPARD C&D LANDFILL	C&D	------	03050206-03	(Edisto River/South Edisto River)

All point source and nonpoint sources that occur in the Edisto River System are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). All discharges are held to water quality standards for the state. Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat. In addition, all programs are currently undergoing cooling water intake structures rules (40 CFR 122 and 125) analysis to assess the likelihood of impingement or entrainment in efforts to ensure compliance with the proposed EPA 316(b).

c. Toxic and thermal discharge inventory and assessment-none

d. Channelization and dredging inventory and assessment

The following is a list of historic dredging programs that occurred in the Edisto River System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
4/1/1994	Edisto	SAC-1994-10226	SP	EXCAVATION IN OXBOW LAKE	Bamberg	33.230560	-80.849170
5/26/1998	Edisto	SAC-1998-11456	SP	BASIN DREDGING EDISTO ISLAND	Colleton	32.493390	-80.342420
11/16/1999	Edisto	SAC-1999-11853	SP	DREDGING A CANAL	Colleton	32.754500	-80.450700
10/16/2000	Edisto	SAC-2000-13153	NWP	INTAKE DREDGING CANADYS STATION	Colleton	33.065980	-80.623240

It is highly unlikely past dredging operations are causing detrimental impacts on adult American shad migration and utilization of historic habitat.

e.The following is a list of land use and water withdrawal activities that occur in the Edisto River:

Land Application Sites	*Type*	*ND #*	*Section Number*	*Section Name*
TOWN OF EDISTO BEACH/FAIRFIELD GOLF COURSE	DOMESTIC	ND0063789	03050206-03	(Edisto River/South Edisto River)
JEREMY CAY	DOMESTIC	ND0071510	03050206-03	(Edisto River/South Edisto River)
TOWN OF SEABROOK ISLAND	DOMESTIC	ND0063347	03050206-04	(North Edisto River)
BP FARMS LLC	INDUSTRIAL	ND0087807	03050206-04	(North Edisto River)
BRABHAM DIRT PIT/HOLLYWOOD	INDUSTRIAL	ND0087131	03050206-04	(North Edisto River)

Water Quantity	*REG. CAPACITY (MGD)*	*PUMP. CAPACITY (MGD)*	*Section Number*	*Section Name*
CITY OF CHARLESTON	150	100	03050206-03	(Edisto River/South Edisto River)

All land use and water withdrawals that occur in the Edisto River are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat.

f. Atmospheric deposition assessment

Atmospheric deposition is measured as a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies as part of the National Atmospheric Deposition Program (NADP). This organization uses many networks (NTN, AIRMoN, MDN, AMNet, and AMNoN) to monitor methyl mercury, ammonia, etc. Detailed information concerning atmospheric deposition in SC can be found at the following website: http://nadp.sws.uiuc.edu/data/annualmaps.aspx

It does not appear that current levels of atmospheric deposition are impacting adult American shad migrations or utilization of historic habitat.

g. Climate change assessment

A changing climate will present water-related challenges for American shad in several areas including: water quality, water quantity and changes in sea level. Current climate models predict continued warming across the southeast, with the greatest temperature increases projected in summer. Average annual temperatures are projected to rise 4.5°F by the 2080s under a lower emissions scenario and 9°F under a higher emissions scenario with a 10.5°F increase in summer. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration. Drought conditions could potentially impact American shad recruitment and long duration drought could negatively impact multiple year classes. Sea level rise is of concern because of the expected change in location of the saltwater/freshwater interface. As sea level rises, saltwater will move further up the river systems of the state thus reducing the amount freshwater spawning habitat available. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. A changing climate will impact the water resources of South Carolina and will present challenges for American shad management.

Action: Develop a climate change plan.

Regulatory Agencies/Contacts: South Carolina Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address climate change.

Progress: A "draft" plan has been developed and is still under review (Appendix 2)

Cost: Unknown at this time.

Timeline: Unknown

h. Competition and predation by invasive and managed species assessment

Aquatic invasive species occur throughout South Carolina's coastal rivers, and non-native ictalurids are some of the most ubiquitous invasive species. Flathead catfish and blue catfish were introduced into South Carolina in 1964 and are now found in all of South Carolina's coastal rivers. A significant portion of blue catfish and especially flathead catfish diet is comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad. Ictalurid population information is currently unavailable for South Carolina's coastal rivers; however current studies are occurring in South Carolina and other neighboring states to assess the potential impacts of non-native catfish on American shad.

Action: Develop a invasive species plan.

Regulatory Agencies/Contacts: South Carolina Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address invasive species.

Progress: SCDNR programs are currently monitoring catch rates of invasive catfish as part of non-targeting sampling and any flat head catfish captured during these activities are being removed from the system. In addition, current eradication programs, such as those on the Satilla River, GA, are being reviewed by SCDNR staff to determine if such programs are feasible for SC Rivers.

Cost: Unknown at this time.

Timeline: Unknown

Combahee River

Habitat Assessment

Combahee River is formed at the confluence of Salkehatchie and Little Salkehatchie Rivers and flows 64 km to Saint Helena Sound. Combahee River and its tributaries begin south of the piedmont fall line and flow unimpeded throughout their length (193 km) (McCord 2003). Similar to the Edisto River, Combahee River is characterized by clear tannic acid-stained water flowing across flat, low elevation land.

Historic Habitat

American shad had access to all of the Combahee River and its major tributaries throughout the 3,325 km^2 watershed (SCDHEC 2013). The inland limit of American Shad in the Salkehatchie and Combahee Rivers are not clear, but migrating fish were present near the "source" of the river (Welch 2000). Stevenson (1899) did not distinguish between the two rivers in his report, but did state that "shad ascend a distance of 85 miles" and that the difficulty of ascending the stream prevented him from assessing small fisheries upstream.

Current Useable Habitat

Spawning - American shad have access to all suitable habitats in the watershed as there are no barriers to migration. In the Combahee River, 20 km of suitable freshwater riverine channel spawning habitat is available. In addition, American shad are found for 73 km in the Salkehatchie River (McCord 2003).

Rearing - Suitable rearing habitats are similar to the listed waterways for suitable spawning habitat with the addition of 15,584 ha of estuary in the Combahee River basin (SCDHEC 2013).

Threats Assessment

a. Barriers to migration inventory and assessment

There are no dams on the Combahee River.

b. The following is a list of point source facilities that occur in the Combahee River:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*	*Receiving Stream*
TOWN OF YEMASSEE	COMBAHEE RIVER	SC0025950	DOMESTIC	03050207-07	(Combahee River)

All point source and nonpoint sources that occur in the Combahee River System are closely monitored by the South Carolina Department of Health Environmental Control (DHEC). All discharges are held to water quality standards for the state. Therefore, it is highly unlikely these programs impact adult American shad migration and utilization of historic habitat. In addition, all programs are currently undergoing cooling water intake structures rules (40 CFR 122 and 125) analysis to assess the likelihood of impingement or entrainment in efforts to ensure compliance with the proposed EPA 316(b).

c. Toxic and thermal discharge inventory and assessment-none

d. Channelization and dredging inventory and assessment

The following is a list of historic dredging programs that occurred in the Combahee River System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
4/26/1994	Combahee	SAC-1994-10243	SP	MILL POND MAINTENANCE	Colleton	32.677780	-80.686110
7/14/1999	Combahee	SAC-1999-15974	NWP	COMBAHEE LANDING SILT REMOVAL	Hampton	32.706230	-80.827530

It is highly unlikely past dredging operations are causing detrimental impacts on adult American shad migration and utilization of historic habitat.

e. Land use inventory and assessment-none

f. Atmospheric deposition assessment

Atmospheric deposition is measured as a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies as part of the National Atmospheric Deposition Program (NADP). This organization uses many networks (NTN, AIRMoN, MDN, AMNet, and AMNoN) to monitor methyl mercury, ammonia, etc. Detailed information concerning atmospheric deposition in SC can be found at the following website: http://nadp.sws.uiuc.edu/data/annualmaps.aspx

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Action: Develop a climate change plan.

Regulatory Agencies/Contacts: South Carolina Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address climate change.

Progress: A "draft" plan has been developed and is still under review (Appendix 2)

Cost: Unknown at this time.

Timeline: Unknown

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Goal/Target: Establish recommendations to address invasive species.

Progress: SCDNR programs are currently monitoring catch rates of invasive catfish as part of non-targeting sampling and any flat head catfish captured during these activities are being removed from the system. In addition, current eradication programs, such as those on the Satilla River, GA, are being reviewed by SCDNR staff to determine if such programs are feasible for SC Rivers.

Cost: Unknown at this time.

Timeline: Unknown

References

Burns, F. 1887. Rockfish in South Carolina. Bulletin U.S. Fish Commission (1886) 6: 18pp.

McCord, J. W. 2003. Alsosid Habitats for South Carolina Watersheds. South Carolina Department of Natural Resources. Diadromous Fisheries Program, Office of Fisheries Management, Marine Resources Division. Charleston. 6 pp.

South Carolina Department Health and Environmental Quality, 2013. http://www.scdhec.gov/environment/water/shed/shed.htm.

Stevenson, C. H. 1899. The shad fisheries of the Atlantic coast of the United States. Report of the Commissioner, U.S. Commission of Fish and Fisheries. 29: 103-269 pp.

Welch, S. M. 2000. A Report on the Historical Inland Migrations of Several Diadromous Fishes in South Carolina Rivers. Clemson University, Department of Aquaculture, Fisheries and Wildlife. 19 pp.

Appendix 1. Details of dredging occurring near Georgetown, SC.

JOINT
PUBLIC NOTICE

CHARLESTON DISTRICT, CORPS OF ENGINEERS
1949 Industrial Road, Room 140
Conway, South Carolina 29526
and the
S.C. DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
OFFICE OF OCEAN AND COASTAL RESOURCE MANAGEMENT
1362 McMillan Avenue, Suite 400
Charleston, South Carolina 29405

REGULATORY DIVISION AUGUST 28, 2013
Refer to: P/N # 1987-08703-3H

Pursuant to Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403), Sections 401 and 404 of the Clean Water Act (33 U.S.C. 1344), and the South Carolina Coastal Zone Management Act (48-39-10 et.seq.) an application has been submitted to the Department of the Army and the S.C. Department of Health and Environmental Control by

UNITED STATES COAST GUARD
CIVIL ENGINEERING UNIT
15608 SW 117TH AVENUE
MIAMI, FLORIDA 33177

for a permit to dredge within

WINYAH BAY/PEE DEE RIVER

at a location south of U.S. Highway 17 bridge on an existing Coast Guard station located on Marina Drive, in Georgetown, Georgetown County, South Carolina (Latitude: 33.362535°N; -79.268591°W)

In order to give all interested parties an opportunity to express their views

NOTICE

is hereby given that written statements regarding the proposed work will be received by the **Corps** until

15 Days from the Date of this Notice,

and **SCDHEC** will receive written statements regarding the proposed work until

30 Days from the Date of this Notice

from those interested in the activity and whose interests may be affected by the proposed work.

The proposed work consists of maintenance dredging within the Pee Dee River. In detail, the work consists of dredging approximately 11,000 cubic yards of material from two (2) acres of the Pee Dee River to a depth of -10' below mean low water (MLW) with an allowable overdepth of -1' below MLW. The proposed dredging will occur around the existing Coast Guard pier. Dredging will be performed by hydraulic cutterhead dredge with the dredged material piped to and disposed of in an existing upland confined disposal basin (Waccamaw Point disposal area). The applicant stated that measures taken to avoid and minimize impacts to the aquatic resources consist of the following: limiting the scope of dredging to primarily within previously vessel transited boundaries; dredged material will be disposed of utilizing a hydraulic pipeline to an existing upland disposal basin; and sediment testing will be conducted. The applicant offered no compensatory mitigation for the impacts associated with the proposed work. The purpose of the proposed project as stated by the applicant is to provide clear berthing areas alongside the Coast Guard Georgetown pier which provides mooring and water access for Coast Guard vessels supporting the USCG mission of national maritime security and safety.

The District Engineer has concluded that the discharges associated with this project, both direct and indirect, should be reviewed by the South Carolina Department of Health and Environmental Control in accordance with provisions of Section 401 of the Clean Water Act. As such, this notice constitutes a request, on behalf of the applicant, for certification that this project will comply with applicable effluent limitations and water quality standards. The work shown on this application must also be certified as consistent with applicable provisions the Coastal Zone Management Program (15 CFR 930). The District Engineer will not process this application to a conclusion until such certifications are received. The applicant is hereby advised that supplemental information may be required by the State to facilitate the review.

This notice initiates the Essential Fish Habitat (EFH) consultation requirements of the Magnuson-Stevens Fishery Conservation and Management Act. Implementation of the proposed project would impact (2.0) acres of estuarine substrates and emergent wetlands utilized by various life stages of species comprising the red drum, shrimp, and snapper-grouper management complexes. Our initial determination is that the proposed action would not have a substantial individual or cumulative adverse impact on EFH or fisheries managed by the South Atlantic Fishery Management Council and the National Marine Fisheries Service (NMFS). Our final determination relative to project impacts and the need for mitigation measures is subject to review by and coordination with the NMFS.

The District Engineer has consulted the most recently available information and has determined that the project is not likely to adversely affect any Federally endangered, threatened, or proposed species and will not result in the destruction or adverse modification of designated or proposed critical habitat. This public notice serves as a request to the U.S. Fish and Wildlife Service and the National Marine Fisheries Service for any additional information they may have on whether any listed or proposed endangered or threatened species or designated or proposed critical habitat may be present in the area which would be affected by the activity, pursuant to Section 7(c) of the Endangered Species Act of 1973 (as amended).

Pursuant to Section 106 of the National Historic Preservation Act (NHPA), this public notice also constitutes a request to Indian Tribes to notify the District Engineer of any historic properties of religious and cultural significance to them that may be affected by the proposed undertaking.

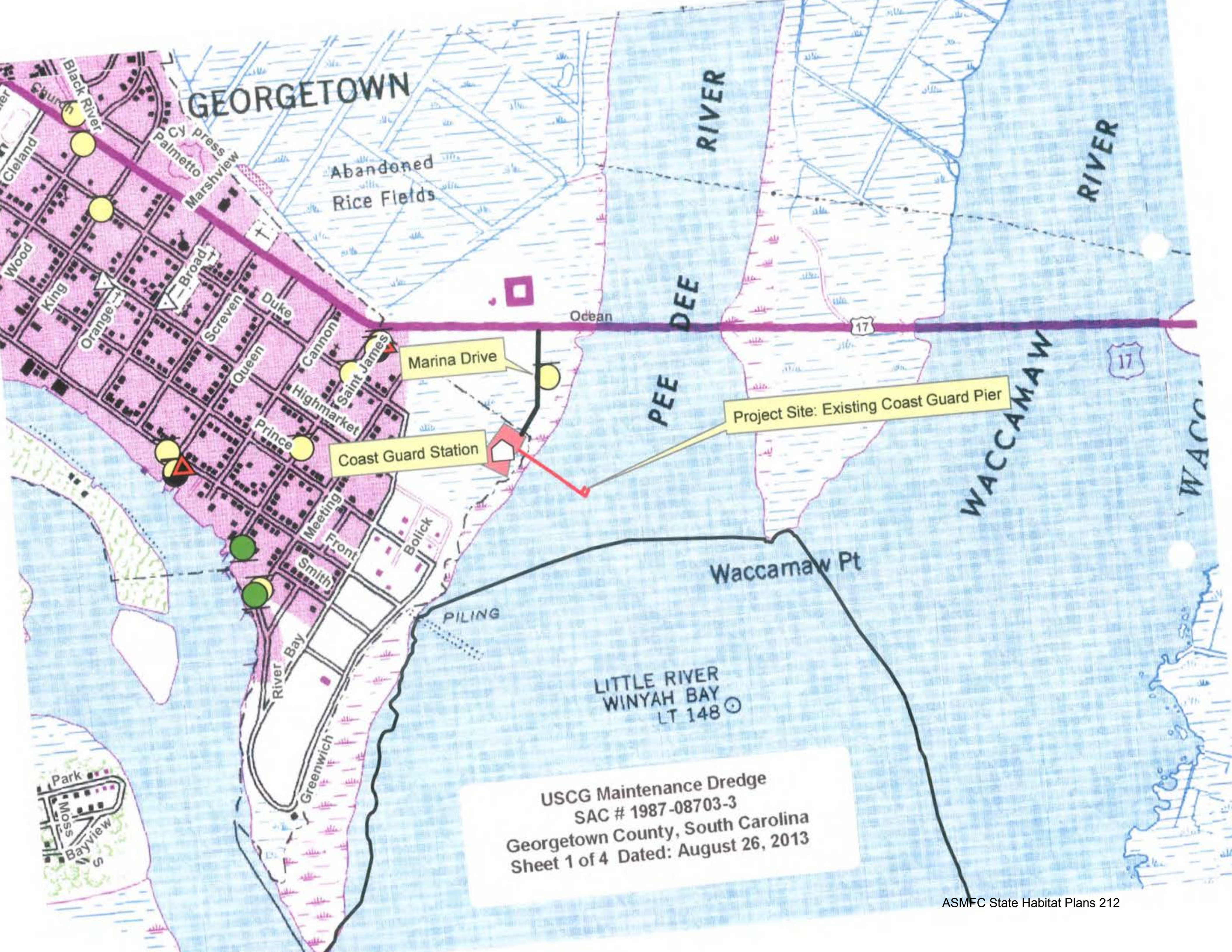
In accordance with the NHPA, the District Engineer has also consulted the latest published version of the National Register of Historic Places for the presence or absence of registered properties, or properties listed as being eligible for inclusion therein, and this worksite is not included as a registered property or property listed as being eligible for inclusion in the Register. To insure that other cultural resources that the District Engineer is not aware of are not overlooked, this public notice also serves as a request to the State Historic Preservation Office to provide any information it may have with regard to historic and cultural resources.

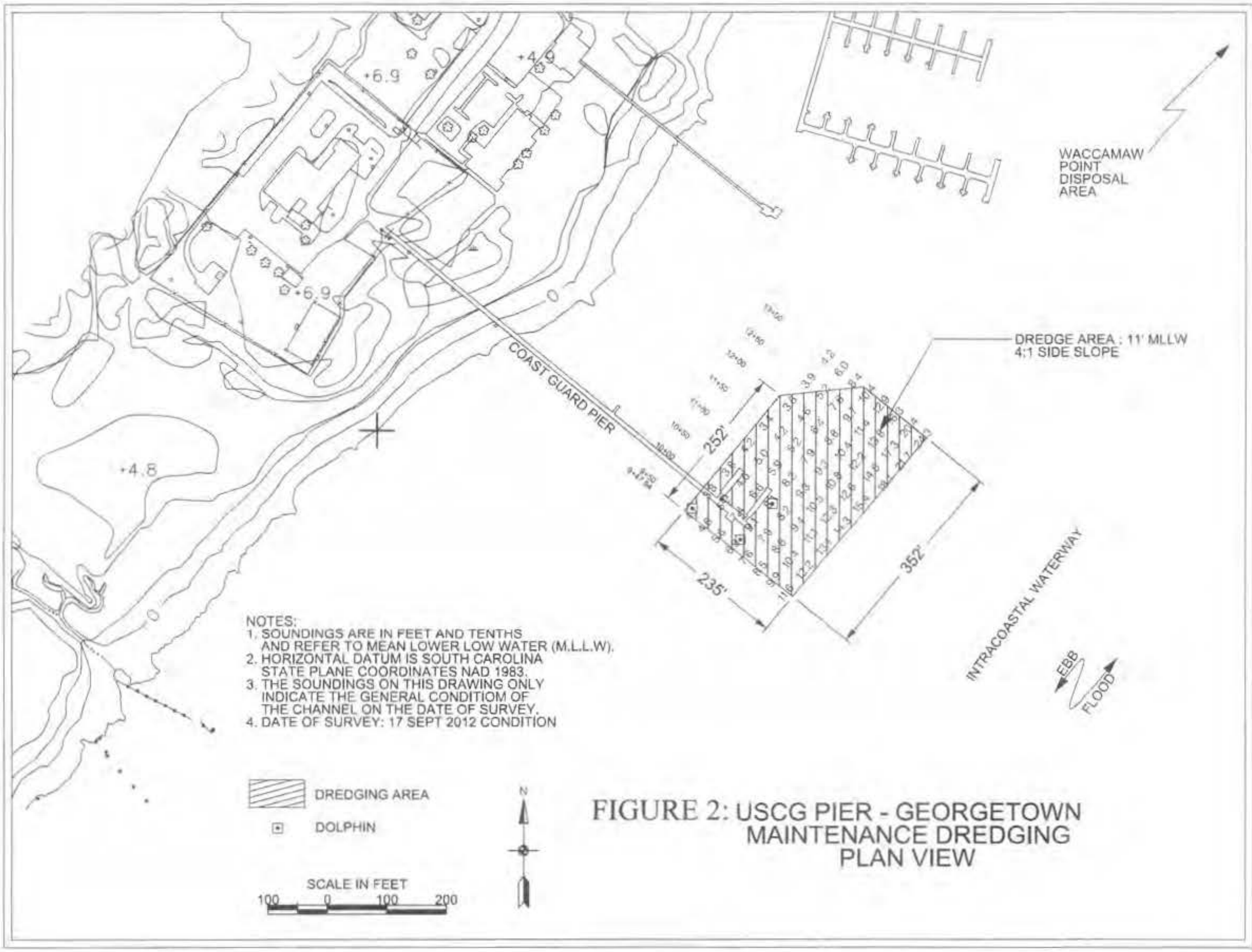
Any person may request, in writing, within the comment period specified in this notice, that a public hearing be held to consider this application. Requests for a public hearing shall state, with particularity, the reasons for holding a public hearing.

The decision whether to issue a permit will be based on an evaluation of the probable impact including cumulative impacts of the activity on the public interest and will include application of the guidelines promulgated by the Administrator, Environmental Protection Agency (EPA), under authority of Section 404(b) of the Clean Water Act and, as appropriate, the criteria established under authority of Section 102 of the Marine Protection, Research and Sanctuaries Act of 1972, as amended. That decision will reflect the national concern for both protection and utilization of important resources. The benefit which reasonably may be expected to accrue from the project must be balanced against its reasonably foreseeable detriments. All factors which may be relevant to the project will be considered including the cumulative effects thereof; among those are conservation, economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife values, flood hazards, flood plain values, land use, navigation, shoreline erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production and, in general, the needs and welfare of the people. A permit will be granted unless the District Engineer determines that it would be contrary to the public interest. In cases of conflicting property rights, the Corps of Engineers cannot undertake to adjudicate rival claims.

The Corps of Engineers is soliciting comments from the public; Federal, state, and local agencies and officials; Indian Tribes; and other interested parties in order to consider and evaluate the impacts of this activity. Any comments received will be considered by the Corps of Engineers to determine whether to issue, modify, condition or deny a permit for this project. To make this decision, comments are used to assess impacts on endangered species, historic properties, water quality, general environmental effects, and the other public interest factors listed above. Comments are used in the preparation of an Environmental Assessment and/or an Environmental Impact Statement pursuant to the National Environmental Policy Act. Comments are also used to determine the need for a public hearing and to determine the overall public interest of the activity.

If there are any questions concerning this public notice, please contact Rob Huff at 843-365-4239.


GEORGETOWN
Abandoned
Rice Fields
PEE DEE RIVER
WACCAMAW RIVER
Ocean
17
Marina Drive
Coast Guard Station
Project Site: Existing Coast Guard Pier
Waccamaw Pt
PILING
LITTLE RIVER
WINYAH BAY
LT 148
Black River
Church
Cypress
Palmetto
Marshview
Cleland
Wood
King
Orange
Broad
Screven
Duke
Queen
Cannon
Saint James
Highmarket
Prince
Meeting
Front
Bolick
Smith
River
Bay
Greenwich
Park
Moss
Bayview
USCG Maintenance Dredge
SAC # 1987-08703-3
Georgetown County, South Carolina
Sheet 1 of 4 Dated: August 26, 2013



USCG Maintenance Dredge
SAC # 1987-08703-3
Georgetown County, South Carolina
Sheet 2 of 4 Dated: August 26, 2013

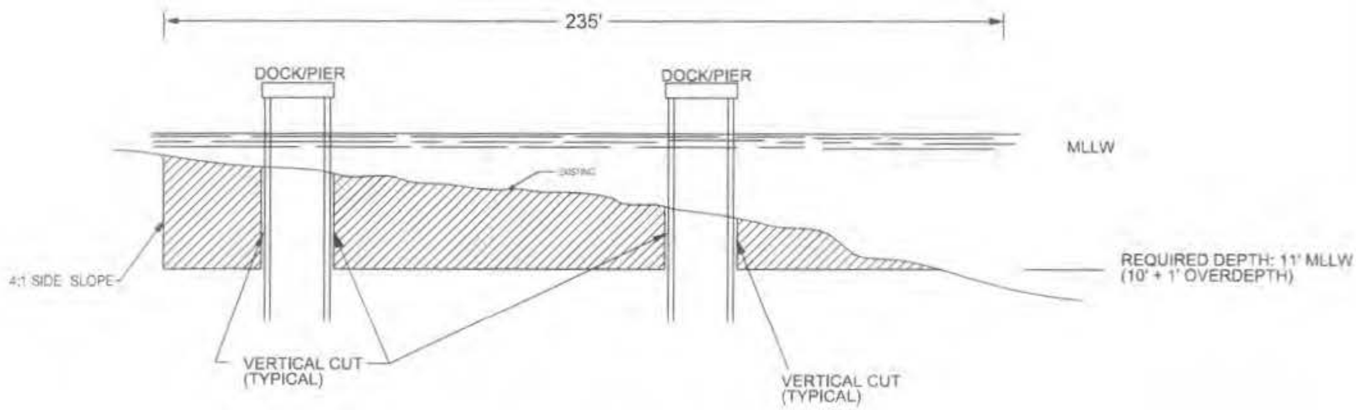
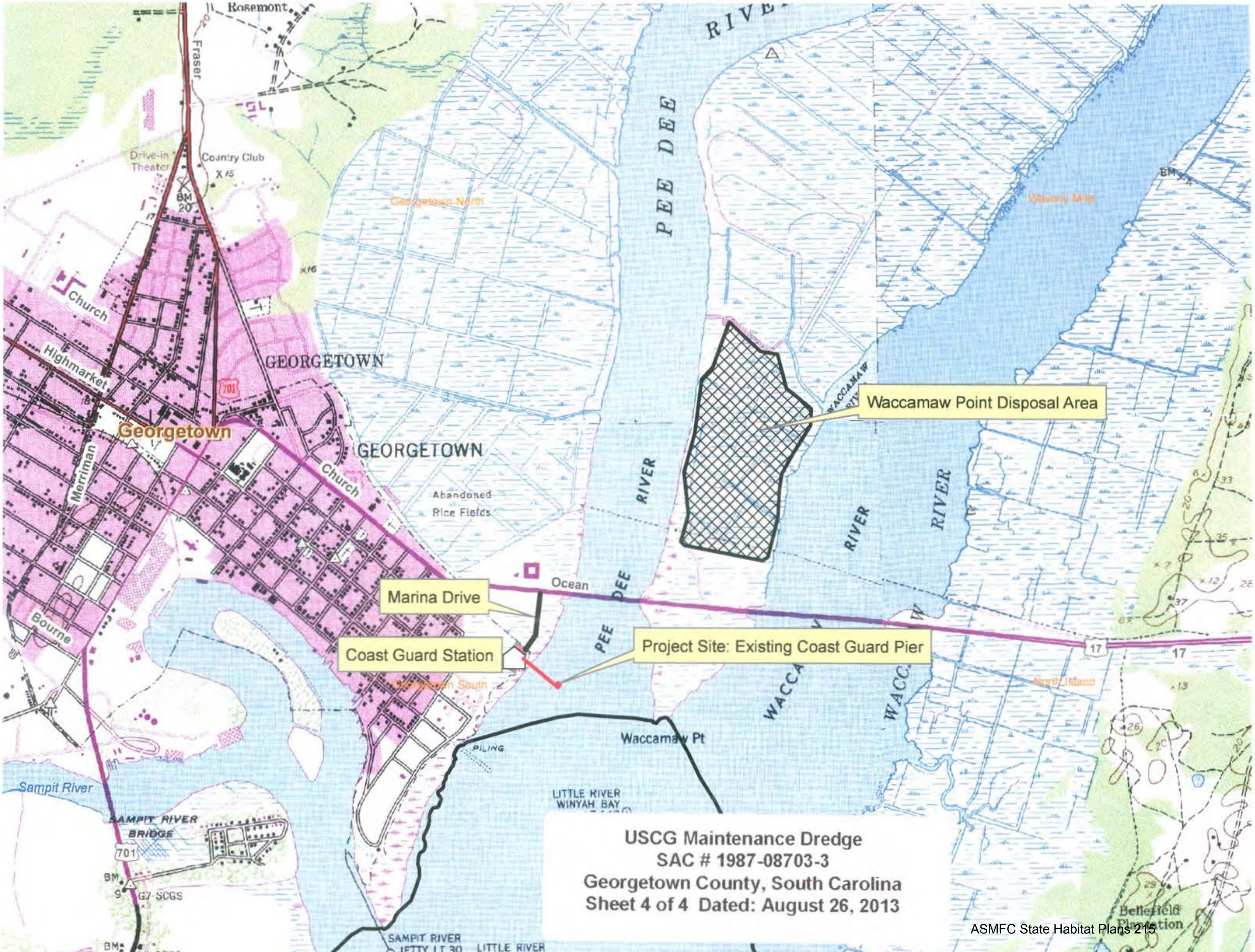


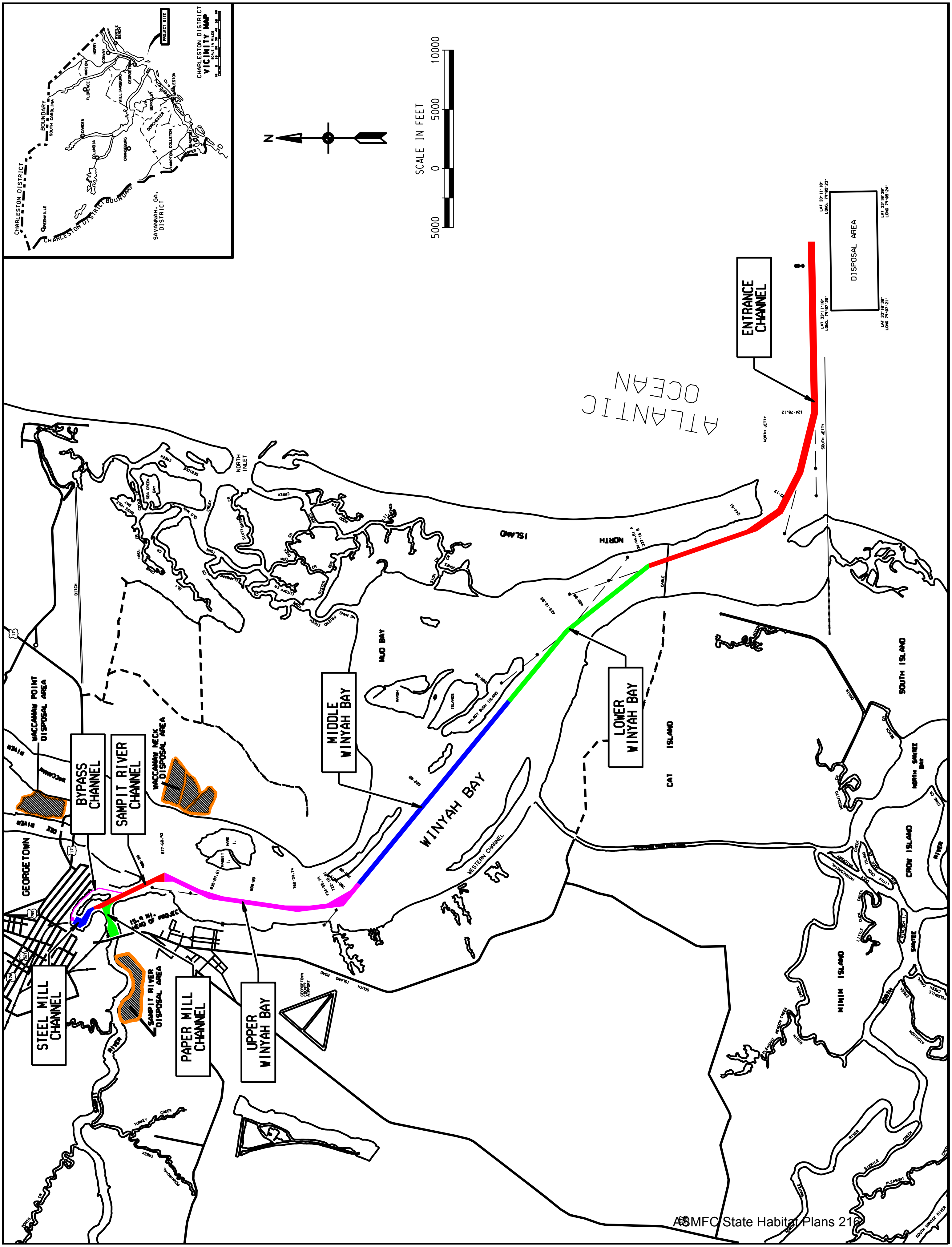
FIGURE 3: PIER DREDGING CROSS-SECTION

NOT TO SCALE

DREDGING PRISM

USCG Maintenance Dredge
SAC # 1987-08703-3
Georgetown County, South Carolina
Sheet 3 of 4 Dated: August 26, 2013


Waccamaw Point Disposal Area
Marina Drive
Coast Guard Station
Project Site: Existing Coast Guard Pier
PEE DEE RIVER
WACCAMAW RIVER
GEORGETOWN
Georgetown
Abandoned Rice Fields
Ocean
Church
Highmarket
Merriman
Bourne
Fraser
Rosemont
Country Club
Drive-in Theater
Waccamaw Pt
Sampit River
SAMPIT RIVER BRIDGE
LITTLE RIVER WINYAH BAY
SAMPIT RIVER JETTY LT 30
PILING
Bellefield Plantation
USCG Maintenance Dredge
SAC # 1987-08703-3
Georgetown County, South Carolina
Sheet 4 of 4 Dated: August 26, 2013


CHARLESTON DISTRICT
VICINITY MAP
PROJECT SITE
SCALE IN FEET
5000
0
5000
10000
N
ENTRANCE CHANNEL
DISPOSAL AREA
ATLANTIC OCEAN
NORTH ISLAND
NORTH INLET
SOUTH JETTY
NORTH JETTY
LOWER WINYAH BAY
MIDDLE WINYAH BAY
WINYAH BAY
MUD BAY
CAT ISLAND
SOUTH ISLAND
NORTH SANTEE BAY
CROW ISLAND
MINIM ISLAND
WESTERN CHANNEL
WACCAMAW POINT DISPOSAL AREA
WACCAMAW NECK DISPOSAL AREA
BYPASS CHANNEL
SAMPIT RIVER CHANNEL
GEORGETOWN
STEEL MILL CHANNEL
SAMPIT RIVER DISPOSAL AREA
PAPER MILL CHANNEL
UPPER WINYAH BAY

Appendix 2. SCDNR "draft" Climate Change document

DNR

CLIMATE CHANGE IMPACTS TO NATURAL RESOURCES IN SOUTH CAROLINA

This document is available on the Department of Natural Resources web site at http:www.dnr.sc.gov/

FOREWORD

In recent years state natural resource agencies including the South Carolina Department of Natural Resources (DNR) have been engaged in discussions about climate change. Staff at DNR, and many of our counterpart state agencies, are routinely asked some of the following questions:

1. What might happen to our fish, wildlife and marine resources if climate change should have an effect on them?
2. Are invasive and noxious species likely to be able to exploit subtle changes in air or water temperature or water quality or quantity?
3. What impact might climate change have on water resources and its continued availability for both humans and fish and wildlife?
4. What are some of the common-sense things we can do to adapt to climate change if it begins to occur?
5. How might recreational boating be affected if our lakes and reservoirs are impacted by climate change?
6. What monitoring programs are in place that will enable us to be able to predict impacts to natural resources or recreational use before they occur?
7. What technologies are necessary to enable science-based natural resource monitoring programs?

These are just a few of the questions we must consider given our mandate to be the stewards of natural resources in South Carolina. In reality, there are many more questions and none of them have easy answers. Facing complex issues and preparing for an uncertain future are nothing new to the DNR. We utilize a sound, science-based approach and have been doing this for many decades. DNR does not have experts in the field of climate change or personnel involved in pure climate change research. However, scientists, biologists, and other personnel from DNR have reviewed the available scientific literature on climate change and the possible impacts on the state's natural resources and drafted a guidance document to help us navigate the path forward.

Over the past few decades scientists have documented melting glaciers, diminishing polar sea ice, shifting of growing seasons, changes in migratory patterns of birds and fish, rising sea levels and many other climate-related phenomena. These changes and countless more like them may have substantial consequences for both the environment and the economy. Nationally, hunting, fishing and wildlife-related recreation alone add $122 billion to the economy each year. In South Carolina, natural resources are essential for economic development and contribute nearly $30 billion and 230,000 jobs to the state's economy. Access to abundant recreational opportunities and natural assets play an important role in economic growth and quality of life at the local, regional and state levels, so protection and enhancement of our natural resources can and should be part of our overall economic development strategy.

Any changes to our coastal environment could cause substantial economic consequences. Shoreline changes affect property uses, land values, tourism, and natural resources management as well as traditional uses such as hunting and fishing, timber management and agriculture.

Some have argued that natural variability and chance have the major influences over climate change, that this is a natural process, and that climate scientists have been overreacting. At DNR, we do not profess to know why all of these changes seem to be occurring, but we do understand that we have a responsibility to stay abreast of the latest science as we strive to make the best decisions possible in the management of the state's natural resources.

All of these potential impacts require a science-based approach to decision making. Moving forward, we should develop an efficient strategy incorporating baseline measurements, monitoring, and data analyses to provide decision makers accurate assessments and predictions of future environmental changes. We know that we must be prepared for change should it occur.

This report is a first step in the process of identifying and gathering published information on how climate change may affect wildlife, fisheries, water supply and other natural resources in South Carolina. We have identified some key adaptive steps necessary to respond to potential climate change in our state. This report is being released for public review, and we invite our citizens and leaders to participate by providing their comments. Public comments may be submitted electronically to climatechange@dnr.sc.gov or by mail to Climate Change, PO Box 167, Columbia, SC 29202. We will appreciate receiving your comments by May 24, 2013.

Signature:

Alvin A. Taylor
Director

ACKNOWLEDGEMENTS

This report is the product of the direct efforts of a number of dedicated South Carolina Department of Natural Resources staff from various internal divisions who both participated in the construction of and advocated for this document. Department of Natural Resources participating staff represented their respective divisions with the clear understanding that such an effort is vital in order to protect and conserve natural resources during a period of potentially rapid climate change. Many other agency employees provided input, and, most importantly, encouraged the preparers toward the goal of producing a draft and ultimately a final report. Staff contributors from their respective divisions included:

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Executive
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Kevin Kibler

Staff listed above constituted the South Carolina Department of Natural Resources Climate Change Technical Working Group, and they collaborated to provide direction and copy for this document. We are very grateful both to Ann Nolte who reviewed two versions of this document and provided very capable editorial assistance and also to Kay Daniels and Ivetta Abramyan who assisted the effort in many ways.

Bob Perry
Compiler and Editor

DEFINITIONS

Sources:

1. Glossary of Terms used in the IPCC Fourth Assessment Report.[1]
2. American Geological Institute, Glossary of Geology.[2]
3. NOAA.[3]
4. Climate Literacy.[4]

Adaptation – Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, moderating harm or exploiting beneficial opportunities.

Albedo – The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo; the albedo of soils ranges from high to low; vegetation-covered surfaces and oceans have a low albedo. The Earth's albedo varies mainly through varying cloudiness, snow, ice, leaf area and land cover changes.

Anadromous – Migration of aquatic organisms from the sea to freshwater to spawn.

Anthropogenic – Effects, processes or materials that are derived from human activities, as opposed to those occurring in biophysical environments without human influence. Resulting from or produced by human beings.

Assemblage – The smallest functional community of plants or animals.

Atmosphere – The mixture of gases surrounding the Earth, retained by gravity. It protects life by absorbing ultraviolet solar radiation, warms the surface through heat retention (the greenhouse effect), and reduces temperature extremes between day and night.

Benthic – Relating to the bottom of a sea or lake or to the organisms that live there.

Catadromous – Migration of aquatic organisms from freshwater to the sea to spawn.

Climate – The characteristic weather of a region, particularly as regards temperature and precipitation, averaged over some significant interval of time. Climate in a narrow sense is usually defined as the average weather, or more rigorously, as a statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the *climate system*. In various parts of this report different averaging periods, such as a period of 20 years, also are used.

Climate change – Climate change refers to a change in the state of the climate that can be identified, for instance by using statistical tests, by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal

[1] http://www.ipcc.ch/publications_and_data/publications_and_data_glossary.htm. Last accessed Jan 2011.
[2] http://www.agiweb.org/pubs/glossary/. Last accessed May 2011.
[3] http://www.weather.gov/glossary/. Last accessed Mar 2011.
[4] https://gcce.larc.nasa.gov/index.php?q=resources/climate-literacy&page=7. Last accessed Apr 2011.

processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climatology – The study of climate, the long-term average of conditions in the atmosphere, ocean, and ice sheets and sea ice described by statistics, such as means and extremes.

Demersal – Refers to species living near the benthic, or bottom, zone of the sea.

Diadromous – Migration of aquatic organisms between fresh and salt waters; includes both anadromous and catadromous.

Ecological services – Humankind benefits from a multitude of resources and processes supplied by natural ecosystems including products such as clean drinking water and processes such as decomposition and assimilation of wastes.

Endangered species – A species of flora or fauna whose numbers are so small that the species is at risk of extinction.

Evapotranspiration – The sum of water vapor evaporated from the Earth's surface and transpired from vegetation to the atmosphere from sources such as the soil, forest canopy interception and surface waters.

Feedback mechanism - A loop system in which the system responds to a change either in the same direction (positive feeback) or in the opposite direction (negative feedback).

Fossil fuel – A general term for any hydrocarbon that may be used for fuel, chiefly coal, petroleum and natural gas formed by decomposition and compression of buried dead organisms.

Glacial maximum – The time or position of the greatest advance of a glacier, or of glaciers.

Greenhouse effect – The natural effect produced as greenhouse gases allow incoming solar radiation to pass through the Earth's atmosphere, but prevent most of the outgoing infrared radiation from the surface and lower atmosphere from escaping into space. Life on Earth could not be sustained without the natural greenhouse effect. However, if the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

Greenhouse gas (GHG) – The gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. There are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances.

Habitat – An ecological, environmental or physical area inhabited by a particular species of animal, plant or other organism.

Insolation – A measure of the amount or rate of solar radiation (Sun) energy received on a given surface area in a given time. **IN**cident **SOL**ar radi**ATION**

Last glacial maximum (LGM) – The time of maximum extent of the ice sheets during the last glacial period, 18,000 years ago. For the central and eastern United States this is referred to as the Wisconsin glaciations. The most recent glacial period lasted from 110,000-11,700 years ago, during the Pleistocene. The

Holocene begins at the end of the Pleistocene, and is considered an interstadial in Quaternary/Pleistocene glaciations.

Little Ice Age – An interval of time between approximately AD 1400-1900 when temperatures in the Northern Hemisphere generally were colder than today, especially in Europe. Originally employed for a mid-Holocene event in the Yosemite area, California, about 3,000 years BC.

Medieval Warm Period (MWP) – An interval of time between AD 1000-1300 in which some Northern Hemisphere regions were warmer than during the Little Ice Age that followed.

Milankovitch theory – An astronomical theory of glaciation, formulated by Milutin Milankovitch, Yugoslav mathematician, in which climatic changes result from fluctuations in the seasonal and geographic distribution of insolation, determined by variations of the Earth's orbital elements, namely eccentricity, tilt of rotational axis and precession. It is supported by recent radiometrically dated reconstructions of ocean temperature and glacial sequences.

Mitigation – An anthropogenic intervention to reduce the anthropogenic forcing of the climate system including strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

Outgassing –The release of trapped or embedded gases

Paleoclimate Proxies – A proxy climate indicator is a local record that is interpreted, using physical and biophysical principles, to represent some combination of climate-related variations back in time. Climate-related data derived in this way are referred to as proxy data. Examples of proxies include pollen analysis, tree ring records, characteristics of corals and various data derived from ice cores.

Paleoclimatology – The study of climate during periods prior to the development of measuring instruments, including historic and geologic time, for which only proxy climate records are available.

Paleotempestology – The study of past tropical cyclone activity (hurricanes) by means of geological proxies and historical records.

Pleistocene – The earlier of 2 Quaternary epochs, extending from the end of the Pliocene, about 1.8 million years ago, until the beginning of the Holocene, about 11,600 years ago.

Sea-level rise – The contextual relationship between land and the sea when the surface of the sea is increased in height relative to land due to increased water volume of the ocean and/or sinking of the land.

Sequestration – The removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis.

Stadial – A short period of colder temperatures during an interglacial (warm period) separating the glacial periods of an ice age. It can be marked by a glacial readvance. The Little Ice Age is a stadial event. This is opposite of an interstadial, which is a short, warm period occurring within a longer glacial period and is marked by a temporary glacial retreat.

Teleconnections – Refers to a recurring and persistent large-scale pattern of pressure and circulation anomalies spanning vast geographical areas. Teleconnection patterns also are referred to as preferred modes of low-frequency (or long time scale) variability. Although these patterns typically last for several weeks to several months, they sometimes can be prominent for several consecutive years, thus reflecting an important part of both the interannual and interdecadal variability of the atmospheric circulation. Many of the teleconnection patterns also are planetary-scale in nature, and span entire ocean basins and continents. For example, some patterns span the entire North Pacific basin, while others extend from eastern North America to central Europe. Still others cover nearly all of Eurasia. They are climate anomalies that are related to each other but occur at large distances from each other perhaps scanning thousands of miles.

Threatened species – A species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Troposphere – The lowest portion of Earth's atmosphere, from the surface to about 10 km in altitude at mid-latitudes (ranging from 9 km at high latitudes to 16 km in the tropics on average), where clouds and weather phenomena occur. In the troposphere, temperatures generally decrease with height. It contains approximately 75% of the atmosphere's mass and 99% of its water vapor and aerosols**.**

Vostok Ice Core – In January 1998, this ice-drilling project, a collaborative between Russia, the United States and France at the Russian Vostok station in East Antarctica yielded the deepest ice core ever recovered, reaching a depth of 3,623 m. Preliminary data indicate the Vostok ice-core record extends through four climate cycles, with ice slightly older than 400,000 years ago.

Water supply – The total amount of water within a defined area that is available for human and other uses.

Wisconsin Glaciation or Wisconsin Stage – the classical fourth glacial stage (and last) of the Pleistocene Epoch in North America. It followed the Sangamon Interglacial Stage and preceded the current Holocene Epoch.

Younger Dryas – A period 12,900-11,600 years ago, during the deglaciation, characterized by a temporary return to colder conditions in many locations, especially around the North Atlantic.

ACRONYMS AND ABBREVIATIONS

ACE Basin – Ashepoo, Combahee and Edisto rivers basin
ASMFC – Atlantic States Marine Fisheries Commission
AMO – Atlantic Multi-Decadal Oscillation
BMRI – Baruch Marine Research Institute, of the University of South Carolina
CO_2 – Carbon dioxide
COR – Coastal Reserves and Outreach of the MRD
CWCS – Comprehensive Wildlife Conservation Strategy
DHEC – South Carolina Department of Health and Environmental Control
DNR – South Carolina Department of Natural Resources
ENSO – El Niño-Southern Oscillation
FAA – Federal Aviation Administration
GIS – Geographic Information Systems
GHG – Greenhouse gas
GSP – Greenville-Spartanburg Airport National Weather Service Station
HAB – Harmful Algal Bloom
LED – Law Enforcement Division of DNR
LGM – Last Glacial Maximum
LWC – Land, Water and Conservation Division of DNR
MARMAP – Marine Resources Monitoring, Assessment and Prediction Program
MJO – Madden-Julian Oscillation
MRD – Marine Resources Division of DNR
MRRI – Marine Resources Research Institute, of MRD
NGO – Non-governmental organization
NOAA – National Oceanic and Atmospheric Administration
NWS – National Weather Service
OFM – Office of Fisheries Management of MRD
QBO – Quasi-Biennial Oscillation
SAB – South Atlantic Bight
SAMFC – South Atlantic Marine Fisheries Council
SEAMAP – Southeast Area Monitoring and Assessment Program
SENRLG – Southeast Natural Resource Leadership Group
SERTC – Southeastern Regional Taxonomic Center
USC – University of South Carolina, National Weather Service Station
USGS – United States Geological Survey
USHCN – United States Historical Climatology Network
WFF – Wildlife and Freshwater Fisheries Division of DNR

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EXECUTIVE SUMMARY

Global warming and cooling have occurred naturally throughout history, but changes in the past were usually much slower than the rate of warming that has occurred in the last few decades. Both land and ocean temperature measurements independently indicate a warming trend since around 1880, but since 1979, land temperatures have increased approximately twice as fast as ocean temperatures (0.25 °C per decade versus 0.13 °C per decade). Since the mid 1970s, the average surface temperature has increased by about 1°F (0.56 °C). If this trend continues, by the end of this century, average global temperature is projected to rise between 2-11.5ºF (1.1-6.4°C). Observed climate-related changes are expected to continue, and are likely to result in new natural resource impacts and changes that potentially disrupt or damage ecological services, water supplies, agriculture and forestry, fish and wildlife species and their habitats, endangered species and commercial and recreational fishing and hunting.

The South Carolina Department of Natural Resources (DNR) is charged by law with the management, protection and enhancement of natural resources in South Carolina and thus is the steward of the state's natural resources for their use and enjoyment by the public. In South Carolina, natural resources are essential for economic development and contribute nearly $30 billion and 230,000 jobs to the state's economy. The DNR recognizes the need to address potential climate change as a threat-multiplier that could create new natural resource concerns, while exacerbating existing tensions already occurring as a result of population growth, habitat loss, environmental alterations and overuse. Thoughtful and careful planning regarding climate change is needed in order to protect the valuable natural resources of the Palmetto State. In response to these challenges, DNR has identified potential impacts of climate change on the natural resources of South Carolina, and developed an adaptive response strategy to offset, minimize or delay the effects of a changing climate on natural resources. The agency will:

1. Gather factual, accurate information and data on how climate change may affect wildlife, fisheries, water supply and other natural resources within the state,
2. Identify monitoring and data needs required to assess impacts of climate change in the state,
3. Use factual information, data, research and modeling to determine what actions need to be taken to address climate change,
4. Ensure data quality; provide original research that addresses information needs; and validate modeling results with collected data,
5. Identify opportunities to partner with other state agencies and academic institutions where needed to accomplish this mission,
6. Identify ways for state officials, local government and citizens to assist in mitigation of or adaptation to natural resource impacts related to climate change, and
7. Locate and obtain available funding to assist in meeting agency mission and goals related to climate change.

Climatology is the study and analysis of weather records over an extended period of time. The study of climate prior to the use of instrumental records is known as paleoclimatology. Results from paleoclimate studies indicate that climate variation is a natural phenomenon; Earth's climate has changed many times throughout history. Currently, we are in an interglacial, or warm, period, which began at the end of the last glacial maximum 13,500 years ago. Other results from paleoclimate studies show that climate has changed episodically on a variety of timescales, and some of these changes have occurred quite abruptly. Climate has varied through time under the influence of its own internal dynamics involving changes such as volcanic eruptions and solar variations. Now, human-caused changes in atmospheric composition appear to be influencing climate change.

To date, no systematic study of South Carolina's paleoclimate has been completed. Some studies have addressed climatic conditions at a specific time or at a specific site, but no studies document the state's climate before instrumental records became available. The state's paleoclimate record should be studied at several time scales to establish a baseline for current climatic conditions and future trends. South Carolina climatological trend data, 1895-2010, has been analyzed and shows a warming trend that started during the 1970s continuing to the present. A warming trend was also observed in winter coastal water temperatures during a study performed from 1950-2010. Severe weather is a persistent feature of South Carolina's climatology. No discernible relation is seen between the number of tornadoes or coastal hurricanes land falls and the aforementioned warming trends.

Current climate models predict continued warming across the southeast, with the greatest temperature increases projected in summer. Average annual temperatures are projected to rise 4.5°F by the 2080s under a lower emissions scenario and 9°F under a higher emissions scenario with a 10.5°F increase in summer. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration.

Sea level rise is a serious concern in South Carolina due to our extensive coastline. Sea level rise will affect coastal habitats such as estuaries, creeks, marshes, managed wetlands, hammocks, sand dunes and beaches by modifying patterns of sea water encroachment, flooding, erosion and deposition. It will also affect fish and wildlife species that depend on these habitats, as well as any related activities such as fishing, hunting and tourism. Some habitats may adapt by depositional growth or inland migration, but coastal development could impede the latter in many areas. Potential management responses include inland retreat, coastal reinforcement and beach nourishment, but each option has ecological and economic costs.

A changing climate will present water-related challenges in several areas to include water quality, water quantity and changes in sea level. Rainfall and streamflow are tied directly to seasonal climatic conditions. Although DNR has no direct responsibility in regulating water quality, issues of water quality and quantity are difficult to separate when availability is in question. By statute DNR is responsible for water planning in

South Carolina. A comprehensive statewide water policy is needed to maintain and preserve surface- and ground-water supplies. Basic information needed for this work is lacking or threatened due to limited funding. Necessary steps are required to maintain and expand the availability of reliable information needed for a water assessment. Sea-level rise, drought and flooding are occurring, and sea-level rise already is creating shoreline change. Several drought periods in recent years have adversely affected agricultural interests, forestry and water supply. Planning and monitoring is needed prior to and during drought events. A predicted result of climate change is the increase in intense storm events causing greater water inputs in shorter periods of time, affecting flood frequency and duration.

Temperature rise is expected to affect a number of natural resource issues in South Carolina. Habitats and life histories of species within the state may be shifted both in terms of time and space. This could result in changes to feeding and nesting areas as well as reproductive cycles. Additionally, ecosystem-wide regime shifts may result in major changes in species diversity and interactions at all trophic levels. Temperature has a direct effect on the physiology and survival of aquatic species. Commercial and recreational landings of aquatic species may be affected when life histories shift. Ranges for species may shift so they no longer occur in South Carolina, while other more temperature tolerant species may thrive where they had not done so previously. Harmful algal blooms caused by certain species of microscopic, photosynthetic algae can cause a wide range of detrimental effects that are species-specific. These effects may include shading and destruction of estuarine grass habitat, shellfish poisoning and toxin production that can bioaccumulate in the food chain potentially inducing sickness and death in wildlife and humans. Increasing temperatures can reduce oxygen levels in coastal waters through a variety of mechanisms such as a decrease in the solubility of oxygen, an increase in productivity and stratification of the water column. These factors can result in dead zones in coastal and estuarine waters. Increasing ocean acidification is related to increasing carbon dioxide levels in the Earth's atmosphere. Ocean acidification (decreasing Ph) raises concerns about the future of coral reefs and other species that incorporate calcium carbonate into their skeletons including mollusks, crustaceans and some plankton.

Habitat decline, a shifting climate regime, increasing development, particularly in coastal areas, and rising sea level represent constraints and barriers to dispersal and migration of fish, wildlife and plant species. Maintenance of migratory corridors is essential for the ability of wildlife and fish to find suitable habitat and for population maintenance. Temperature changes likely will change the vegetative structure of wildlife habitats throughout the state. Habitat loss not only affects the area in which the species can live, it also affects food availability and availability of suitable nesting and breeding areas. Impacts associated with temperature changes most likely will be greater in the higher elevations of the state. Precipitation changes will affect both surface and groundwater levels and will result in impacts to both terrestrial and aquatic systems. As the nation strives to locate and develop alternative, cleaner and more carbon-neutral sources of energy, it is important to understand that such energy sources may result in additional impacts to wildlife, fish and their habitats.

Species of greatest conservation need are identified in the *South Carolina Comprehensive Wildlife Conservation Strategy*; these include endangered and threatened species and species of concern. Although DNR has collected some short- and long-term information relative to some of these species and their habitats, the collective database is insufficient to understand the role of climate change in the population trends of these species. It also is difficult to identify conservation actions needed to offset or mitigate the effects of climate change. DNR should strengthen and standardize the inventory and monitoring of greatest conservation need species and their habitats.

Increased temperatures, changes in rainfall and other environmental factors affected by climate shifts can create ideal conditions for proliferation of invasive plant and animal species, including parasites and pathogens. Regardless of the manner in which they have become established, these species already are affecting native animals and their habitats. As climate changes, we likely will see an increase of exotic species migrating to South Carolina. Habitats can be destroyed as resources are over-utilized. Invasive and non-indigenous species have the potential to outcompete native species for food and other resources. Species currently located in Florida and southern Georgia that come from more temperate parts of the world have been historically limited to ranges south of South Carolina by cold winters. They are now of major concern. Significant climate change could allow range expansion in these exotic species that would be detrimental to native species.

Climate warming has been linked with a general increase in pathogens of marine, aquatic and terrestrial organisms. This may negatively impact the populations of certain species, including some of economic importance.

Wildlife and fish populations likely will be altered as climate change occurs. While such changes may lead to a reduction of commercial and recreational hunting and fishing opportunities of some species, other opportunities may increase for those species which could benefit from an altered climate. Regardless of whether climate change produces commercial and recreational winners or losers, it will be important for DNR to implement long-term monitoring of harvested species in order to detect temporal and spatial changes in numbers and prevent unsustainable population declines. Further, it will be important for DNR to keep the public and policy makers informed, through outreach and education efforts, of changes as they occur in order to reduce the potential for conflict between human and natural resource needs.

A critical element of the agency's response to climate change is to increase public awareness of the potentially adverse and positive effects resulting from these changes. Agency efforts at outreach and education are first, to strengthen and increase partnerships with other agencies and organizations involved in climate change research and policy and planning; second, to assist local communities in planning for change, such as providing coastal resiliency to reduce overall vulnerability of economic and ecological systems to climate variations; and, third, to communicate information on climate change to citizens of South Carolina using the World Wide Web and public forums. Additionally, scientific research results will be published in peer-reviewed journals.

In order to meet the agency's long-term ability to respond to climate change impacts in South Carolina, numerous additional strategies and technologies will be required. First, DNR should implement a resource inventory and monitoring program to track trends in resource abundance and distributions at the species and landscape level. Second, the agency must expand its technology infrastructure to support the climate change studies including implementing various direct and remotely-sensed measurement platforms to provide *in situ* documentation of critical climate change parameters and the integration of these data into a comprehensive database. Third, DNR must develop appropriate data access, scientific analysis and resource management decision-support tools to assess climate change impacts and to develop appropriate resource management strategies. Fourth, DNR must develop the expertise required to meet the challenges of understanding and addressing the vast array of environmental impacts and natural resource management issues associated with climate change. Staff training in various analytical, modeling and geographic information systems software, and associated technologies is essential.

This report identifies the overriding natural resource issues and provides recommended actions to keep South Carolina at the forefront of conserving natural resources during an era of changing climate. These overarching issues include the potential for:

1. Detrimental change in habitat,
2. Detrimental change in abundance and distribution of species,
3. Detrimental change in biodiversity and ecosystem services,
4. Detrimental change to the traditional uses of natural resources,
5. Detrimental change in the abundance and quality of water, and
6. Detrimental change in sea level.

Specific tasks identified by DNR in order to move forward in an era of climate change while protecting natural resources include:

1. Spatial mapping,
2. Monitoring and establishing living and non-living resources and climate trends,
3. Habitat acquisition,
4. Adaptation strategies on DNR-titled properties,
5. Integration and analysis of data,
6. Outreach and education,
7. Developing additional partnerships and collaborating with others, and
8. DNR leading by example.

DNR is making climate change an integral part of the agency's ongoing mission by integrating climate change into the DNR organizational culture, its structure and all aspects of its work. These key steps include:

1. Develop an approach that will incorporate climate change into DNR strategic and operational plans and existing structure to be used as a vehicle for internal and external communication,
2. Ensure that all levels of agency staff are aware of and engaged in climate-change initiatives,
3. Update and align DNR actions with regional and national climate change initiatives as appropriate,
4. Work with stakeholders and partners on fish, wildlife and habitat adaptation and mitigation,
5. Prepare an internal and external outreach strategy to communicate climate change issues, and
6. Develop clear and measurable indicators to track the results of DNR climate change efforts.

To accomplish its mission, DNR recommends the following core climate change efforts:

1. Policies and Opportunities – focus on grants, legislation, partnerships and strategic planning,
2. Research and Monitoring – focus on standardized monitoring protocols and state-specific data (including gaps) and predictive modeling,
3. Communication and Outreach – focus on the DNR messages and a climate change communication plan,
4. Adaptation – focus on the activities related to unavoidable climate change impacts on natural resources
5. Operations – focus on positioning DNR as a leader by reducing the agency's carbon footprint, improving its energy efficiency and decreasing operational costs.
    a. Achieve increased fuel economy through various methodologies.
    b. Achieve increased energy efficiency through energy audits and adoption of practicable energy audit recommendations.
    c. Implement practicable water efficiency measures for agency buildings.
    d. Implement paperless internal communications and document management.

DNR is taking a lead role among South Carolina state agencies to advance the scientific understanding of the vulnerability of South Carolina's vital natural resources during an era of changing climate. This will enable the agency, its partners, constituents and all Palmetto State citizens to avoid or minimize the anticipated impacts while protecting South Carolina's natural resources.

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1.0 INTRODUCTION

1.1 Climate Change

Climate change, such as global warming and cooling, has occurred naturally throughout history over timescales that vary from decades to hundreds of thousands of years. However, changes in the past were usually much slower than the rate of warming that has been measured in the last few decades. Figure 1.1 provides the annual global temperature anomalies for the past 130 years, including both land and ocean temperature trends. Land temperatures increase faster than ocean temperatures due to the greater heat capacity of the ocean and its ability to transfer more heat to the atmosphere in the form of evaporative cooling.[5] Both land and ocean temperature measurements independently indicate a warming trend since around 1880, but since 1979, land temperatures have increased approximately twice as fast as ocean temperatures (0.25 °C per decade versus 0.13 °C per decade)[6]. Although temperature changes vary over the globe, since the mid 1970s, the average surface temperature has increased by about 1°F (0.56 °C) [7]. If this trend continues, by the end of this century, average global temperature is projected to rise between 2-11.5ºF (1.1-6.4°C)[8].

While some of this warming has a natural cause, there is evidence that human activity is disproportionally contributing to the measured warming. The concern over human activities arises primarily from fossil fuel combustion, which releases carbon dioxide and other greenhouse gases, and changes in land use. The introduction of external greenhouse gases into the atmosphere alters the radiative balance of the earth by changing its atmospheric composition, which enhances the natural greenhouse effect. There are complex interactions between many of these processes.

The increase in global temperatures is just one consequence of a changing climate. The various components of the climate and earth system are linked through complex feedback mechanisms, so that a change in one component, such as temperature, can induce changes and adjustments in other components. Changes already observed, or projected to occur, include sea level rise; changes in rainfall patterns; increases in

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[5] Rowan T. Sutton, Buwen Dong, Jonathan M. Gregory (2007). "Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations". *Geophysical Research Letters* **34** (2).

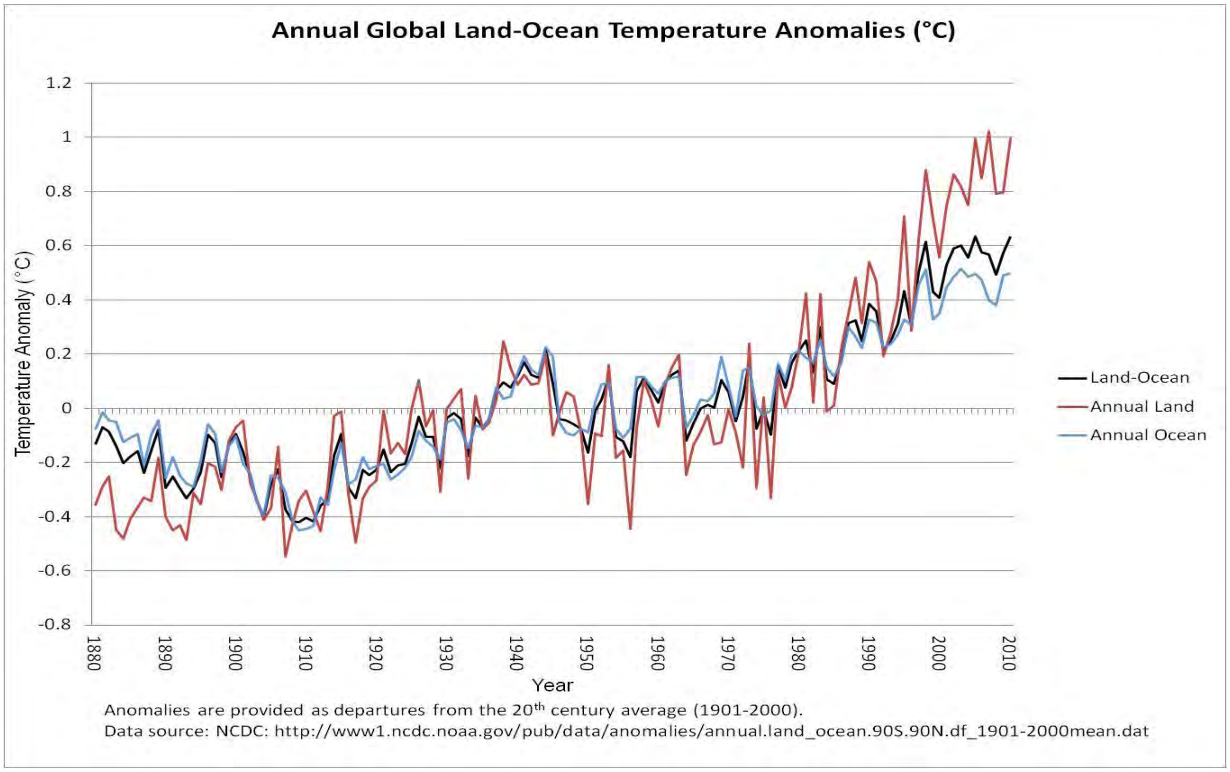
[6] Chapter 3, p. 237, in IPCC AR4 WG1 (2007). Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.B.; Tignor, M.; and Miller, H.L.. ed. *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

[7] (NOAA)2008 State of the Climate Report

[8] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning,Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

frequency of extreme weather events; decreases in ice mass of glaciers, ice sheets and sea ice; ocean warming and acidification[9]; and alterations in ocean circulation patterns.

Figure 1.1 Annual land, annual ocean, and combined annual land-ocean global temperature anomalies for the past 130 years indicating a significant rise over the last 30 years. Land surface temperatures are generated from the Global Historical Climate Network-Monthly (GHCN-M). Sea surface temperatures are determined using the Extended Reconstructed Sea Surface Temperature (ERSST) analysis[10].



The South Carolina Department of Natural Resources recognizes the need to address potential climate change as a threat-multiplier that could create new natural resource concerns, while exacerbating existing tensions already occurring as a result of population growth, habitat loss, environmental alterations and overuse. Climate-related changes may adversely affect the environment in many ways, potentially disrupting or damaging ecological services, water supply, agriculture and forestry, fish and wildlife species and their habitats, endangered species and commercial and recreational fishing. One particular impact is sea-level rise and its effects on coastal areas. Rising sea level may amplify problems of coastal flooding, coastal erosion, and general disruptions to sensitive coastal and estuarine ecosystems. Thoughtful and careful

[9] Effects of Climate Change and Ocean Acidification on Living Marine Resources, Written testimony presented to the U.S. Senate Committee on Commerce, Science and Transportation's Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard, May 10, 2007

[10] http://www.ncdc.noaa.gov/cmb-faq/anomalies.php. Last accessed October, 2011

planning regarding climate change is needed in order to protect the valuable natural resources of the Palmetto State. In response to these challenges, DNR has prepared this report to address potential impacts of climate change on the natural resources of South Carolina and guide the agency's adaptive response strategy to offset, minimize, or delay these effects.

1.2 Background

South Carolina's natural resources contribute nearly $30 billion and 230,000 jobs to the state's economy. These economic benefits include forestry, mining, recreational fishing, hunting and wildlife viewing, a large part of the tourism market, and the recreational industry. South Carolina's beaches alone generate about $3.5 billion annually and support 81,000 jobs. Fishing, hunting and wildlife viewing contribute almost $2.2 billion annually to South Carolina's economy and support nearly 59,000 jobs, while the state's forestry industry exports more than $1 billion in forest products, supporting more than 83,000 jobs[11].

DNR is charged by law (Titles 48 and 50, South Carolina Code of Laws (1976), as amended) with the management, protection and enhancement of natural resources in South Carolina[12]. Additionally, DNR is charged with regulating watercraft operation and associated recreation, including establishing boating safety standards. Title 49, South Carolina Code of Laws, authorizes DNR as the state agency responsible for considering water supply (domestic, municipal, agricultural and industrial) issues, water quality facilities and controls, navigation facilities, hydroelectric power generation, outdoor recreation, fish and wildlife opportunities, and other water and land resource interests. This title also charges DNR with aquatic plant management, comprehensive drought planning, management and coordination of State Scenic Rivers and the conservation, protection, and use of floodplain lands.

DNR is the steward of the State's natural resources and is responsible for the protection and management of these resources for the use and enjoyment of the public. Natural resources within DNR's purview include land, water, mineral and biological resources. In carrying out its responsibilities, DNR must balance its objectives and actions holistically in order to most appropriately protect and sustain the natural resources of South Carolina.

DNR is a multifaceted agency consisting of the fish and wildlife sciences and the offices of the State Climatologist, State Geologist and State Hydrologist. Scientists in all divisions of the DNR are concerned over the potential impacts of climate change on natural resources. In fact, natural resource agencies across the nation, both state and federal, are examining climate change and the specific issues affecting their area of responsibility and core mission. DNR recognizes climate change as a real phenomenon, grounded in numerous scientific studies, and DNR recognizes that

[11] Underappreciated Assets: The Economic Impact of South Carolina's Natural Resources, University of South Carolina Moore School of Business, 2009, http://www.dnr.sc.gov/green/greenreport.pdf
[12] http://www.scstatehouse.gov/code/statmast.htm. Last accessed October 2011.

thoughtful and careful planning is needed in order to protect the natural resources of the Palmetto State to benefit its citizens in the future.

South Carolina state government has been involved in the climate change discussion primarily through the Climate, Energy and Commerce Advisory Committee called to action by former Governor Mark Sanford in 2007. The committee consisted of elected officials and leaders from government agencies, utilities, non-government organizations, businesses, and industry. The final committee report examined present and projected state contributions to GHG, and recommended ways to reduce GHG output over the next planning horizon, which was defined as by 2020 and beyond. Of particular note, the report recommended a comprehensive set of 51 specific policies to reduce GHG emissions and address climate-, energy-, and commerce-related issues in South Carolina[13]. The State has taken positive steps toward developing policies that will decrease the contribution of GHG emitted from Palmetto State sources, and the State has joined with states across the nation in an effort to mitigate the potential impacts of climate change by reducing the greenhouse effect [14].

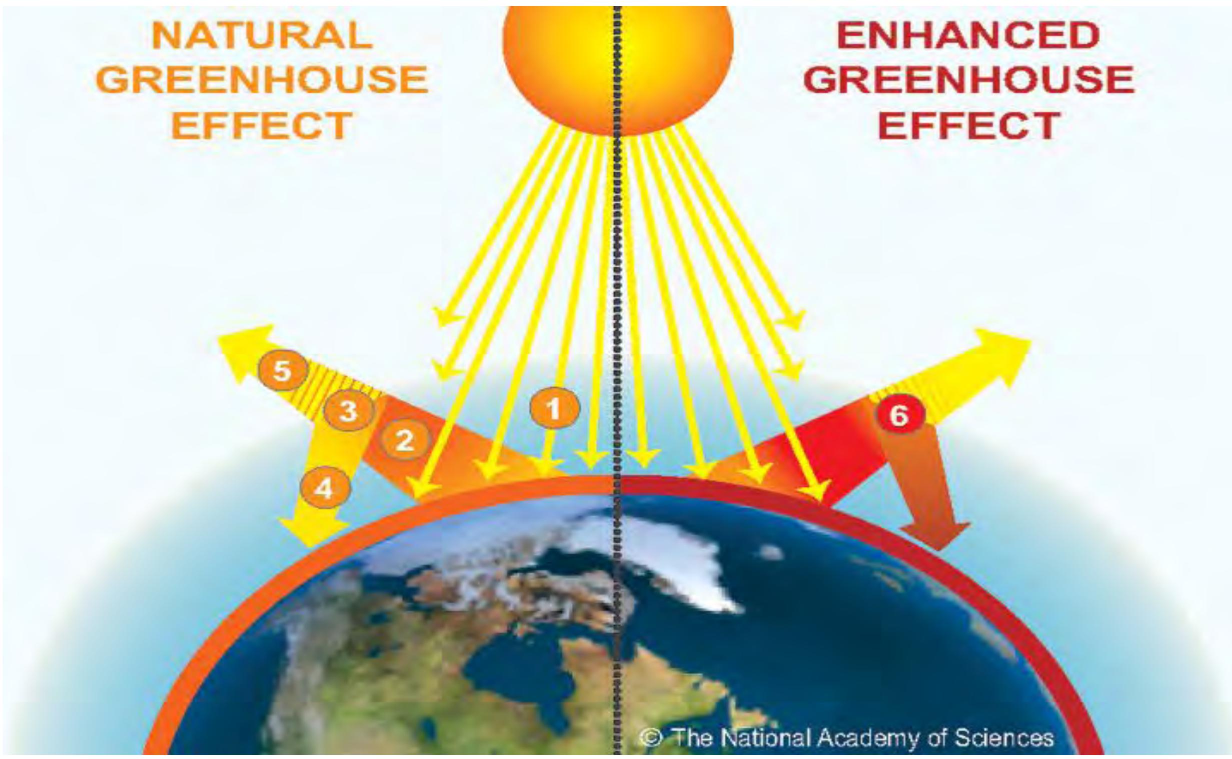
1.3 Greenhouse Effect

The greenhouse effect is a natural phenomenon that keeps the Earth insulated from the cold temperatures in space. Solar radiation enters the atmosphere and is absorbed and reemitted back from the Earth's surface as infrared energy. The greenhouse gases (GHGs) in the atmosphere prevent some of this heat energy from escaping back into space and reflect it back down to the surface. Since the industrial revolution, however, emissions of these gases have increased and accumulated. These larger volumes of atmospheric GHG are trapping more and more heat resulting in an enhanced greenhouse effect. The greenhouse effect is depicted in Figure 1.2.

There are ten primary GHGs, of which water vapor (H_2O) is the only GHG that is solely naturally occurring. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are naturally occurring and also are created from anthropogenic sources[15]. After water vapor, carbon dioxide is the second most abundant greenhouse gas. It occurs naturally as part of the carbon cycle, which includes inputs from animal and plant respiration, ocean-atmosphere exchanges of gases, as well as outgassing from volcanic eruptions. It is also estimated to be responsible for 9–26 percent of the greenhouse effect[16]. Since the mid 18th century, anthropogenic activity has increased the concentration of carbon dioxide and other greenhouse gases (Figure 1.3). This has resulted in atmospheric concentrations of carbon dioxide being 100 ppm higher than pre-industrial levels[17].

[13] South Carolina Climate, Energy and Commerce Advisory Committee. 2008. Final Committee report. 653 pp. Hereinafter CECAC 2008. http://www.scclimatechange.us/index.cfm Last accessed October 2011.
[14] http://www.scclimatechange.us/ Last accessed Jan 2011.
[15] Center for Sustainable Systems, University of Michigan. 2010. "*U.S. Greenhouse Gases Factsheet.*" Pub. No. CSS05-21. http://css.snre.umich.edu/css_doc/CSS05-21.pdf. Last accessed October 2011.
[16] [4]Kiehl, J.T.; Trenberth, K.E. (1997). "Earth's Annual Global Mean Energy Budget" (PDF). *Bulletin of the American Meteorological Society* **78** (2): 197–208
[17] Climate Change 2001: Working Group I: The Scientific Basis: figure 6-6.

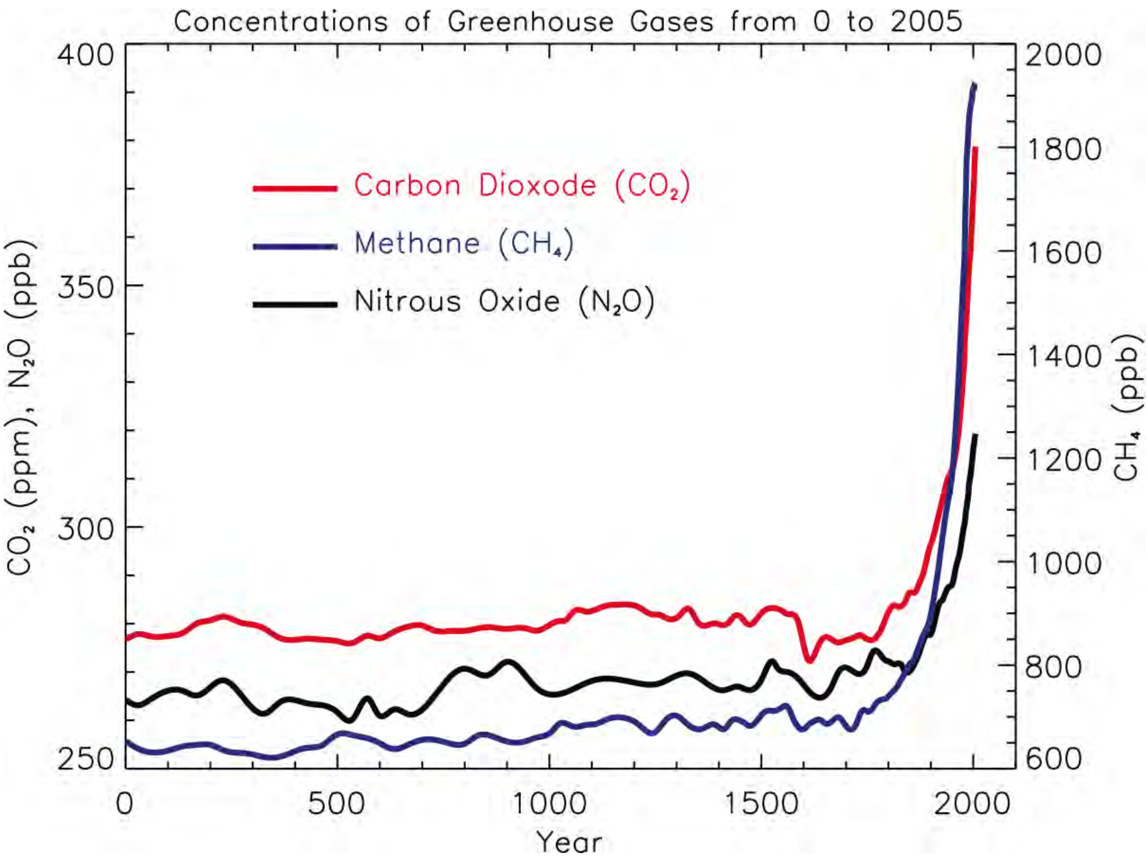
Figure 1.2 The greenhouse effect illustrated: visible sunlight passes through the atmosphere without being absorbed. Some of the sunlight striking the earth is (1) absorbed and converted to infrared radiation (heat), which warms the surface. The surface (2) emits infrared radiation to the atmosphere, where some of it (3) is absorbed by greenhouse gases and (4) re-emitted toward the surface; some of the infrared radiation is not trapped by greenhouse gases and (5) escapes into space. Human activities that emit additional greenhouse gases to the atmosphere (6) increase the amount of infrared radiation that gets absorbed before escaping to space, thus enhancing the greenhouse effect and amplifying the warming of the Earth[18].



Methane (CH_4) is the third most abundant greenhouse gas, and remains in the atmosphere for approximately 9-15 years. It is over 20 times more effective in trapping heat than carbon dioxide (CO_2) over a 100-year period[19]. It is formed from a variety of natural and anthropogenic processes. Methane occurs naturally when organic material decomposes. The main natural sources of methane are wetlands, termites, bodies of water, and gas hydrates. The major anthropogenic sources are landfills, natural gas and petroleum systems, agriculture, and coal mining.

[18] Reprinted by permission of the Marian Koshland Science Museum of the National Academy of Sciences, http://www.koshland-science-museum.org.
[19] http://www.epa.gov/methane/. Last accessed October 2011

Figure 1.3 This figure shows the concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) in the atmosphere from year 0 to 2005.



Source: National Center for Atmospheric Research (NCAR), WMO:Concentrations of greenhouse gases from 0 to 2005, http://gcmd.nasa.gov/records/GCMD_WMO_Concentrations_greenhouse_gases0-2005.html

Nitrous oxide (N_2O) is the fourth most abundant greenhouse gas. Despite its lower concentration, it is 310 times more powerful at trapping atmospheric heat than carbon dioxide, and remains in the atmosphere for 120 years[20]. It is naturally emitted from oceans and soils, but anthropogenic sources include agricultural (mostly nitrogen fertilization) and industrial activities, fossil fuel combustion, and nitric acid production.

Between 10,000 and 150 years ago, atmospheric concentrations of CO_2, CH_4, and N_2O were relatively stable. In the last 150 years, concentrations of CH_4 and N_2O increased 148% and 18%, respectively[21]. Table 1.1 compares the preindustrial and current levels of the primary anthropogenically-produced GHG and their radiative forcing. Radiative forcing is a measure of the influence an external factor has on the balance of incoming and outgoing energy and is an index of the importance of the factor as a potential

[20] http://www.epa.gov/nitrousoxide/. Last accessed October 2011
[21] IPCC (2007) *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change; Ed. S. Solomon et al.; Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

climate change mechanism. Radiative forcing values are for changes relative to preindustrial conditions in 1750 and are typically expressed in watts per square meter (W/m^2).

Table 1.1 Preindustrial and current levels of the primary anthropogenically-produced GHG and their radiative forcing.

Gas	Preindustrial level	Current level	Increase since 1750	Radiative forcing (W/m^2)
Carbon dioxide	280 ppm	388 ppm	108 ppm	1.46
Methane	700 ppb	1745 ppb	1045 ppb	0.48
Nitrous oxide	270 ppb	314 ppb	44 ppb	0.15

Source: http://en.wikipedia.org/wiki/Greenhouse_gas, Last Accessed

1.4 Climate

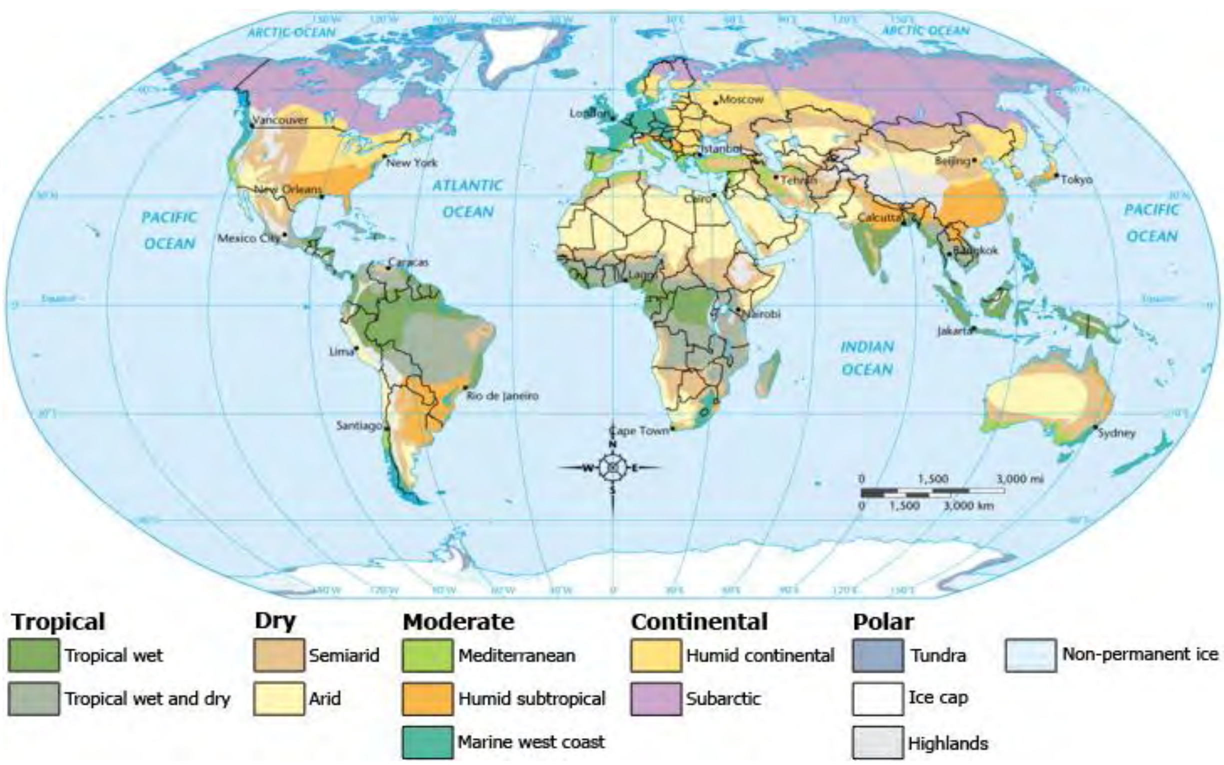
Climate is defined as the complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, flora and fauna. Climate can be described in terms of the average temperature, humidity, atmospheric pressure, precipitation, wind and other parameters over a period of time, ranging from months to millions of years. Modern climate studies tend to use intervals of 30 years to define climate norms. The climate of a location is affected by its latitude, terrain and altitude, as well as nearby water bodies and their currents[22]. The generalized worldwide climate classifications are depicted in Figure 1.4.

Climate has varied through time under the influence of its own internal dynamics involving changes such as volcanic eruptions and solar variations. Now, human-caused changes in atmospheric composition appear to be influencing climate change. Ultimately, the energy of the Sun drives the Earth's climate. Climate changes may occur in a limited number of ways including: (1) changes in incoming solar radiation resulting from changes in Earth's orbit or in the Sun itself, (2) changes in the fraction of solar radiation that is reflected back into space, otherwise known as albedo, and (3) changes in the amount of infrared radiation reflected back to to Earth by GHG concentrations. Although climate responds directly to these, it also can respond indirectly, through a variety of feedback mechanisms[23]. The climate system is

[22] Thornthwaite, C. W. 1931. The Climates of North America: According to a New Classification, Geo. Rev. 21(4):633-655.
[23] Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson and M. Prather, 2007: Historical overview of climate change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, *eds*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

characterized by positive and negative feedback effects between processes that affect the state of the atmosphere, oceans and land. An example of a climate feedback mechanism is the ice-albedo positive feedback loop. Melting snow exposes more dark ground, with lower albedo, which in-turn absorbs heat that would have been reflected back into space by snow or ice[24].

Figure 1.4 Generalized worldwide climate classifications noting the southeastern United States to be part of the humid subtropics.



1.5 <u>Weather</u>

Weather occurs in the troposphere, or the lowest portion of the atmosphere. It is the current, localized condition of atmospheric elements.[25] Common weather factors that affect daily life include wind, clouds, rain, sleet, snow and fog. Less common weather events that occur in South Carolina and the southeastern United States are tornadoes and hurricanes. These natural disasters cause economic distress as well as loss of property and life.

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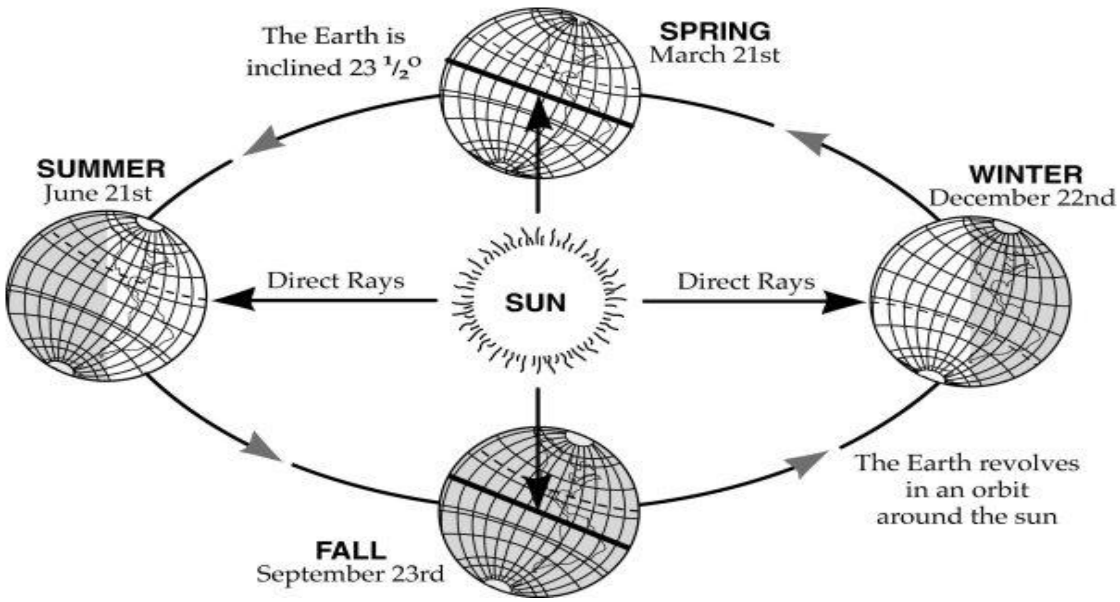
[24] Heimann, M. and M. Reischstein. 2008. Terrestrial ecosystem carbon dynamics and climate feedbacks. Nature. 451(289-292).
[25] Karl, T. R., J. M. Melillo and T. C. Peterson, eds. 2009. Global Climate Change Impacts in the United States. Cambridge University Press.

The Earth rotates daily on its axis, and its axis precesses, or wobbles, over the course of a year (Fig 1.5). Thus, the incident angle of solar insolation on a seasonal basis. Weather results from many factors, but the primary cause is differential heating of the Earth rotating on a variable axis and orbiting around the sun. This differential heating varies by time and location and is complicated by topography and bathymetry resulting in variability in temperature, moisture distribution and atmospheric dynamics. Figure 1.5 depicts the Earth's orbit around the Sun and the relative inclination of the Earth to the Sun.

Figure 1.5 The Earth orbits around the Sun. As the Earth moves around the Sun it is tilted 23.5° from the perpendicular. The Earth's revolution and inclination cause the changing seasons. The arrows extending from the Sun to the Earth represent where the direct rays of the Sun strike the Earth on the first day of each season.[26]



1.6 Methodology

Although temperature at the surface of the Earth is typically used as a primary indicator of climate change, there are other key measures that should be considered. Some of the other key measures and datasets include air temperature observed above both the land and sea, water temperature at the sea-surface extending hundreds of meters below the surface, changes in humidity, changes in sea level, and changes in sea-ice, glaciers and snow cover[27].

[26]
[27] Evidence: The state of the climate, Met Office, UK, 2010 http://www.metoffice.gov.uk/media/pdf/m/6/evidence.pdf Last accessed Oct. 2011

1.6.1 Satellite versus Surface Observations

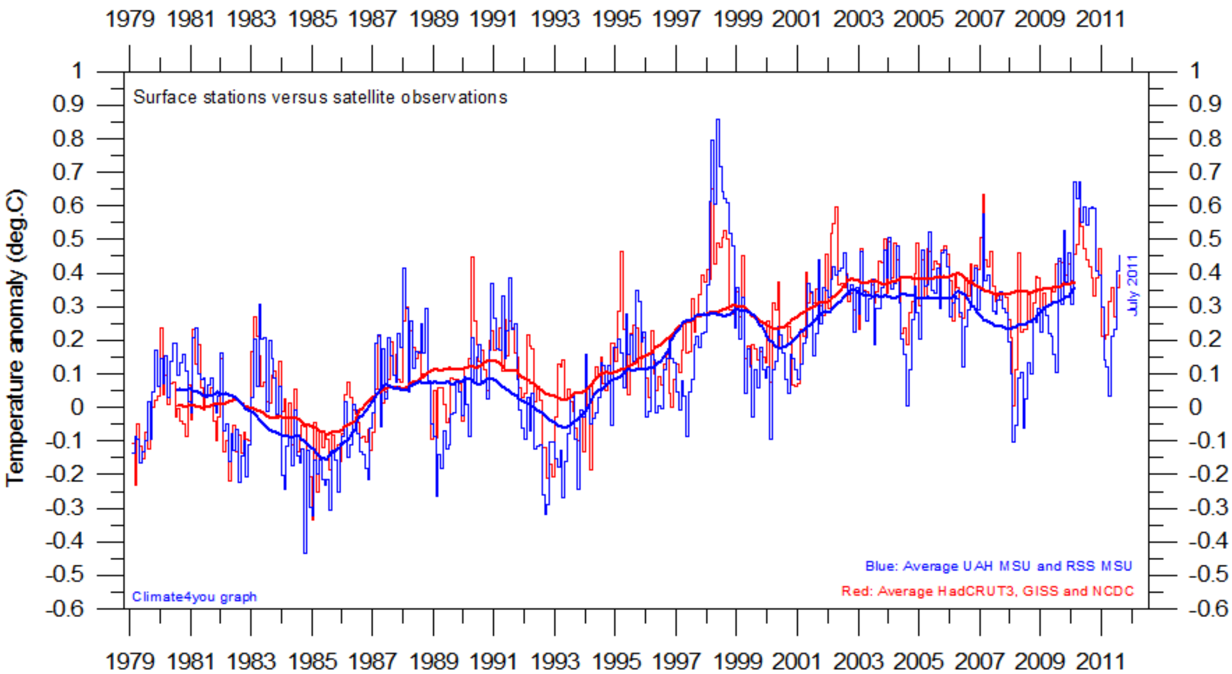
Deriving reliable global temperature from instrument data is a difficult task because the instruments are not evenly distributed across the planet, the hardware and locations have changed over time, and there has been extensive land use change around some of the sites. There are three main datasets showing analyses of surface global temperatures; the joint Hadley Centre/University of East Anglia Climatic Research Unit temperature analysis (HadCRUT), Goddard Institute for Space Studies (GISS), and the National Climatic Data Center (NCDC). These datasets are updated on a monthly basis and are generally in close agreement.

Since the satellite era took off in the late 1970s, both atmospheric and surface temperatures were able to be determined using satellite measurements. Satellites do not measure temperature directly, but instead measure how much light is emitted or reflected in different wavelength bands. Using mathematical calculations, temperature time series are indirectly inferred and reconstructed. This is advantageous over other methods because it provides global coverage. Because of slight differences in methodology, satellite-derived temperature datasets often differ. Thus it is imperative to make routine corrections due to orbital drift or decay, and sensor deterioration.

Two satellite datasets, the Remote Sensing Systems (RSS) dataset and the one prepared by the University of Alabama in Huntsville (UAH), utilize Microwave Sounding Units (MSU) of orbiting satellites to estimate lower tropospheric temperature. This is done by measuring microwave emissions of oxygen molecules, which increase proportionally to temperature. Lower tropospheric temperatures are expected to be slightly higher than surface temperatures, so the surface temperature record produced using these measurements is adjusted accordingly. Temperature measurements based on MSU also provide sparse coverage of Arctic and Antarctic regions. Figure 1.6 indicates that the average surface-based temperatures are slightly different to those obtained by satellites. Although the general agreement is good, satellites seem to record a larger temperature variability than surface observations. Additionally, over the entire time period shown in this plot, the average of the surface-based estimates suggests a less than 0.1^{o}C larger global temperature increase, compared to the average of satellite-based observations. The surface temperature record has increased at approximately 0.17 °C/decade since 1979. Comparing these values to satellite temperature estimates through January 2011, RSS shows an increase of 0.148 °C/decade while UAH finds an increase of 0.140°C/decade.[28]

[28] Remote Sensing Systems". http://www.ssmi.com/msu/msu_data_description.html. Retrieved 2009-01-13. "UAH". http://vortex.nsstc.uah.edu/data/msu/t2lt/tltglhmam_5.4. Retrieved 2011-01-14.

Figure 1.6 Average monthly global surface air temperature estimates (HadCRUT3, GISS and NCDC) and satellite-based temperature estimates (RSS MSU and UAH MSU). The thin lines indicate the monthly value and the thick lines represent the simple running 37 month average, nearly corresponding to a running 3 year average.



1.6.2. Climate Models and Projections

Climate models are based on computer programs that contain various mathematical equations. These equations quantitatively describe how atmospheric variables such as temperature, air pressure, wind, greenhouse gases and precipitation respond to incoming and outgoing solar radiation. Climate models are used for a variety of purposes from the study of climate system dynamics to future climate predictions. Predicting temperature changes caused by increases in atmospheric concentrations of greenhouse gases is one of the better known applications of climate modeling.

The Intergovernmental Panel on Climate Change (IPCC) is currently the leading international organization for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). The IPCC is a scientific body that reviews the most recent scientific, technical, and socio-economic information produced worldwide. Although the IPCC does not conduct any original research or monitor climate data, its membership consists of the leading researchers and scientists in climate studies.

The IPCC delivered assessment reports in 1990, 1995, 2001, and 2007. Within these reports are model-derived estimates of future climate (i.e. projections). Some of these climate projections are based on scenarios that assume different levels of future CO_2 emissions. Each scenario has a range of possible outcomes associated with it. The most optimistic outcome assumes an aggressive campaign to reduce CO_2 emissions; the most pessimistic is a "business as usual" scenario, while other scenarios fall in between. In the Fourth Assessment Report published in 2007, some of the projections state that global temperatures could rise between 1.1 and 6.4 °C (2.0 and 11.5 °F) during this century and that sea levels could rise by 18 to 59 centimeters (7.1–23 in).

1.7 Climate Change Adaptation and Mitigation

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as:

> *The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.*[29]

Adaptation may be more simply defined as *coping*. Climate scientists agree that climate change will occur in the future, even if the rates of GHG emissions decline. Adapting to climate change will therefore become necessary in certain regions in order to protect or sustain certain environmental systems, species and habitats. The need for adaptation may be increased by growing populations in areas vulnerable to extreme events. However, according to the IPCC:

> *Adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long term as most impacts increase in magnitude*.[30]

Mitigation for climate change will involve changes in environmental and industrial behavior and practices such as reducing the rates of GHG emissions and increasing the rates of GHG sequestration. Decreasing consumption of fossil fuels is the best way to reduce GHG emissions, although these may be reduced by other ways such as conservation and recycling practices and utilizing alternative forms of energy. One of the best ways to sequester CO_2 is to protect acreage and growing timber – this is a natural fit for DNR's overall mission and is in keeping with DNR objectives to make land available to the using public.

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[29] Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[30] Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate ChangeCore Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland. pp 104

1.8 DNR Climate Change Mission Statement

DNR's mission in response to the potential challenges of climate change to South Carolina is two-fold:

1. Identify issues and assess potential impacts of climate change on the natural resources of South Carolina, and
2. Develop an adaptive response strategy in order to offset, minimize, or delay the effects of climate change on natural resources.

The potential issues and impacts of climate change on people, landscapes, ecosystems, and other features will vary. Understanding these potential impacts and issues will play a significant role in adaptation planning by the agency, and it will provide a foundation for leaders to make informed and effective decisions. At a time when funding for climate change adaptation is scarce, understanding the potential consequences associated with climate change is vital. Table 1.2 provides a generalized summary of potential climate change phenomena.

Table 1.2 Generalized summary of potential climate change impacts and consequences.[31] While some impacts and consequences may not directly affect South Carolina, all are expected to create indirect effects.

Climate Change Phenomena	Potential Impacts	Potential Consequences
• Increasing land, surface water, sea surface and atmospheric temperatures • Rising sea level	• More frost-free days/year • More heat waves • Changes in precipitation cycles • More frequent and prolonged droughts • Increased evapotranspiration • Increased frequency of wildfire • More severe flood events • More problems with invasive species • Spatial changes in species' ranges • Changes in timing of ecological events such as animal migration • Intra- and inter-specific competition for available resources as food chains are altered • Loss of sea ice, glacial coverage and polar snowpack • Increased coastal flooding • Increased coastal erosion • Rising water tables • Saltwater intrusion • Increased nonpoint source pollution • Increases in toxic substances flowing from upstream to coastal areas • Increases in numbers of threatened and endangered species • Decline in forest growth	• Widespread human health impacts • Changes in ecosystem services such as the ability of streams and wetlands to naturally filter, assimilate and degrade pollution • Decline in water quality and quantity • Surface and sea-water pH changes • Decline in productivity and availability of fish and other aquatic species although some species could benefit • Economic losses directed toward business associated with natural resource management in both inland as well as coastal zones • Loss of beaches • Increased storm surge flooding • Impacts to coastal infrastructure • Salt marsh conversion to open water • Freshwater marsh conversion to salt marsh • Loss of important recreational and commercial fishing and shell fishing habitats • Loss of coastal forest habitats • Loss of cultural resources • Extinction of threatened and endangered species

[31] National Oceanic and Atmospheric Administration NOAA. 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers. NOAA Office of Ocean and Coastal Resource Management. Hereinafter NOAA 2010. http://coastalmanagement.noaa.gov/climate/adaptation.html. Last accessed Sept 2010

1.9 Agency Goals to Address a Changing Climate

In response to the DNR Climate Change Mission Statement the agency will have the following goals:

1. Gather factual, accurate information and data on how climate change may affect wildlife, fisheries, water supply and other natural resources within South Carolina,
2. Identify monitoring and data needs required to assess impacts of climate change in the state,
3. Use factual information, data, research and modeling to determine what actions need to be taken to address climate change,
4. Ensure data quality, provide original research that addresses information needs and validate modeling results with collected data,
5. Identify opportunities to partner with other state agencies, academic institutions and non-profit organizations where needed to accomplish the mission,
6. Identify ways for state officials, local government and citizens to assist in mitigation of or adaptation to natural resource impacts related to climate change, and
7. Locate and obtain available funding to assist in meeting agency mission and goals related to climate change.

1.10 DNR Resource Divisions, Organization and Responsibility

1.10.1 Land, Water and Conservation Division

The DNR Land, Water and Conservation Division (LWC) develops and implements programs that study, manage and conserve land and water resources. This is accomplished by providing guidance in resource development and management through planning, research, technical assistance, public education and development of a comprehensive natural resources database. The scope of the division is broad and incorporates expertise in climatology, flood-plain mapping, geology, hydrology, land use, rivers and water conservation.

1.10.2 Marine Resources Division

The Marine Resources Division (MRD) is responsible for the management and conservation of the state's marine and estuarine resources. It also works with regional authorities such as the Atlantic States Marine Fisheries Commission (ASMFC) and the South Atlantic Fishery Management Council (SAFMC) to ensure that marine resources are sustainably managed throughout their range. MRD has 3 main sections with the following responsibilities:

1. The Office of Fisheries Management (OFM) reviews coastal development activities, recommends marine fishing seasons and fish size/creel limits,

issues permits and conditions for the harvest of marine species (e.g. fish, shrimp, crabs and oysters) and tracks trends in the harvest of marine species.

2. The Marine Resources Research Institute (MRRI) conducts research and long-term surveys of inshore and offshore resources (e.g., finfish, shellfish and marine habitats), assesses the effects of human activities on coastal resources, and operates marine stocking research programs (e.g., red drum and striped bass).
3. Coastal Reserves & Outreach (CRO) is responsible for MRD functions relating to coastal land management, education and outreach, and all programs in the ACE Basin National Estuarine Research Reserve[32] (1 of 28 reserves in the National Estuarine Research Reserves System).[33]

Data from numerous MRD programs indicate that the physical and biological systems of the coastal zone have already been impacted by increasing population density and development. Additional pressure on these systems from climate change is likely to exacerbate system degradation, although the extent of future degradation related to climate change is uncertain.[34] Ecological, social, educational and technological issues associated with climate change impacts in the marine environment are reviewed in this report.

1.10.3 Wildlife and Freshwater Fisheries Division

The Wildlife and Freshwater Fisheries (WFF) Division of DNR develops and implements programs that manage and conserve the wildlife and freshwater fishery resources of the state. The Wildlife Section protects, manages and enhances the state's habitats and associated wildlife for the public benefit of present and future generations. The Wildlife Section also is responsible for the state's Endangered Species Program which protects and enhances a variety of declining species and diminishing habitats. The Freshwater Fisheries Section provides protection, enhancement, and conservation of South Carolina inland aquatic resources. It also provides recreational fishing opportunities for the state's citizens through its operation of hatcheries, regional fisheries management, state public fishing lakes, research and diadromous fisheries coordination.

Pressures from increasing development, habitat loss and increasing numbers of invasive species have changed the landscape of South Carolina, negatively affecting wildlife and fish resources.[35] Climate change will exacerbate the effects of these pressures. Given the potential for severe impacts to our natural resources, it is critical

[32] http://www.nerrs.noaa.gov/Doc/SiteProfile/ACEBasin/html/resource/protland/lunerr.htm. Last accessed Dec 2010.
[33] http://www.chbr.noaa.gov/ecosystems/nerrs.aspx. Last accessed Oct 2011.
[34] NOAA. 2000. The potential consequences of climate variability and change on coastal areas and marine resources: Report of the Coastal Areas and Marine Resources Sector Team U.S. National Assessment of the Potential Consequences of Climate Variability and Change U.S. Global Change Research Program. D. F. Boesch, J.C. Field and D. Scavia, *eds*. NOAA Coastal Analysis Prog. Decision Analysis Series No. 21. 181 pp. http://www.cop.noaa.gov/pubs/das/das21.pdf. Last accessed Dec 2010.
[35] Environmental Law Institute. 2002. Mitigation of impact to fish and wildlife habitat: Estimating costs and identifying opportunities. http://www.elistore.org/Data/products/d17_16.pdf. Last accessed Oct 2011.

to plan ahead to address the effects of climate change on our native wildlife and fish species and essential habitats.

2.0 THE CLIMATE OF SOUTH CAROLINA – PAST AND PRESENT

2.1 Paleoclimatology: Recent Studies and Contributions to Climate Modeling

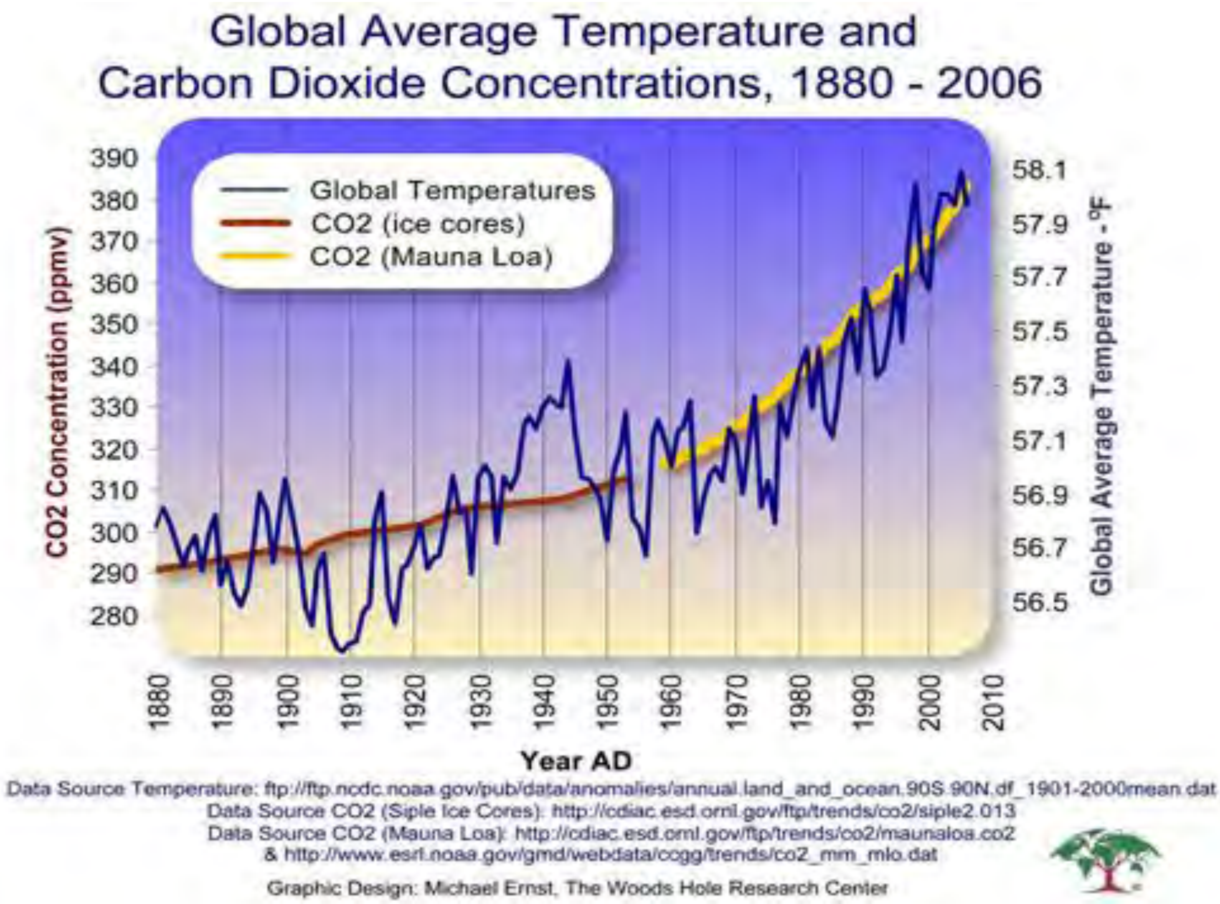
Climatology is the study and analysis of weather records over an extended period of time. Instruments such as thermometers and rain gauges have evolved since the 1700s and are now routinely used to record weather conditions. To reconstruct climate from an earlier time, it is necessary to use natural climate recorders, such as ice cores, tree rings, ocean and lake sediments, and corals. Measurements collected from these natural climate archives are called proxies because they do not provide a direct measurement of climate, as an instrument does. Rather, scientists deduce past climatic conditions from the physical and biological parameters contained in the proxy. The study of climate prior to the use of instrumental records is known as paleoclimatology.

Climatic conditions preserved in various proxies provide a way of understanding past changes in the environment where the proxy grew or existed. The ring width of a tree is an example of a proxy for temperature, or in some cases rainfall, because the thickness of the annual ring is sensitive to the temperature and rainfall of that year. The greatest understanding of paleoclimate comes when there are multiple data sets, providing a robust view of conditions. Figure 2.1 illustrates a reconstruction of global average temperature and CO_2 concentrations using both proxy measures of CO_2 from the Vostok ice core and instrumental CO_2 records from Mauna Loa Observatory in Hawaii.

Paleoclimate studies indicate that the earth's climate has changed many times throughout its history, and cycles of climate change have been recognized on a variety of time scales. Results from paleoclimate studies include the identification of regular episodic changes and the concept of abrupt climate change. The first is the result of a robust and expanding paleoclimate database. The second result owes, in part, to the greater precision of the datasets that have revealed dramatic climate shifts occurring in very short time spans.[36]

[36] NANRC 2001.

Figure 2.1 Global Temperature and CO_2 Concentration Since 1880. Data from NOAA's National Climate Data Center (NCDC) & Oak Ridge National Laboratory.[37]



2.2 Results of Studies

Paleoclimatic records are more precise and accurate in the last million years, and the last 650,000 years have been extensively studied because of well-preserved glacial and geological records. Currently, we are in an interglacial, or warm, period, which began at the end of the last glacial maximum (LGM) 13,500 years ago. The identification of episodic climates shows that glacial-interglacial, or cooling-warming, cycles can be recognized in the last million years, and that recurring intervals can be recognized. A well-supported theory suggests that these intervals correspond to Earth's orbital deviations. The relationship between orbital variations and glacial periods is referred to as a Milankovitch cycle. Although the Milankovitch Theory accounts for many glacial periods, some periods still defy a solely celestial cause.

[37] Data from NOAA's National Climate Data Center (NCDC) and Oak Ridge National Laboratory. http://www.whrc.org/resources/primer_fundamentals.html last accessed July 2010.

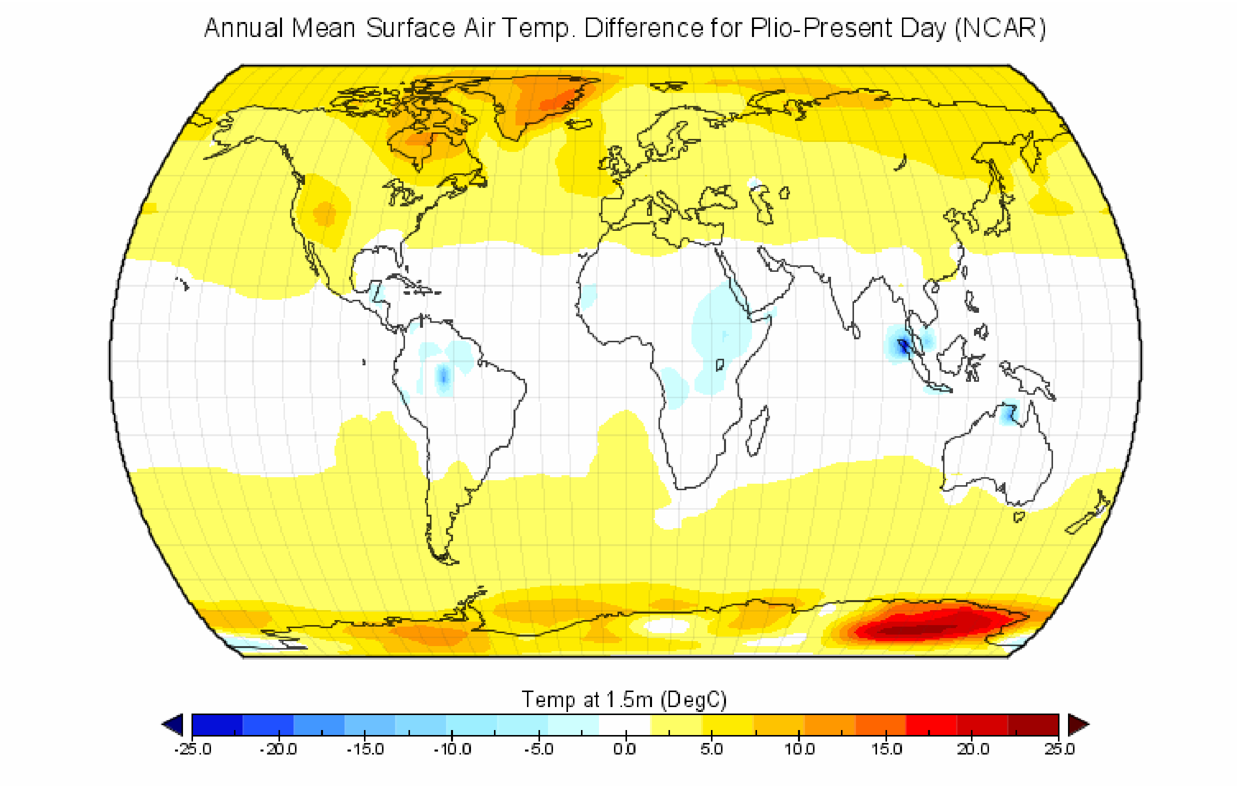
Much research has focused on the last 13,500 years, since the end of the last glacial period, and particularly on the last 2,000 years. The last 2,000 years are of interest because interglacial conditions were relatively stable, and thus provide a baseline to study modern climate variations. Three significant periods of climate variation, however, have occurred since the end of the LGM. In the upper latitudes of the Northern Hemisphere 12,800-11,500 years ago, oxygen-isotope-derived temperatures from an ice core in Greenland indicate conditions approximately 45-59°F (7-15°C) colder than present-day Greenland. This late Pleistocene glacial stadial event, or cooler period, is referred to as the Younger Dryas. The end of the Younger Dryas was marked by rapid transition from stadial to interglacial conditions and occurred in a time span of 20 years, possibly even less. The Medieval Warm Period occurred between 800-1300 AD and is primarily documented in Europe. It is recognized as an interglacial period bracketed by older and younger stadial events, so the description of warm is relative. Another stadial event in more recent times is also of interest. The Little Ice Age occurred from the 16th until the mid-19th centuries and affected the Northern Hemisphere, although in lesser magnitude than the Younger Dryas. There are numerous historical records documenting the shifts which occurred during the Little Ice Age.[38]

The recognition of a mid-Pliocene warm period (Fig 2.2), approximately 3.3 to 3.0 million years ago, may provide insight into what could happen during the present period of climate change. The mid-Pliocene change happened recently enough that the configuration of continents and oceans has not changed significantly, and air and ocean currents probably were similar to those of today. Mean-global temperatures during the mid-Pliocene warm period were 2-3°C above pre-industrial-age temperatures. CO_2 levels were in the range of 360-400 ppm, and the extent of ice sheets was reduced compared to today. These conditions resulted in sea level being 15-20 meters above present-day levels, and there was lower continental aridity.

The second major result of paleoclimate studies is the recognition of abrupt shifts in climatic conditions. Some of these shifts involved extreme changes in conditions, such as large magnitude warming events with increases of up to 61°F (16°C). The time scale of some shifts is as little as 10 years. The causes of rapid climate shifts are not fully understood, but it is thought they result from a combination of several natural processes.[39] The question now is whether human inputs of GHGs, along with trends in natural processes, trigger an abrupt climate change. If an abrupt shift in climate is possible, prudent planning necessitates efforts to predict both the magnitude and duration of the change.

[38] Jansen, E., J. Overpeck, K.R. Briffa, J.-C. Duplessy, F. Joos, V. Masson-Delmotte, D. Olago, B. Otto-Bliesner, W.R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba and D. Zhang, 2007: Palaeoclimate. *in* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, *eds.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 66 pp.
[39] NANRC 2001.

Figure 2.2 Annual Mean Surface Air Temperature Difference between Pliocene and Present Day. Global temperatures, particularly at high latitudes, are believed to have been significantly warmer than today.[40]



2.3 Paleoclimate Summary and Recommendations for the Future

Paleoclimate studies indicate that climate variation is a natural phenomenon. The focus of paleoclimate studies is shifting now toward identifying the processes and causes of climate change. To date, no systematic study of South Carolina's paleoclimate has been done. Some studies have addressed climatic conditions at a specific time or at a specific site, but no studies have been done to document the state's climate over an extended period of time. The state's paleoclimate record should be studied at several time scales. First, the climate since European settlement should be reconstructed by examining local and state records, which would provide a detailed account of climate over the last 400 years. Instrument records can be integrated into this history. In addition to shorter term studies, studies extending back several thousand to several hundred thousand years could be useful.

[40] http://geology.er.usgs.gov/eespteam/prism/products/agu3.pdf

2.4 South Carolina Climate in the Early 21st Century[41]

South Carolina's location provides a mild climate and, in normal years, generous rainfall. Several factors responsible for this include our relatively low latitudinal location and a strong moderating influence from Atlantic Ocean warm water. Also of importance are the Blue Ridge Mountains to the north and west, which help block or delay movement of cold air masses from the northwest.

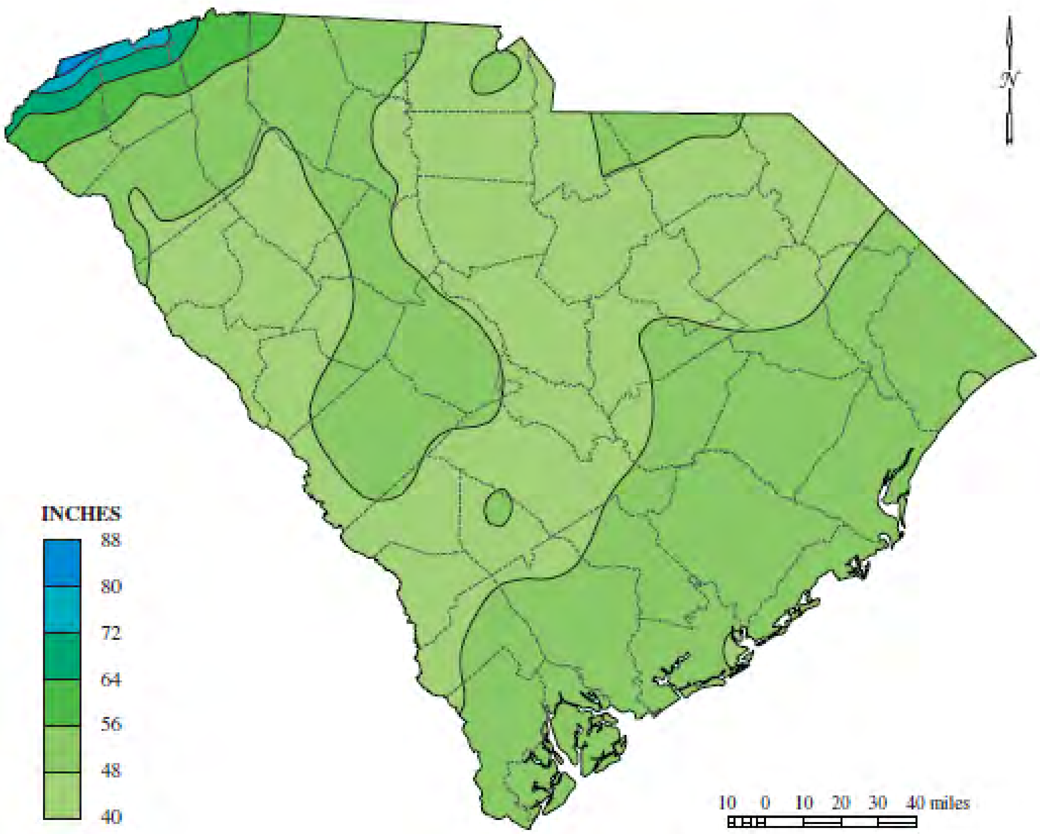
2.4.1 Precipitation

Precipitation in South Carolina is ample and distributed with two maxima and two minima throughout the year. The maxima occur during March and July; the minima occur during May and November. There is no wet or dry season; only relatively heavy precipitation periods or light precipitation periods. No month of the year averages less than 2 inches (5 cm) of precipitation anywhere in South Carolina. In the northwestern corner of the state, winter precipitation is greater than in summer and the reverse is true for the remainder.

The South Carolina average annual precipitation is slightly more than 48 inches (122 cm). Average annual precipitation is heaviest in the northwestern counties because moist air is forced up the mountains to higher and cooler elevations, where condensation and precipitation are initiated. In the Blue Ridge Mountains, 70-80 inches (179-203 cm) of rainfall occur on average at the highest elevations (Fig. 2.3), with the highest annual average of 79.29 inches (201.40 cm) occurring at Caesars Head. Across the foothills, average annual precipitation ranges from 60 inches (152 cm) to more than 70 inches (179 cm). In the eastern and southern portions of the Piedmont, the average annual rainfall ranges from 45-50 inches (114-127 cm). Areas in the northern Midlands report the lowest rainfall on average, between 42-47 inches (107-119 cm). Precipitation amounts are a little higher across the Coastal Plain. A secondary statewide maximum occurs parallel to the coast 10-20 miles (16-32 km) inland. This maximum, 50-52 inches (127-132 cm) is a result of the diurnal sea-breeze front thunderstorms prevalent during summer.

[41] http://www.dnr.sc.gov/climate/sco/ClimateData/cli_sc_climate.php. Last accessed May 2011.

Figure 2.3 South Carolina average annual precipitation, 1971-2000.



There is little difference in monthly rainfall distribution for the months of December-March, with the exception that the monthly total for March is somewhat higher than for any of the previous three months. During March, rainfall along the coast begins to increase, and by May the normal for the southern coast exceeds 5 inches (13 cm). At the same time, the central part of South Carolina receives only about 3 inches (8 cm) of rain and the mountains more than 5 inches (13 cm). During the summer, our weather is dominated by a maritime tropical air mass known as the Bermuda high, which forces warm, moist air inland from the ocean. As the air comes inland, it rises and forms localized thunderstorms, resulting in a precipitation maximum. Summer rainfall (June – August) is heaviest in the mountains, with 4-7 inches (10-18 cm) monthly, and along the coast with 6-8 inches (15-20 cm) monthly. During September, the greatest rainfall on average occurs along the coast. This is due to the passage of tropical storms and hurricanes that may influence coastal weather at this time of year. During October-November precipitation on average is at a minimum throughout the state. Any heavy precipitation during this period is likely to be the result of a hurricane or early winter storm. The greatest documented 24-hour rainfall was 14.80 inches (35.56 cm) observed at Myrtle Beach on September 16, 1999. The greatest total annual precipitation occurred in 1979 at Hogback Mountain in Greenville County, where more than 120 inches (305 cm) was recorded.

Wintry precipitation, such as snow, sleet and freezing rain, also affect South Carolina. Snow and sleet may occur separately, together, or mixed with rain during the winter months from November-March, although snow has occurred as late as May in the mountains. Measurable snowfall may occur from 1-3 times in a winter in all areas except the Lowcountry, where snowfall occurs on average once every 3 years. Accumulations seldom remain very long on the ground except in the mountains.

Typically, snowfall occurs when a mid-latitude cyclone moves northeastward along or just off the coast. The greatest snowfall in a 24-hour period was 24 inches (61 cm) at Rimini in February 1973. During December 1989, Charleston experienced its first white Christmas on record, and other coastal locations had more than 6 inches (15 cm) of snow on the ground for several days following. Episodes of sleet and freezing rain are observed statewide, although less frequently in the Lowcountry. One of the most severe cases of ice accumulation from freezing rain took place in February 1969 in several Piedmont and Midlands counties with significant timber losses and power disruptions.

Abnormal weather patterns can alter or restrict precipitation, resulting in prolonged dry spells. Periods of dry weather have occurred in each decade since 1818 (National Water Summary 1988-1989 Hydrologic Events and Floods and Droughts, 1991). The earliest records of drought indicate that some streams in South Carolina went dry in 1818, and fish in smaller streams died from lack of water in 1848. The most damaging droughts in recent history occurred in 1954[42], 1986[44], 1998-2002[43], and 2007-2008.[44] Severe droughts occur about once every 15 years, with less severe widespread droughts about once every 7 years. In 1954, the beginning of one of South Carolina's record droughts, only 20.73 inches (52.65 cm) of precipitation fell at Rimini, in Clarendon County, to set the record annual low precipitation value for the State.

2.4.2 Temperature

The state's annual average temperature is about 61°F (16°C). Local averages range from 55°F (12°C) at Caesars Head in the mountains to 66°F (19°C) along the southern coast at Beaufort (Fig 2.3). Elevation, latitude and distance from the coast are the main influences on temperature. The state's record low of -19°F (-28°C) was recorded at Caesars Head on January 21, 1985. Along the coast, ocean water temperatures vary a very small amount daily and annually when compared with adjacent land areas. The air

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[42] National Water Summary 1988-1989 - Hydrologic Events and Floods and Droughts (1991), 2375, United States Geological Survey, United States Government Printing Office, Denver, Colorado.

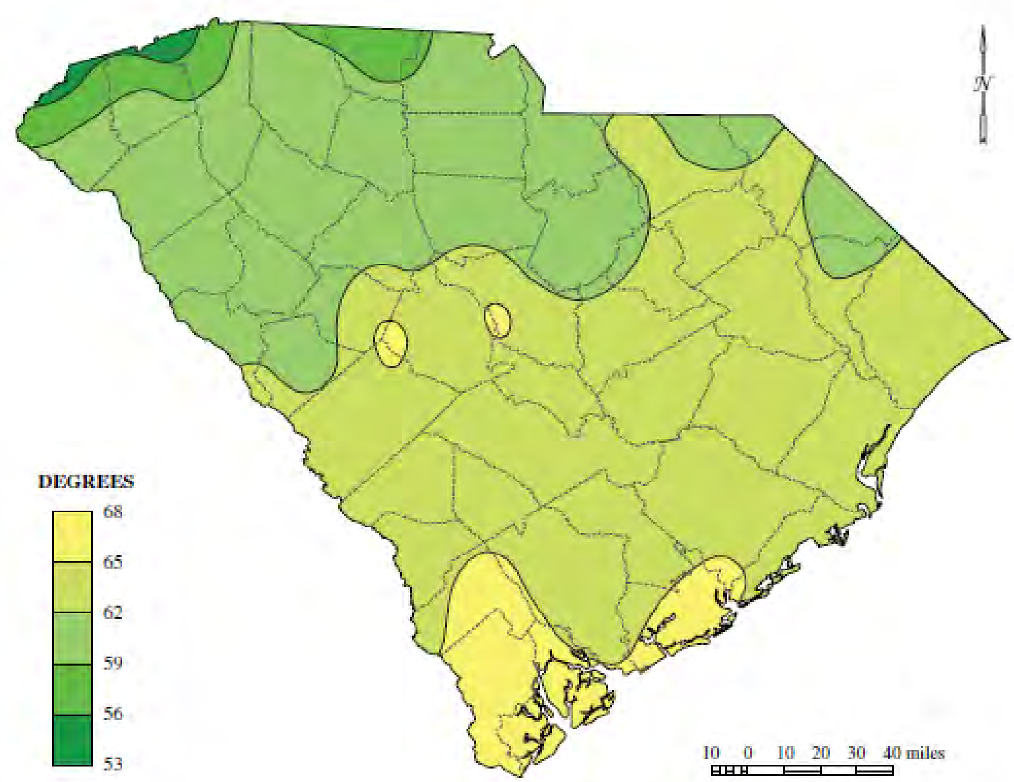
[43] Gellici, J.A., M. Kiuchi, S.L. Harwell, and A.W. Badr (2004), Hydrologic Effects of the June 1998-August 2002 Drought in South Carolina, South Carolina Department of Natural Resources Open File Report, Columbia, S.C.

[44] South Carolina Department of Natural Resources On-line Archived Drought Status, http://www.dnr.sc.gov/climate/sco/Drought/drought_press_release.php, 2008.

over coastal water is cooler than the air over land in summer and warmer than the air over land in winter, thus providing a moderating influence on temperatures at locations near the coast. Records show maximum temperatures along the coast to average 4-5°F (2°C) lower than maximum temperatures in the central part of the State. The record high temperature, 111°F (44°C), has occurred in central South Carolina 3 times: at Calhoun Falls on September 8, 1925; at Blackville on September 4, 1925; and at Camden on June 28, 1954. January is the coldest month, with monthly normal temperatures ranging from 39°F (4°C) at Caesars Head to 51°F (11°C) at Beaufort. July is the hottest month, with monthly average temperatures ranging from 72°F (22°C) at Caesars Head to 82°F (28°C) at Charleston.

The growing season for most crops is limited by fall and spring freezes and ranges from 200 days in the coldest areas to about 280 days along the south coast. In areas where most of the major crops are grown, the growing season ranges from 210-235 days. The average date of the last freezing temperature in spring ranges from March 10 in the south to April 1 in the north. Fall frost dates range from late October in the north to November 20 in the south. Minimum temperatures of less than 32°F (0°C) occur on about 70 days in the upper portion of the state and on 10 days near the coast. The central part of South Carolina has maximum temperatures of 90°F (32°C) or more on about 80 summer days. There are 30 such days along the coast and 10-20 in the mountains.

Figure 2.4 South Carolina average annual temperature, 1971-2000.



2.4.3 Severe Weather

Severe weather in the form of violent thunderstorms, hurricanes and tornadoes occurs occasionally. Thunderstorms are common in the summer months, but violent storms usually accompany squall lines and cold fronts in the spring. These storms are characterized by lightning, hail, high winds and they sometimes spawn tornadoes. Most tornadoes occur from March-June, with April being the peak month. In the 61-year period 1950-2010, South Carolina averaged 15 tornadoes per year. The majority of these tornadoes (81%) were short-lived EF-0 and EF-1 tornadoes on the Enhanced Fujita scale.[45] Stronger, more destructive tornadoes are rare, but do occur with a consistent annual frequency of 2-4 per year. Since 1950 eleven destructive EF-4 tornadoes have touched down in South Carolina with wind speeds of 166-200 miles per hour.

Tropical cyclones affect the South Carolina coast on an infrequent basis, but do provide significant influence annually through enhanced rainfall during the summer and fall months. Depending on storm intensity and proximity to the coast, tropical systems can be disastrous. Historically, hurricanes are more frequent in late summer and early fall; however, tropical cyclones have affected South Carolina as early as May and as late as November. From the late 1800s-2010, 171 tropical cyclones have affected the state. South Carolina has experienced 3 major hurricanes since the 1950s: Category 4 Hazel on October 15, 1954; Category 3 Gracie on September 29, 1959; and Category 4 Hugo on September 21, 1989.

2.4.4 El Niño-Southern Oscillation Influence on South Carolina's Climate

The Palmetto State's climate is complicated by a number of oscillations in the global atmosphere and ocean that can shift and alter distant weather patterns. There are many of these oscillations, some better known and studied than others: Quasi-Biennial Oscillation (QBO), Madden-Julian Oscillation (MJO), El Niño-Southern Oscillation (ENSO) and Atlantic Multi-Decadal Oscillation (AMO). Each oscillation can interact with others to provide a complex forcing for downstream sensible weather. Thus, changes in these oscillations and their interactions produce changes in regional climate.

The ENSO with embedded Kelvin waves is the best understood oscillation. ENSO is a coupled atmosphere-ocean circulation pattern that induces teleconnections in the Northern Hemisphere atmosphere, complicating South Carolina weather and climate by shifting the position of the jet stream. The ENSO has 3 phases: warm, neutral and cold. El Niño is the warm phase of the ENSO and is characterized by abnormally warm ocean water occurring along the coast of Peru and eastern equatorial Pacific Ocean. The ENSO cold phase, La Niña, is characterized by a deep pool of abnormally cold water across the eastern equatorial Pacific affecting upper atmospheric circulation patterns. During the El Niño portion of ENSO, increased precipitation falls along the Gulf Coast and Southeast due to a stronger than normal, and more southerly, polar jet

[45] http://www.spc.noaa.gov/efscale/. Last accessed May 2011.

stream.[46] During La Niña events, the storm track is shifted northward. Analysis of past La Niña winter events indicates that South Carolina weather was warmer and drier than the weather observed during neutral or El Niño events. Periods of severe to extreme drought experienced in South Carolina during 1954, 1988, 1998-2002 and 2007-08 are correlated with La Niña events in the Eastern Pacific Ocean. There is no clear periodicity of these drought-producing events. Conversely, El Niño winters in South Carolina on average tend to be wetter and cooler than the weather during neutral or La Niña events.

2.5 Analyzing South Carolina Climate Trends

A major hurdle for any climate study is locating a long-term continuous record of observational data. The National Oceanic and Atmospheric Administration United States Historical Climate Network (USHCN) is a well-documented, accurate source of daily and monthly state climate data for the period 1895-to the present. These data consist of minimum, mean and maximum temperatures and precipitation totals measured at 28 stations located across the state and provide the longest record of weather conditions in South Carolina.

To evaluate climate variability in South Carolina, a first-order analysis of the annual mean monthly USHCN temperature data was performed. Temperature data recorded at the Greenville-Spartanburg (GSP) Airport in Greer, University of South Carolina (USC) in Columbia, Beaufort and Georgetown were used to investigate trends in temperature variability. These stations were selected to represent the three major geographic divisions of South Carolina: mountains-piedmont, midlands-sandhills, and coastal plain. The data from these 4 climate observing stations revealed similar temperature trends that are presented in Figures 2.5-2.8.

After a pronounced cool period occurring from 1895-1904, a net average warming period occurred at USC, Beaufort and Georgetown (Fig. 2.5-2.8). During the 1905-1938 warming trend, mean temperatures at GSP rose rapidly in the first 8 years, remaining neutral until 1958 (Fig. 2.5); the GSP data demonstrated the cooling trend lagged approximately 10 years behind the other stations studied. Another pronounced cooling period is observed in the coastal station data from the period 1948-1968. This cooling period also is noted in the data collected at USC.

Of particular importance in the discussion over climate change is the good agreement of a warming trend beginning in 1970 to the present for all 4 stations. This warming trend is most pronounced in the GSP and Beaufort data sets.

[46] Climate Prediction Center, El Nino and La Nina-related Winter Features over North America, http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/nawinter.shtm. Last accessed Dec 2010.

Figure 2.5 Annual mean temperatures at Greenville-Spartanburg Airport (GSP), South Carolina, 1895-2010.[47]

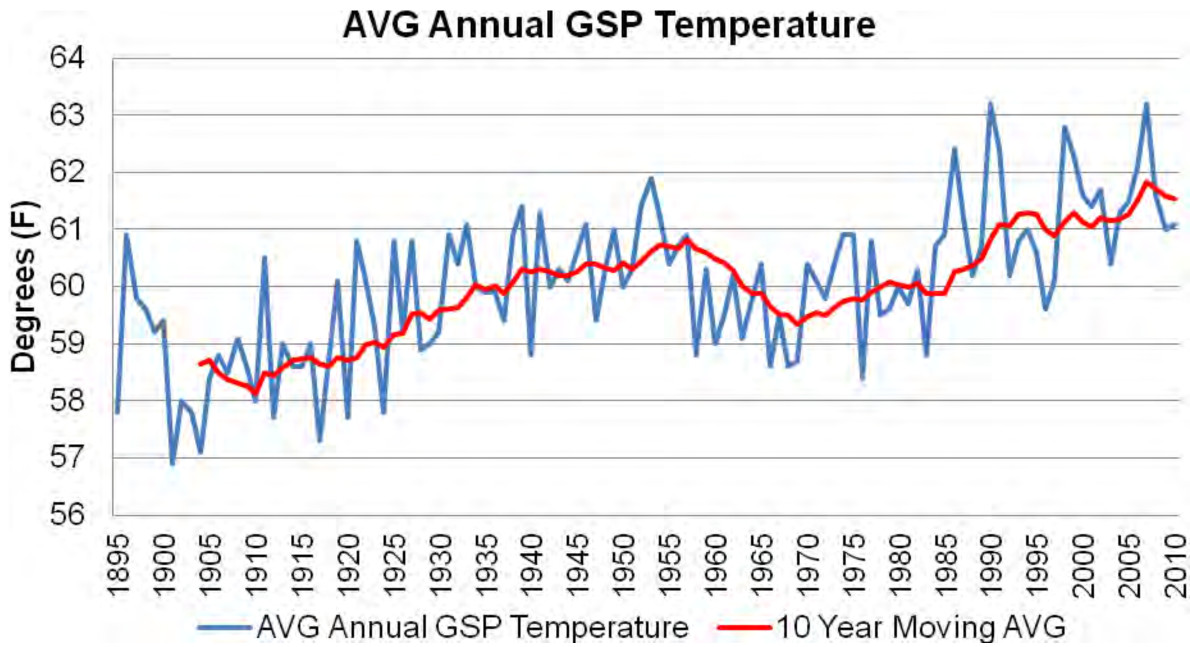
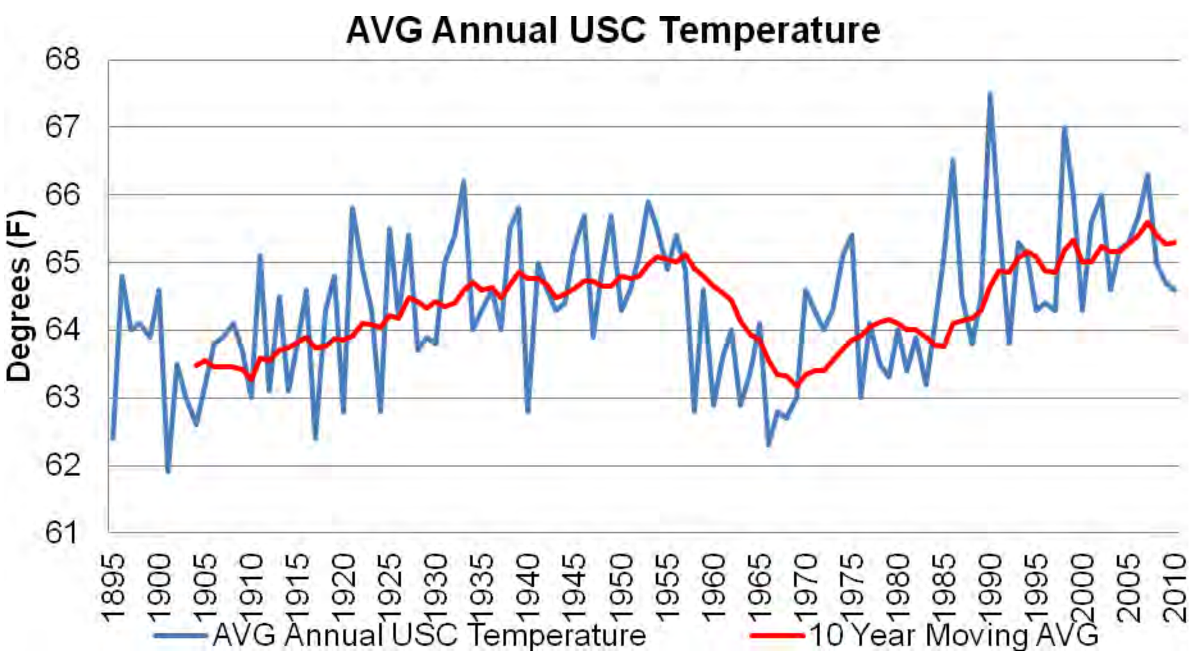


Figure 2.6 Annual mean temperatures at University of South Carolina (USC), Columbia, South Carolina, 1895-2010.[48]



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[47] National Oceanic and Atmospheric Administration Climate Research Data. The Daily Historical Climatology Network
http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html . Last accessed July 2010. Hereinafter NOAA/USHCN.
[48] NOAA/USHCN.

Figure 2.7 Annual mean temperatures at Beaufort, South Carolina, 1895-2010.[49]

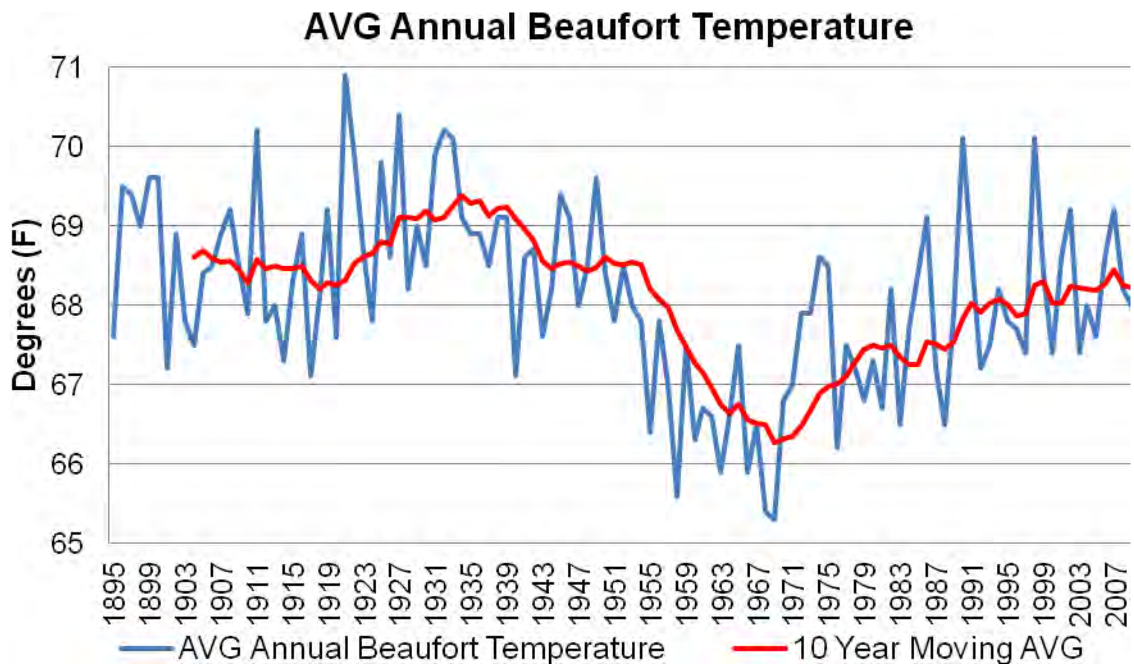
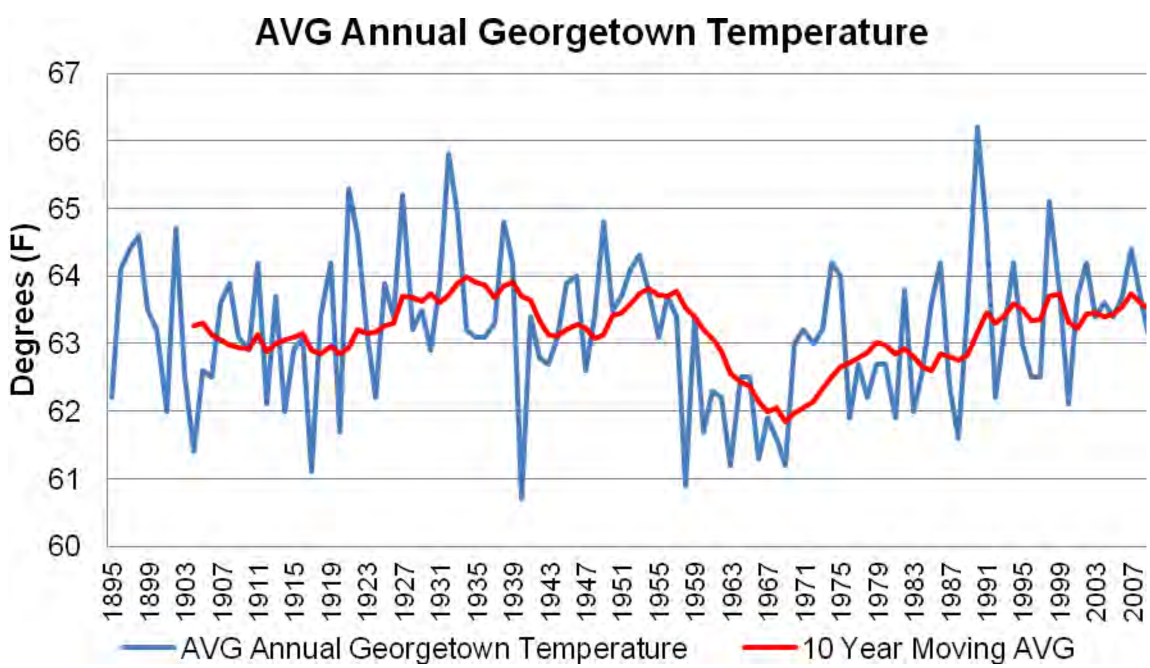


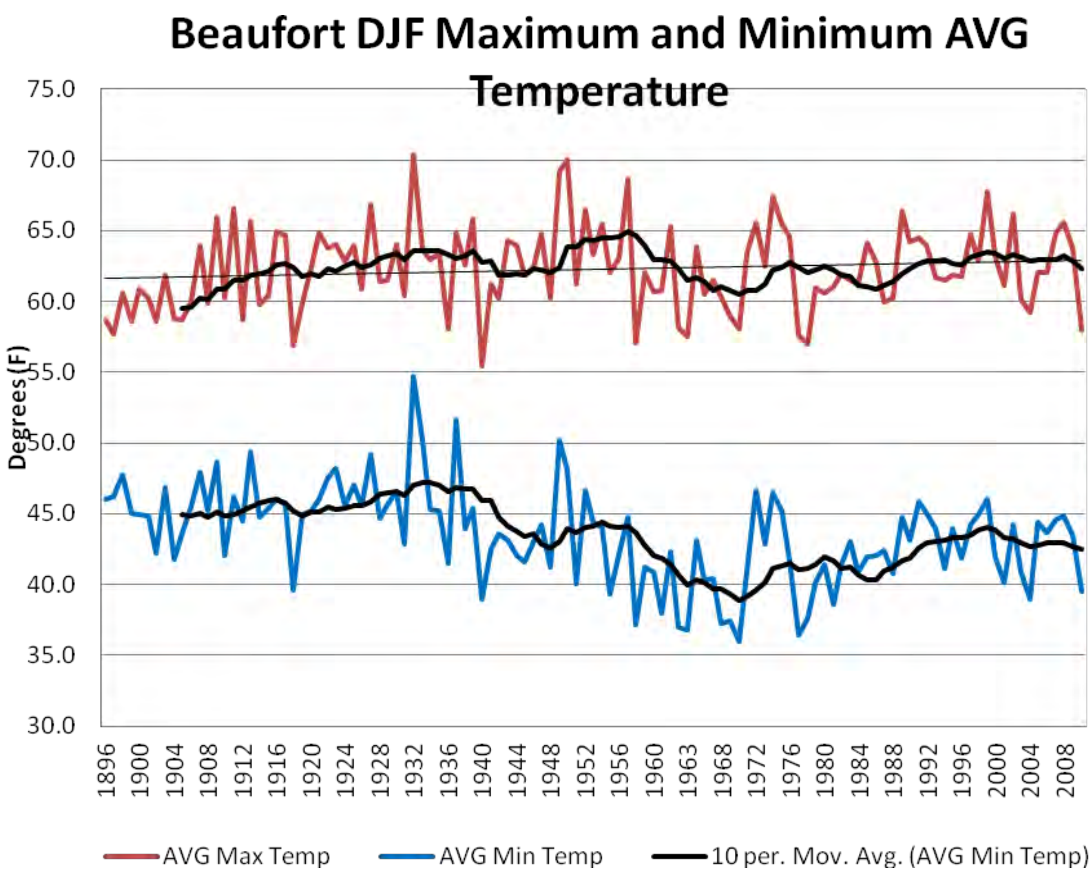
Figure 2.8 Annual mean temperatures at Georgetown, South Carolina, 1895-2010.[50]



49 NOAA/USHCN.
50 NOAA/USHCN.

USHCN data for Beaufort were investigated further to explore winter temperature trends. The December-January-February (DJF) monthly mean temperature data were plotted for the period of record 1896-2010 (Fig 2.9). Winter maximum temperatures demonstrated a slight warming trend for the period and conversely, minimum winter temperatures showed a very slight cooling trend. The long-term winter temperature trend was similar to the cool-warm-cool-warm trend seen in Beaufort's annual mean temperature data presented in Figure 2.7.

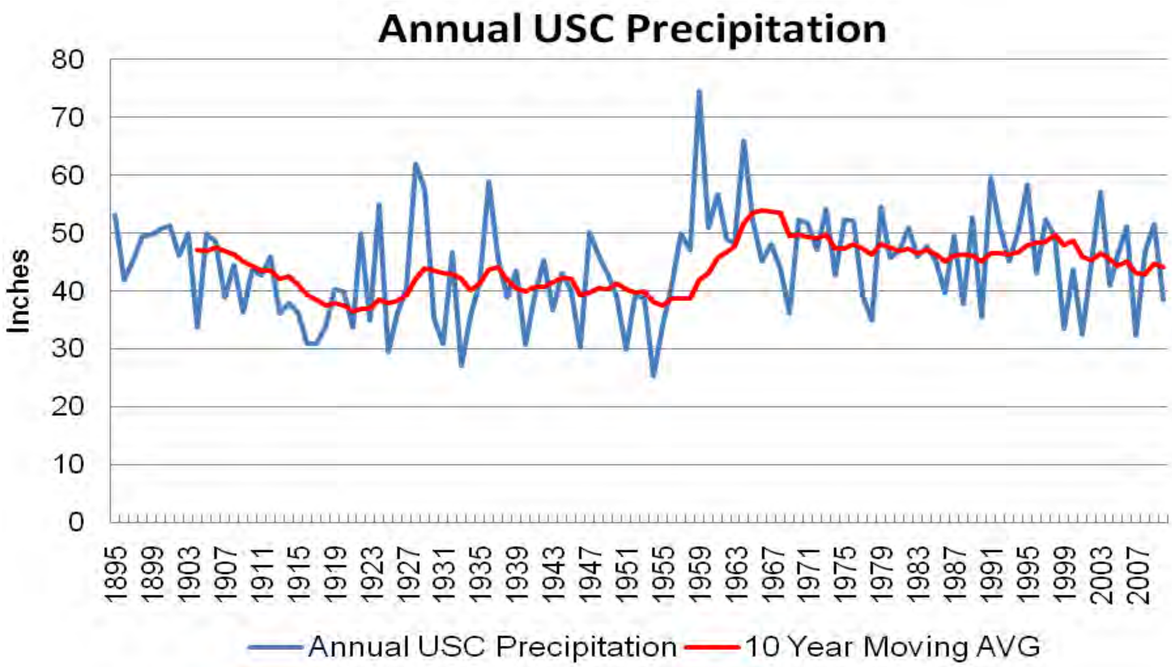
Figure 2.9 December, January, February average and median air temperatures recorded in Beaufort, South Carolina, 1895-2010.[51]



Examination of the USHCN annual rainfall data for the 5 stations showed no discernible trends, as shown, for example, in Figure 2.10. Lengthy periods of drought were evident in the data record as well as years with precipitation maxima. Some of the wetter years coincided with tropical cyclone activity, which can deliver a quarter to a third of the total annual rainfall amount in a single tropical storm event. There was poor correlation of the precipitation data and the annual temperature data (Fig 2.6, 2.10).

[51] NOAA/USHCN.

Figure 2.10 Cumulative annual precipitation, USC, Columbia, South Carolina, 1895-2010.[52]

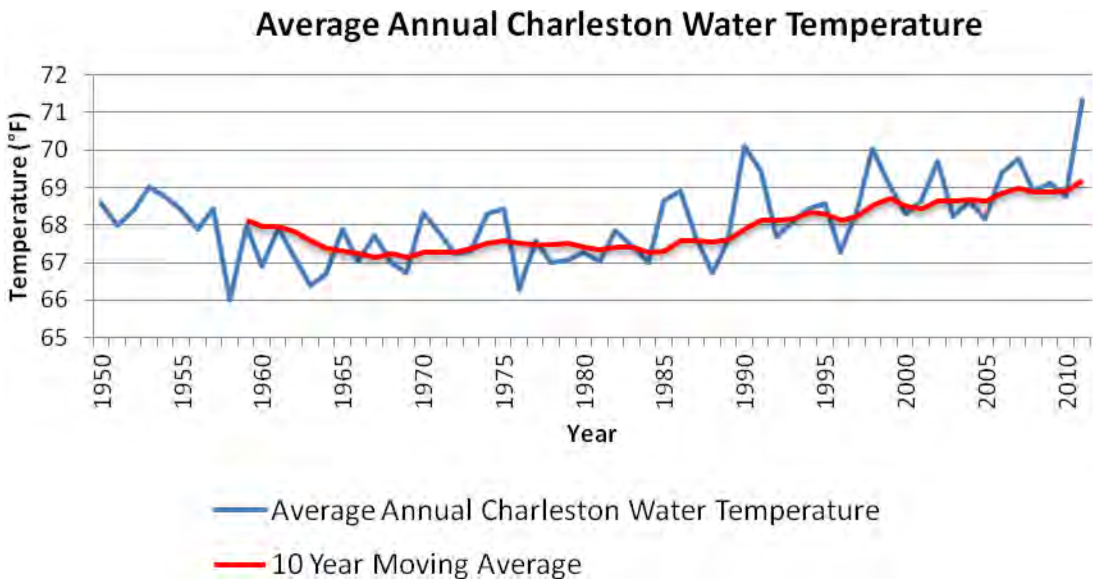


In addition to the temperature and precipitation study, a trend analysis of annual sea-water temperature data was completed using annual water temperature samples collected from the Charleston Harbor (Figure 2.11). The 10-year moving average of annual Charleston water temperature (Figure 2.11) shows relatively constant water temperatures from 1970 through 1985 before a steady warming trend began in 1985.

Data on severe storms were examined to discern any trends in severe storms. These data proved to be problematic due to the subjective nature of calculating the number of storm reports. Tornadoes and coastal hurricane landfalls provide a more objective measure to evaluate trends and variability; however, each has some inherent limitations. Tornado data from the period 1950-2010 (Fig. 2.12) demonstrate an increasing trend in these severe storms. This increasing trend is believed to be due to improved communications and detection capability, rather than climate change, and is attributable to increased population levels and the advent of Doppler radar technology in the early 1990s.

[52] NOAA/USHCN.

Figure 2.11 Average annual water temperature for Charleston, South Carolina, 1950-2010[53]



A tally of tropical cyclones making landfall along the South Carolina coast from 1878-2010 was plotted with a 10-year moving average calculation in order to note any trends (Fig. 2.13). Despite improvements in satellite technology, which can identify tropical cyclones, and indications that coastal water temperatures may be increasing, there is no evidence that tropical cyclone activity has increased along the South Carolina coast over the last 122 years .

[53] South Carolina Department of Natural Resources, Marine Resources Division

Figure 2.12 Annual observed South Carolina tornadoes, 1950-2010, demonstrating a Linear trend. [54]

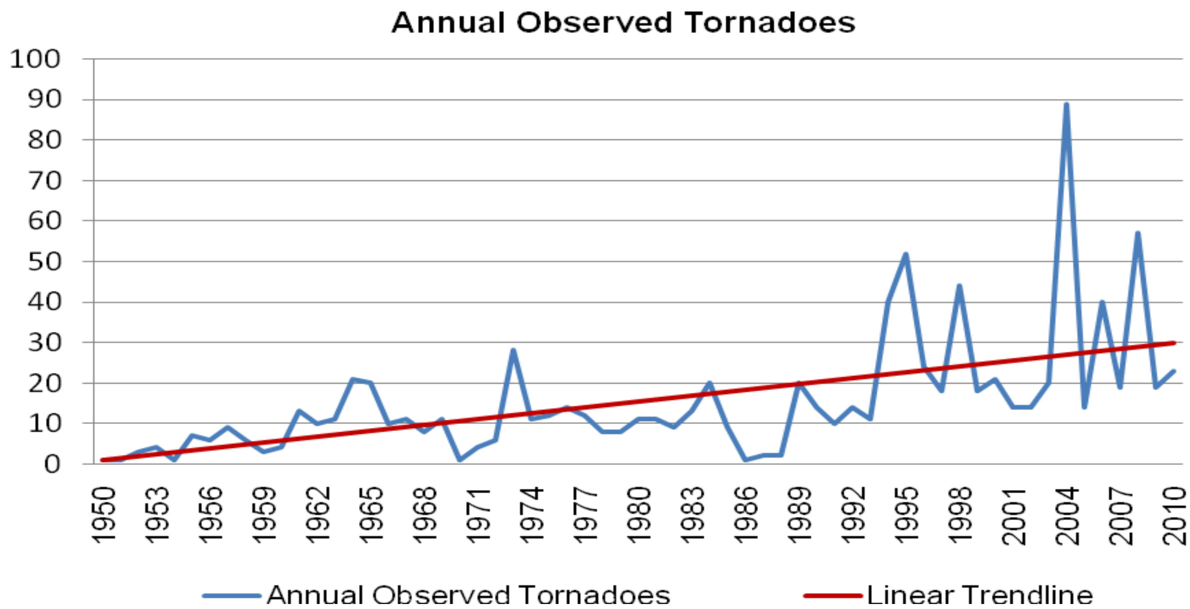
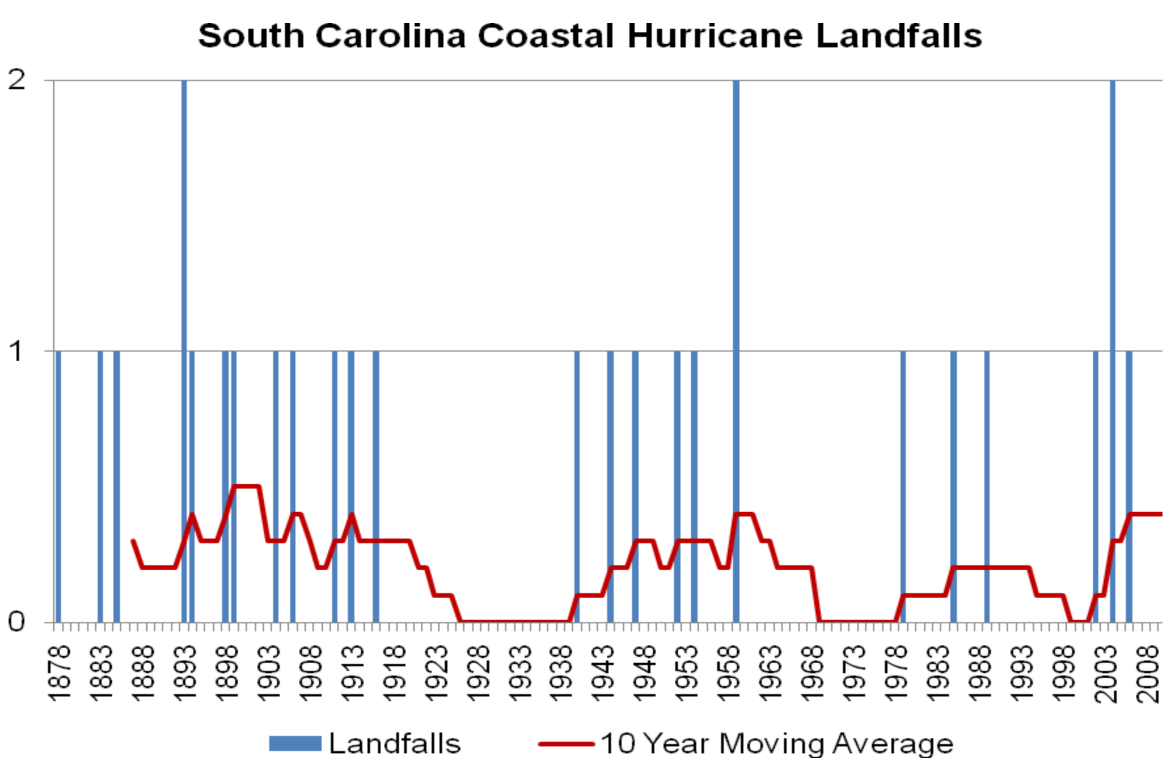


Figure 2.13 South Carolina coastal hurricane landfalls with a 10-year moving average applied.[54]



[54] http://www.nhc.noaa.gov/pastall.shtml. Last accessed Sept 2010.

2.6 Conclusions Based on South Carolina Data Examination

Temperature and precipitation data provide a record of variations in South Carolina climate extending back into the late 1800s. Air-temperature data from 1970 to the present show a steady increase in mean annual temperatures. Coastal water temperatures also support the recent warming phase, but the water temperature data record is not as extensive and continuous as the air temperature data. At this time, there is no definitive signal that tornadoes and hurricanes making landfall are increasing in the state. It must be noted that there is uncertainty in drawing broad conclusions on the recent and future climate of South Carolina based on examination of these kinds of localized data sets. In order to reduce uncertainty, more comprehensive data sets collected over a longer period of time and covering a larger geographic area must be examined.

2.7 Examination of Regional Climate Data and Predictive Models

The southeastern United States may be particularly vulnerable to climate change because of the risks associated with its low-lying coastline, periodically occurring winter storms and tropical systems.[55] The rich biodiversity of the Southeast could be exposed to more risks related to drought, plant and animal pathogens and invasive species. The Southeast is home to more than 400,000 farms on almost 80 million acres (32 million ha),[56] over 127 million acres (51 million ha) of timberland[57] and 33% of estuaries[58] and almost 30% of all wetlands in the conterminous United States.[59]

Since it is harder to examine climatic trends at the state level variations over the past in order to make climatic predictions, it is important to examine regional climate trends and models. Compared to the continental United States, the climate of the Southeast is uniquely warm and wet, with mild winters and high humidity. Southeastern average annual temperature has exhibited natural variation for most of the past century; however during the past 40 years annual average temperature has increased about 2°F (1°C).[60] The greatest seasonal change has occurred during winter with freezing days declining 4-7 days per year over the period (Fig. 2.14). Changes in precipitation have been occurring over the past 3 decades with increases in heavy downpours in many parts of the Southeast, even though much of the region has experienced moderate to severe droughts during the same period.[61] While there is uncertainty in projecting trends in

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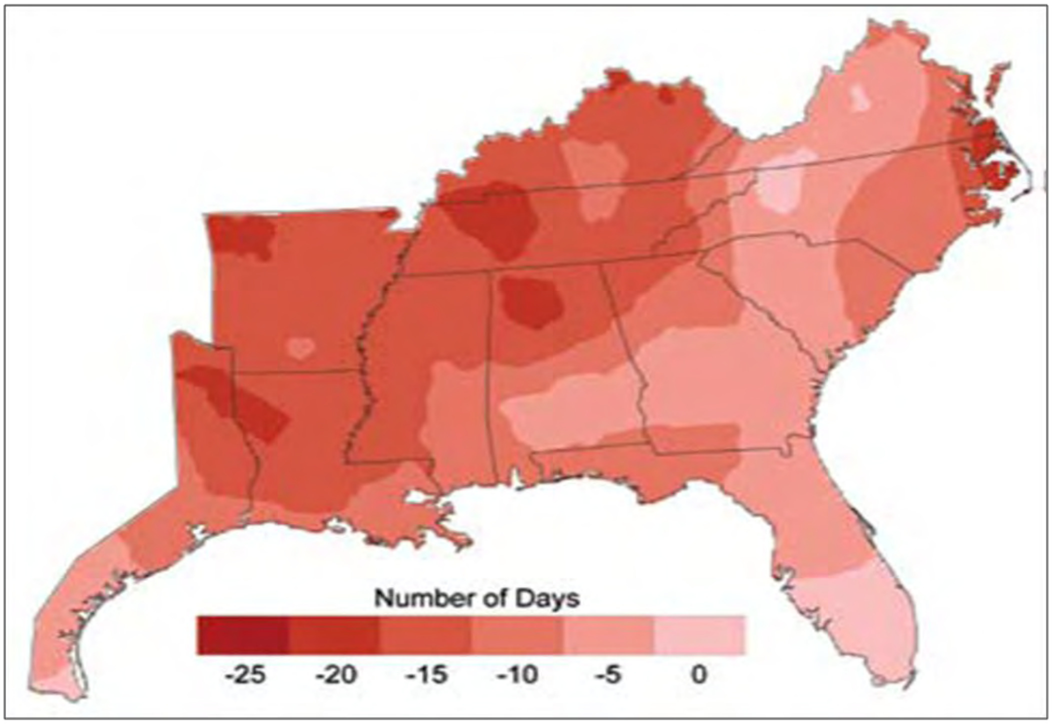
[55] Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, New York.
[56] USDA. 2008. Data Sets: Regional Agricultural Profile System. USDA Economic Research Service. Presentation tool for the 2002 Census of Agriculture. http://www.ers.usda.gov/data/RegionMapper/index.htm. Last accessed July 2010.
[57] USFS. 2010. Stream Temperature Modeling. US.Forest Service. http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml. Last accessed June 2010.
[58] NOAA. 1990. Estuaries of the United States: Vital Statistics of a National Resource Base. Monograph. NOAA National Ocean Service, Strategic Assessment Branch, Rockville, MD.
[59] Dahl, T.E. 1990. Wetland Losses in the United States 1780s to 1980s. US Department of the Interior, Fish and Wildl. Serv, Washington, DC. 167 pp.
[60] Regional Climate Impacts: Southeast. USGCCRP 2009. http://www.globalchange.gov/images/cir/pdf/southeast.pdf. Last accessed Aug 2010. Hereafter USGCCRP 2009.
[61] USGCCRP. 2009.

tropical activity, it is important to address that changes in tropical intensity and frequency has the potential for major implications.

Figure 2.14 Change in freezing days per year from1976 to 2007 in the southeastern United States demonstrating that since the mid-1970s the number of days per year during which the temperature falls below freezing has declined by 4-7 days over much of the Southeast but over 15 days for much of Arkansas, Louisiana, Mississippi and Tennessee.[62]



Current climate models predict continued warming across the Southeast with the rate of warming more than twice the current rate. The greatest temperature increases are projected to occur in the summer months. The number of very hot days of $\geq$ 100°F (38°C) is projected to rise at a greater rate than the average temperature. Under the lower GHG emissions scenario average temperatures in the Southeast are projected to rise by about 4.5°F (2.5°C) over the next 70 years, while a higher GHG emissions scenario is predicted to yield about 9°F (5°C) of average warming. Summers by the 2080s are projected to be about 11°F (6°C) hotter with a much higher heat index. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration.[63]

Interest in the effects of climate change in the Southeast is increasing, but there are any number of impediments to understanding and predicting climate change, including public apathy and a lack of awareness, lack of outreach on adaptation options, lack of

[62] USGCCRP. 2009.
[63]USGCCRP. 2009.

uniform access to information on current climate change risks and a lack of guidance on what information and tools are available. Climate change documentation and development of adaptation strategies also are limited primarily by a lack of funding, a lack of political will and lack of government leadership. Leadership issues may be a result of division of authority across topics as well as geographic and political boundaries across federal, state and municipal governments. All of these factors impede development of effective climate change adaptation policies across the Southeast.[64]

2.8 Climate and Weather Assessment

How will climate change affect day-to-day weather conditions, and how will these weather changes impact South Carolina natural resources and their public use and enjoyment? Can we monitor climate change at useful scales? The recognition and description of climate change and weather patterns are vital to the management of natural resources.

Detailed information about temperature, soil moisture, precipitation and humidity, when combined with long-term weather models and historical climate data, provide valuable information, such as duration of droughts and shifts in the duration of seasons. In turn, this information is used to help citizens in many ways. An important application of accurate climate data is monitoring the shift in frost-free days. An accurate, statewide monitoring system should be integrated with a warning system to alert local officials and citizens when temperatures or weather conditions become hazardous.

Extreme weather events are also of concern. For example, it has been proposed that climate change can influence the intensity and number of storm events.[65] Although supporting data are not entirely conclusive, the physics behind models are well understood. Warmer ocean temperatures potentially can provide more energy to hurricanes, leading to more intense storms. Increased precipitation patterns could have an adverse affect on flooding issues. High intensity rainfalls could lead to greater flooding hazards and mud- or landslides.

Enhanced support is needed for weather-station systems to forecast short-term events and monitor longer term trends. Weather stations that have reliable, long-term homogeneous data provide data needed for the detection and attribution of present and future climate change. Costs and maintenance associated with these systems require partnerships between federal, state and local governments and non-governmental organizations (NGOs). There needs to be a stable, long-term commitment to these weather station systems and to the monitoring and management of the data.

Our understanding of climate change also can benefit from paleoclimate studies. Past climates can indicate the potential range of physical and biological conditions we might

[64]USEPA. 2010. Report on the USEPA Southeast Climate Change Adaptation Planning Workshop. http://epa.gov/region4/clean_energy/Task.5.Report.05.10.2010.pdf. Last accessed Sept 2010.
[65]H. Tompkins. 2002. Climate change and extreme weather events: Is there a connection? Cicerone 3:1-5.

expect. Paleoclimate studies also can provide insight into rates of climate change, conditions prior to major changes and the overall effect to the landscape resulting from climate change. Several lines of research could provide detailed information about past climates. For example, the stratigraphic record in the coastal plain can provide information about sea-level positions, minimums, maximums and rates of change. Carolina bays are known to have detailed fossil assemblages that can help interpret climatic conditions. Coastal lagoons may contain evidence of ancient hurricanes, providing information about the number, age and intensity of storms in the past. The study of ancient hurricanes (paleotempestology) could provide useful information about the frequency and intensity of hurricanes affecting South Carolina during the past. This information could be related to climatic conditions anticipated over the next several decades.

Climate change has the potential to increase flooding events requiring up-to-date flood mapping. The potential for increased flooding events or increased magnitude of flooding events or both could diminish the accuracy of current flood-plain maps. A strong flood-mapping program is needed. Through climate and stream monitoring, DNR may be able to better understand increased hazards, translate the results into a new generation of flood maps and design better emergency response programs.

3.0 CLIMATE CHANGE IMPACTS TO NATURAL RESOURCES IN SOUTH CAROLINA

3.1 Potential Physical Effects Resulting from a Changing Climate

3.1.1 Potential Effects Related to Change in Sea Level

3.1.1.1 Sea-level Rise

Sea level is rising,[66] and whatever the cause, it is a serious concern.[67] The evidence for the rise is visible to anyone who visits the beach. Communities have seen their shoreline retreat, requiring an increased need for beach nourishment. Along some beaches, downed trees and drowned tree stumps are an obvious sign of shoreline retreat. One of the most pronounced effects of sea-level rise will be the effects on shoreline and estuarine habitats and the species that depend on them. Sea-level rise and land subsidence also will affect coastal zone development. Shoreline change takes several forms: erosion, deposition and migration. Monitoring changes in magnitude, direction and rates of these parameters will provide important information to policy and decision makers. Beaches are among the most economically valuable natural resources in South Carolina, and the frequency of beach nourishment projects has accelerated over the past several decades. Impacts to beaches could be exacerbated by increasing intensity and frequency of damaging tropical storms, as predicted under some climate

[66] IPCC. 2007.
[67] EPA, 1989: The Potential Effects of Global Climate Change on the United States. Report to Congress. US Environmental Protection Agency. EPA 230-05-89-052. 401 pp. http://www.epa.gov/climatechange/effects/downloads/potential_effects.pdf. Last accessed Aug 2010.

change scenarios. While the magnitude of sea-level rise expected over the next century is not known with certainty, most models project approximately a 2.0 feet (0.6 m) rise. Estimates of sea-level rise have used multiplier factors ranging from 20-100 to estimate landward intrusion, indicating a potential intrusion boundary of 39-197 feet (12-60 m)[68] – clearly placing much of current beach development in South Carolina in jeopardy. In addition, outflow of coastal rivers, which act as a sand replenishment source, has been altered through more than a century of dam and hydroelectric reservoir development, the Santee and Pee Dee rivers being good examples. Not only are the physical threats of shoreline loss important, but the natural beauty of coastal beaches and the wildlife they sustain are extremely important to the state's economy and cultural heritage, and their sustainment is in doubt.

3.1.1.2 DNR Response and Recommendations

A comprehensive shoreline change strategy is needed to define the rate and magnitude of relative sea-level rise, as well as associated effects including shifting shoreline position, erosion rates and shifting salinity. Consideration of vegetation and aquatic organisms also is important to assess ecosystem change. Tracking sea-level rise and concomitant coastal change is a substantial task, but it is most effective when performed in cooperation with other state, federal and local efforts. Partnerships will be needed to acquire and protect habitat, as well as to collect, host and share regional, specific coast-wide data.

3.1.1.3 Coastal Habitats Affected by Sea-level Rise

The coastal zone is home to a number of unique habitats that are critical to support important wildlife and marine species. These include hammocks, salt and brackish emergent wetlands, that accommodate nesting, resting, and feeding areas for birds and beach dune systems where sea turtles (superfamily *Chelonioidea*) nest. These species and their habitats are especially vulnerable to the treat of sea-level rise.[69] [70]

South Carolina has several thousand small, unique coastal islands associated with larger barrier islands. The hammocks provide valuable resting and feeding stations for migratory shore birds as well as natural refuges for coastal mammals including deer, otter, mink and others. These small islands, ranging in size from less than an acre to several hundred acres, are most numerous between the Santee and Savannah rivers. Termed marsh hammocks or back barrier islands, they typically are located behind the oceanfront barrier islands and adjacent to the larger barrier islands. Other hammocks are located along the Atlantic Intracoastal Waterway or adjacent to coastal rivers and

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[68] IPCC. 2007.

[69] Daniels R. C., T. W. White and K. K. Chapman. 1993. Sea-level rise: destruction of threatened and endangered species habitat in South Carolina. Environ. Manage. 17: 373-385.

[70] Cheung, W., W. Vicky, J. Lam, K. Sarmiento, R. Kearney, R. Watson and D. Pauly. 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries. 10(3):235-251.

estuaries. Almost all are surrounded by expanses of salt marsh, occasionally being bordered by tidal creeks or rivers.[71]

Sea-level rise poses the following risks to hammocks:

1. Low elevation (< 0.3 meters in some cases) increases susceptibility to even modest sea-level rise,
2. They provide preferred habitat for biota requiring freshwater ponds or wetlands for reproduction and are sensitive to sea-water intrusion, and
3. Increased demand for marsh front or water front property has made these formerly unattractive and inaccessible areas economically attractive for development.

Sand dunes and beach habitat on the South Carolina coastline are vital for nesting of sea turtles, including the loggerhead sea turtle (*Caretta caretta*) and for feeding of sea birds. It is widely accepted that most female sea turtles return to their natal region every 2–3 years to nest.[72] Because of this vital link in their natural history, loss of front beach nesting habitat to beach erosion is a serious problem for this threatened species. Furthermore, since beach erosion is typically exacerbated by sea-level rise, rising water levels clearly pose a long-term threat to sea turtle populations. If beach erosion occurs on undeveloped islands, impacts to sea turtles may be minimal as the island simply retreats. However, aerial observations suggest that undeveloped islands in South Carolina are not retreating in a manner that would sustain turtle nesting because erosion is occurring at such a rapid pace.[73] *Bone yards or* dead tree trunks and limbs in the surf zone, exposed peat from geologically older marshes and a general loss of sand, due to dams on major rivers and nourishment projects, all appear to be diminishing the nesting quality of these beaches.[74] Although nourishment on developed beaches can restore some beach function as a nesting area, steep scarps sometimes develop just above the surf zone preventing female sea turtles from nesting or limiting them to lower sites where nests are vulnerable to tidal inundation and wave action.[75] Additionally, research indicates the nourishment process creates significant disruption to the physical and biological compositions of offshore sites where sand is mined and not replenished naturally.[76]

Estuarine flats, salt marshes and creeks form essential habitat to the juvenile stages of many marine species that support important inshore fisheries such as shrimp (*Litopenaeus* and *Farfantepenaeus*), blue crab (*Callinectes sapidus*), spot (*Leiostomus*

[71] Whitaker, J. D., J. W. McCord, P. P. Maier, A. L. Segars, M. L. Rekow, N. Shea, J. Ayers and R. Browder. 2004. An ecological characterization of coastal hammock islands in South Carolina. Final report to Ocean and Coastal Resources Management, SC Dept. of Health and Environmental Control. SC Dept. Nat. Resour. Rept. 115 pp.
[72] Bjorndal, K. A., A. B. Meylan and B. J. Turner. 1983. Sea turtle nesting at Melbourne Beach, Florida, I. Size, growth and reproductive biology. Biological Cons. 26: 65-77.
[73] Dubose Griffin, DNR, personal communication.
[74] Dubose Griffin, DNR, personal communication.
[75] M. Steinitz, M. Salmon, and J. Wyneken. 1998. Beach renourishment and loggerhead turtle reproduction: A seven year study at Jupiter Island, Florida . J. Coast. Resour. 14(3):1000-1013.
[76] Posey M. and T. Alphin. 2002. Resilience and stability in an offshore benthic community: Responses to sediment borrow activities and hurricane disturbance. J. Coast. Resour. 18(4):685-697.

xanthurus), flounder (*Paralichthys spp.*), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*) and gag grouper (*Mycteroperca microlepis*). These flats also sustain high densities of other small species, such as fiddler crabs (*Uca* spp.), snails and killifish (*Fundulus,* spp.), which are important prey for larger fish, crabs and birds. Rising sea levels could contribute to a reduction in the area of intertidal marsh available, especially if coastal development impedes their inland expansion in response to inundation. Reduced salt marsh area would be expected to have a negative impact on the populations of species that rely on salt marsh habitat.

3.1.1.4 DNR Response and Recommendations

The effects of rising sea level and its biological ramifications are at best uncertain and potentially devastating to the coastal zone ecosystem. Substantial resources need to be dedicated to reducing these uncertainties. Support should be given to spatial mapping projects that can model the effects of sea-level rise and assist in identifying methods of reducing its impacts.

Migratory routes and utilization of hammock islands by birds should be quantitatively compared to the mainland and the larger barrier islands. In order to determine relative abundance of birds and mammals, utilization of truly isolated hammocks should be compared to the more accessible hammocks. Other research interests include the importance of woodland edges for birds, the influence of the physical shape on bird utilization (complex shorelines vs. a circular-shaped island), predator-prey interactions and the interrelationships between plants and animals should be studied. Efforts should be made to ensure that land is set aside to serve as isolated hammocks as salt marshes migrate inland as a result of rising sea level.

Cooperative studies and management efforts with beachfront communities should continue to ensure the protection and enhancement of sea turtle nesting beaches. The rate of sea-level rise should be monitored, and resultant information should be used to determine appropriate management options as conditions change. Long-term management plans for beach nourishment should be developed through collaboration among beach communities, researchers and state/federal agencies. These plans should included examination and identification of likely renewable sand resources, beach nourishment funding sources and beach nourishment impacts upon other natural resources.

3.1.1.5 Sea-level Rise Effect on Marine and Coastal Resources

Implications of sea-level rise will require societal considerations that will have both direct and indirect effects on marine and coastal resources. Regarding the gradual inundation of beaches, river banks, and marsh edges, only three basic options are available: retreat inland, armor with sea walls or revetments or, in the case of beaches, nourishment by physically moving sand, usually from offshore. Each of these options has high economic costs as well as potential biological costs.

Sea-level rise could have profound effects on coastal salt marshes, inland brackish marshes and further inland freshwater marshes. Some believe that marshes, with time, can migrate inland and maintain their viability;[77] however if development and armored shorelines prevent potential inland retreat, marsh area will be reduced along with associated living marine resource productivity. Even without the opportunity for marshes to migrate landward, studies in South Carolina have shown that some salt marsh habitats may be resilient to sea-level rise due to sufficient sedimentation that allows the marshes to rise with sea level, while other marsh habitats will not be able to do so, resulting in drowning of those marshes. Similar problems could occur in the state's valuable shellfish beds if the beds cannot migrate landward, or changes in existing habitat conditions destabilize the beds.

If populations that are targeted by recreational and commercial fishing are negatively impacted by climate change, particularly loss of estuarine nursery habitat, mitigation in the form of aquaculture replenishment stocking or for pond grow out of seafood may be in greater demand.

3.1.1.6 DNR Response and Recommendations

Efforts should be undertaken to proactively address marsh migration through the use of migration models that identify likely areas where marshes could migrate. On the basis of these models, strategies should be cooperatively developed to protect these areas from further and future development. Research and development of mariculture techniques for important fishery species should continue or be initiated.

3.1.1.7 Sea-level Effects on the Fresh and Saltwater Interface

Changes in the location of the saltwater/freshwater interface will affect many freshwater and diadromous fish species. As sea level rises, saltwater will move further up the river systems of the state. Species with low salt tolerances and diadromous fish will be limited in their ability to move upstream into better quality habitat due to dams and hydroelectric reservoirs constructed on most South Carolina riverine systems. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. Additionally, the potential exists for increased demand for water releases from reservoirs to fight the salt wedge that will be moving inland.

3.1.1.8 DNR Response and Recommendations

For shifting salinity profiles, a contemporary, comprehensive hydrological survey of the coastal rivers is needed to determine existing and normal salinity patterns. Predictive models to analyze potential for salinity change by river mile should be developed throughout the coastal zone. Information obtained from sound scientific research could

[77] Feagin, R. A., M. Luisa Martinez, G. Mendoza-Gonzalez and R. Costanza. 2010. Salt marsh zonal migration and ecosystem service change in response to global sea level rise: a case study from an urban region. Ecology and Society. 15(4):14. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art14/. Last accessed June 2011.

be used to support development of adaptive management strategies to cope with shifting salinity in coastal rivers.

3.1.1.9 Sea-level Rise Effects on Coastal Managed Wetlands

The coastal landscape of South Carolina has both beauty and ecological significance. Managed tidal wetlands, also known as *rice fields, diked marshes* and *coastal impoundments* are a unique category of tidal coastal wetlands that exist in substantial acreage in and primarily only in South Carolina, largely as relics of a long-past agricultural era. Predominantly occurring in the traditional freshwater tidal zone, the infrastructure of most of the original acreage of managed tidal wetlands has been abandoned for a variety of reasons. However, a portion of the original acreage of these historically, culturally and economically important habitats in the coastal landscape is maintained intact for utilization by migratory birds and for recreational hunting. Conservation of rice plantations and associated managed wetlands in South Carolina is unique and is the predominant basis for habitat protection initiatives enabling modern preservation of tens of thousands of acres of ecologically important wetlands and upland buffer.

Waterfowl migrate during autumn from northern production areas to southern wintering areas, then in spring return northward to nesting areas.[78] Southern wintering allows dispersal over a broad area resulting in diverse foraging opportunities and maintenance of body condition.[79] Optimum wintering waterfowl habitat such as that located within South Carolina managed tidal wetlands is critical to the maintenance of this national trust resource.

Rudimentary wetland habitat management strategies were improved during the period between 1945 and 1985 until they became highly refined and specific.[80] [81] [82] Numerous papers have described prescriptive water quality parameters and water level manipulations designed to produce standing crops of preferred naturally occurring emergent and submerged wetland plants in fresh, intermediate, brackish, saline and hypersaline marshes.[83] [84] [85] [86] [87] [88]

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[78] Welty, J. C. 1975. The life of Birds, 2nd edition. W. B. Saunders Co. Philadelphia, PA. 662 pp.
[79] Baldassarre, G. A. and E. G. Bolen. 1994. Waterfowl ecology and management. John Wiley & Sons, New York, NY. 609 pp.
[80] Gordon, D. H., B. T. Gray, R. D. Perry, M. P. Prevost, T. H. Strange and R. K. Williams. 1989. South Atlantic coastal wetlands. Pages 57-92 *in:* Habitat Management for Migrating and Wintering Waterfowl in North America, L. M. Smith, R. L. Pedersen and R. M. Kaminski, eds. Texas Tech University Press, Lubbock, TX. 574 pp. Hereinafter: Gordon et. al. 1989.
[81] Conrad, W. Brock. Conrad. 1966. A food habits study of ducks wintering on the lower Pee Dee and Waccamaw rivers, Georgetown, South Carolina. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm, 19:93-99.
[82] W. P. Baldwin. 1950. Recent Advances in Managing Coastal Plain Impoundments for Waterfowl, An. Conf. SE Assoc. Game and Fish Comm. 11 pp.
[83] Williams, R. K., R. D. Perry, M. B. Prevost and S. E. Adair. 1998. Management of South Atlantic coastal wetlands for waterfowl and other wildlife. Ducks Unlimited, Inc., Memphis, TN. 26 pp.
[84] Morgan, P. M., A. S. Johnson, W. P. Baldwin and J. L. Landers. 1975. Characteristics and management of tidal impoundments for wildlife in a South Carolina estuary. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 29:526-539.
[85] Landers, J. L., A. S. Johnson, P. H. Morgan and W. P. Baldwin. 1976. Duck foods in managed tidal impoundments in South Carolina. Journal Wildl. Manage. 40:721-728.

Coastal wetland managers have made significant strides in habitat management employing diverse, holistic habitat management plans that incorporate a wide variety of strategies to maximize production of favored plant material, seeds, and tubers and associated invertebrates while allowing for estuarine connectivity.[89] As a result of these successes some coastal landowners in the tidal regime constructed dikes in brackish and saline wetlands not previously included in rice culture.[90] By the mid-1970s over 70,000 acres (112,630 ha) of South Carolina coastal wetlands were in some form of wetland management primarily directed toward attracting waterfowl for recreational hunting and enjoyment.[91] Waterfowl since have flourished in managed tidal wetlands along with other wetland dependent wildlife, most notably shore and wading birds, the bald eagle (*Haliaeetus leucocephalus*) and the American alligator (*Alligator mississippiensis*).[92] DNR manages a total of 32,940 acres (13,331 ha) of managed wetlands at 6 locations that occur in the intertidal zone. The Yawkey Wildlife Center and Santee Coastal Reserve are located in Charleston and Georgetown counties and have dikes and wetlands that front directly on the ocean. These properties have 26.4 miles (42.5 km) and 15.8 miles (25.4 km) of perimeter dikes with 32 and 25 water control structures in these dikes, respectively. These 2 properties are under direct threat from sea-level rise. Existing dikes are minimally adequate in height and any rise will threaten the management of these wetlands. Bear Island WMA in Colleton County and Santee Delta WMA in Georgetown County are located more inland but will be affected by sea-level rise. They have 15.0 miles (24.1 km) and 5.8 miles (9.3 km) of perimeter dikes with 35 and 10 water control structures in these dikes, respectively. Samworth WMA located in Georgetown County and Donnelley WMA located in Colleton County are even further inland but still depend upon the tide to provide water for flooding of the wetlands. These 2 properties have 14.2 miles (22.8 km) and 0.7 miles (1.1 km) of perimeter dikes with 22 and 5 water control structures located in these dikes, respectively.

An embankment of sufficient composition and height is mandatory to seasonally restrict tide water from a managed tidal wetland; water control structures installed in embankments are necessary to adjust, raise or lower water levels in accordance with regularly occurring tides and a desired wetland management strategy.[93] Because the

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[86] Prevost, M. B., A. S. Johnson and J. L. Landers. 1978. Production and utilization of waterfowl foods in brackish impoundments in South Carolina. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 32:60-70.

[87] Perry, R. D. 1987. Methods to enhance target species production in freshwater impoundments. Pages 33-43 *in*: M. R. DeVoe and D. S. Baumann, eds. SC Coastal Wetland Impoundments: Management Implications, Workshop Proc. SC Sea Grant Consortium. Tech. Rep. No. SC-SG-TR-87-1.

[88] Perry, R. D. 1995. Management of tidal freshwater wetlands for waterfowl. Pages D124-D134 *in*: W. R. Whitman, et al. eds. Waterfowl habitat restoration, enhancement and management in the Atlantic Flyway. Third ed. Environmental Manage. Co., Atlantic Flyway Coun. Tech. Sect. and Delaware Div. Fish and Wildl., Dover, DE.

[89] Gordon et. al. 1989.

[90] Miglarese, J. V. and P. A. Sandifer, eds. 1982. An ecological characterization of South Carolina wetland impoundments. SC Mar. Resour. Cent. Tech. Rep. 51. SC Wildl. & Mar. Resour. Dept. Columbia, SC. 132 pp.

[91] Tiner, R. W., Jr. 1977. An inventory of South Carolina's coastal marshes. SC Mar. Resour. Cent. Tech. Rep. 23. SC Wildl. & Mar. Resour. Dept. Columbia, SC. 33 pp.

[92] Gordon et. al. 1989.

[93] Williams, R. K. 1987. Construction, maintenance and water control structures of tidal impoundments in South Carolina. Pages 139-166 *in*: W. R. Whitman and W. H. Meredith. eds. Waterfowl and Wetlands Symposium: Proc .

elevation of managed tidal wetland embankments typically is only slightly higher than the flooded water level of the interior managed wetlands, rising sea level poses a significant threat to their existence, and therefore the sustainability of these habitats for the benefit of migratory waterfowl and other managed tidal wetland species.

Equally important to the management of these wetlands is the salinity of the water used to facilitate water manipulations. At Samworth and Donnelley, freshwater has been the norm and the vegetation communities within the wetlands do not tolerate significant salinity. Even at Yawkey and Santee Coastal Reserve where embankments front on the ocean, relatively low-salinity riverine water has been available for water management purposes. Wetland management scenarios for these wetlands target a range of moderate salinities. As sea level rises and saltwater travels farther inland, fresh water near or at the coast will not occur. Saltwater management strategies will shift to hyper saline; brackish water management strategies will shift to saline; and freshwater management strategies will shift to brackish. These shifting salinity profiles will require DNR to adapt in order to effectively manage wetlands located directly on the coast.

3.1.1.10 DNR Response and Recommendations

Care must be given to ensure current regulatory mechanisms continue to protect this special kind of wetland as well as all other wetlands. Equally important is the need to be certain that the wetland protection regulations embrace an adaptive approach, when necessary, to benefit society and continue to protect all natural resource wetland attributes.

DNR should routinely monitor and maintain dikes, monitor water levels and salinities within and outside the wetlands. Embankments should be raised as needed and water control structures should be maintained and replaced as required. Adaptive relocation of water control structures may be necessary in order to adjust to changing riverine salinity profiles. Adaptive management of these wetlands, based upon water levels and salinities, is critical. Inland expansion or replacement of managed wetlands, by retreat, should be considered as properties become available.

3.1.2 Potential Effects Related to Changes in Water

3.1.2.1 Water Quantity

Water-supply issues are becoming increasingly critical.[94] With more demands on all water resources, it is essential to develop a comprehensive statewide conservation policy that balances human and natural resource needs. Without detailed information about capacity, long-term trends and their relation to the climate and the water budget,

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Symp. On Waterfowl and Wetland Manage. In the Coastal Zone of the Atlantic Flyway. Delaware Dept. of Natural Resour. and Environ. Control. Dover, DE. 522 pp.

[94] Bates, B. C., Z. W. Kundzewicz, S. Wu and J. P. Palutikof, *eds.* 2008: Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp. http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf. Last accessed July 2010.

an efficient and effective water plan will be difficult to implement. Water issues involve both surface and ground waters and include a myriad of factors that must be considered including availability, quality, recharge areas, source-area protection and storage. The primary interest is in fresh water, but at times salt water is an issue, in particular salt-water intrusion into coastal drinking-water wells as well as salt water moving up stream systems from estuaries.[95]

Surface water is monitored primarily by the United States Geological Survey (USGS), but additional information in critical areas would be helpful. Stream gauges provide water quantity information and also are used to monitor flood conditions and issue flood alerts by other agencies. At present, the ground-water monitoring system does not sufficiently cover the state, and a detailed, county-based ground-water monitoring program is needed to determine the availability and sustainability of ground water.

3.1.2.2 DNR Response and Recommendations

An effective policy for water management begins with a fundamental understanding of the behavior and processes that govern water movement and storage. Therefore, the most significant step to improve the understanding of South Carolina water supply is to increase monitoring capability of both surface- and ground-water sources, establish baseline measures of in-stream flow, better understand recharge and define recharge areas, develop databases to compile accumulated results and provide reliable information to assist in management decisions. Accurate assessment of ground-water availability can come only from long-term monitoring and a thorough understanding of the geologic architecture of the aquifers and their confining layers. This type of detailed work includes stratigraphic, subsurface geologic mapping and hydrogeologic studies. Results of these studies and others would reside in an integrated geologic, geophysical and hydrologic database that would benefit not only DNR, but all groups interested in surface- and ground-water issues.

Comprehensive basin-wide water planning should be done for each of the sub-basins in the state. These plans should include a detailed assessment of our ground- and surface-water resources, an assessment of ground- and surface-water use by water-use category, a water-demand analysis for each of the water-use categories, and a comprehensive water plan incorporating water-supply and water-demand management strategies to meet future demands and sustain the resource.

River-basin hydrologic models are needed for each of the sub-basins in South Carolina to predict where and when water shortages will occur and to evaluate the effects that changes in temperature and precipitation will have on surface-water supply. Ground-water flow models are needed in the coastal plain to predict the effects that withdrawals will have on aquifers. These models can be used to evaluate the effects that changes in precipitation and ground-water recharge rates have on our water supply.

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[95] Ranjan, S.P., Kazama, S. and Sawamoto, M. 2006. Effects of climate and land use changes on groundwater resources in coastal aquifers, J. Environ. Manage. 80(1):25-35.

A monitoring network is needed to study interactions between shallow ground water and surface water. The network could also be used to assess antecedent drought and flood conditions, and could be used as a barometer of drought conditions. This network could assist in understanding the relationships between base flow, ground-water levels and changes in precipitation.

3.1.2.3 Water Quality

In addition to affecting water quantity, climate change also will affect water quality.[96] Although DNR does not regulate water quality, the nature of how contaminants enter the water system is a direct function of the physical condition of the environment, including subsurface geology and land-use practices. The LWC can provide important technological and educational assistance in these areas.

3.1.2.4 DNR Response and Recommendations

Support is needed to adequately investigate of the state's subsurface geology. Prior knowledge of subsurface geology is important when planning for industry and development. The impact of accidental spills and remediation of hazardous-waste contamination can be reduced with proper planning. The availability of water, or lack thereof, is highly influenced in parts of the state by subsurface geology. The potential for geologic hazards, fault zones, also needs to be clearly defined. A comprehensive drilling program will help to establish the subsurface framework that influences ground water flow as well as earthquakes.

An expanded surface-water monitoring system also is needed. Monitoring should include water quality parameters such as water temperature, dissolved oxygen, pH, salinity and fecal coliforms. When combined with stream-flow data, this information can yield important information relative to how drought and flooding events impact water quality. These data could be used to augment the South Carolina Department of Health and Environmental Control (DHEC) monitoring system and to provide technical assistance to local governments and other stakeholders involved in land use planning.

A ground-water monitoring network along the coast should be established to measure salt-water intrusion. Strategically located wells in each aquifer should be continuously monitored for water level, temperature and specific conductance.

3.1.2.5 Potential Effects of Changes in Rainfall and Riverine Flow

Estuarine systems are among the most productive ecosystems on Earth and may be among the most sensitive to impacts of climate change as a result of changes in sea level and variation in rainfall that may shift salinity profiles and changes in biotic

[96] IPCC. 2007.

composition.[97] Shifts in salinity profiles in the estuarine system will depend entirely upon freshwater input and rainfall.[98] The projections for rainfall in South Carolina under a warming climate are unknown and require DNR to plan for a range of contingencies. The past decade has been dominated by drought conditions with accompanying shifts in the distribution of species within estuaries. Changes in biotic composition and the prevalence and seasonal distribution of diseased organisms must be expected, but little data exist to predict possible ramifications.

Salinity profiles in estuaries are expected to change as a result of both sea-level rise and changes in precipitation patterns. The former will shift the salinity regimes up estuaries; however the impact of the latter is unknown, as current models do not provide a clear direction to anticipated rainfall in South Carolina over the next few decades.[99] While estuarine species are renowned for their ability to tolerate salinity shifts over a tidal cycle, many have optimal ranges and move in the system according to prevailing conditions.

The worst scenario for sea-level rise could result in a landward shift in salinity resulting from sea-level rise accompanied by drought. This scenario would compress the available habitat, due in part to coastal development, likely resulting in reduced salt-marsh habitat in the optimal salinity ranges. Reduction of the spatial area covered by the salt marsh would reduce abundance and reproduction of estuarine species, as well as affect the entire ecosystem.

Another apparent consequence of extended droughts is drying out and dieback of saltwater marshes. The severe drought in 1999-2002 is thought primarily to have been responsible for salt marsh diebacks along the East Coast and Gulf of Mexico.[100] Studies in the Gulf of Mexico suggest that the drought caused low pH levels which resulted in greater bioavailability of metals which may have been responsible for *Spartina* mortality. On the South Carolina coast, both marsh meadows and marsh fringing tidal creek channels died in 2002.[101] It also is possible that low ground water levels resulting from drought may be related to salt marsh die offs. Salt marsh dieback has obvious implications including a reduction in primary productivity and increased vulnerability to predators of juvenile fishes and invertebrates.[102]

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[97] Michener, W., E. Blood, K. Bildstein, M. Brinson, and L. Gardner. 1997. Climate change, hurricanes and tropical storms and rising sea level in coastal wetlands. Ecological Applications. 7(3):770-801.

[98] Meynecke J., S. Lee, N. Duke andJ. Warnken. 2006. Effect of rainfall as a component of climate change on estuarine fish production in Queensland, Australia. Estuarine, Coastal and Shelf Sci. 69:491-504

[99] IPCC. 2007.

[100] Alber, M., E. Swenson, S. Adamowicz and I. Mendelssohn. 2008. Salt Marsh Dieback: An overview of recent events in the US. Estuarine, Coastal and Shelf Science. 80:201-211.

[101] D. Whitaker, personal observation. Dec 2002.

[102] Minelo, T. and R. Zimmerman. 1985. Differential selection for vegetative structure between juvenile brown shrimp (*Penaeus aztecus*) and white shrimp (*Peneus setiferus*), and implications for predator–prey relationships. Estuarine Coastal Shelf Sci. 20:707–716.

3.1.2.6 DNR Response and Recommendations

Field studies are needed to clearly document the effect and consequences that drought has on the salt marsh and its sensitive ecosystems. These studies would focus on determining the causes of salt marsh dieback and its impacts on primary and secondary productivity.

Accompanying hydrological studies are needed to determine the ambient conditions of coastal ground water and how ground-water levels and water chemistry are influenced by tidal fluctuations, sea-level change and drought. Field-based studies also are needed on the potential ecological and physiological impacts on mollusks, crustaceans and fish resulting from shifting salinity profiles and ocean acidification. Other studies of the migration and dispersal of estuarine species, especially those near the southern limits of their range, are needed.

Support is needed to develop predictive models that project expected sea-level rise, accompanied by a broad range of rainfall and hydrological scenarios. GIS mapping and mathematical modeling of estuarine water salinities as related to changes in river flow and local drought also are needed. This information would define affected marine species that will be forced farther inland than present or whose populations could be negatively impacted by reduced optimal nursery habitat. Mitigation plans could be established and implemented once information is available.

3.1.3 Potential Effects of Temperature Rise

3.1.3.1 Temporal and Spatial Shifts in Habitat and Life Histories

Shifting climate can cause changes in the spatial distribution of habitat and/or temporal aspects of life history. Shifts in habitat can occur in patches across the landscape, or the geographic range of species can shift. Temporal shifts in life history of species also are likely to occur in response to warmer or cooler temperatures, changes in precipitation, changes in vegetation or shifting seasons. For example, species' reproductive cycles can occur earlier or later in the year (budding has been observed to be occurring earlier for some plant species), become shorter or longer in duration, or occur earlier or later in age. Species at the edges of their range or in marginal habitats need to be able to migrate or disperse to adjust to changing habitat conditions.

Striped bass (*Morone saxatilis*) occurring in lakes that thermally stratify, such as lakes Murray and Thurmond, may experience increased incidence of mortality due to the vertical compression of oxygenated habitat. This could lead to population shifts away from striped bass toward species more tolerant of habitat compression such as hybrid striped bass (*Morone saxatilis* x *Morone chrysops*).[103]

[103] Brandt, S. B.; Gerken, M.; Hartman, K. J.; Demers, E. 2009. Effects of hypoxia on food consumption and growth of juvenile striped bass (*Morone saxatilis*). J. Exp. Marine Biol. Ecol. 381: S143-S149 .

3.1.3.2 DNR Response and Recommendations

A comprehensive strategy and long-term monitoring program is needed to assess spatial and temporal impacts to organisms, particularly for sensitive, rare or vulnerable species. Knowledge of life history and range for species is needed to develop effective management strategies to protect wildlife and freshwater and marine fishes and their habitat.

3.1.3.3 Population and Ecosystem Effects

Changes in climatic conditions have been linked with ecosystem-wide regime shifts resulting in major changes in species diversity and interactions at all trophic levels.[104] Climate change also has been associated with a northward shift in the distribution of many marine fish species across the Northern Atlantic, the Northwest Pacific and the Bering Sea.[105] [106] The evidence supporting climate-related shifts in distribution and abundance in the southeastern United States is limited since the issue has not been explicitly examined. The potential effects are profound, especially if economically important species are impacted, or if unexpected shifts occur that affect the biodiversity, stability or resilience of ecosystems.

Temperature has a direct effect on the physiology and survival of aquatic species. For example, temperature directly affects their physical growth and maturity, since the majority of aquatic species is poikilotherms, or cold blooded, and has metabolic rates that fluctuate with environmental temperature. Such changes can affect the rate of energy transfer between trophic levels, influence productivity and the function of the marine ecosystem as a whole. Survival can be directly affected by a species' upper and lower temperature tolerances. Overwinter mortality caused by freezes can have major impacts on the abundance of some species, such as spotted seatrout.[107] Conversely, other species utilizing habitats near their thermal maximum, for instance striped bass (*Morone saxatilis*) utilizing coastal waters, may be negatively impacted by high temperatures in the summer.

The abundance and annual commercial landings of brown shrimp (*Farfantepenaeus aztecus)* appear to have declined steadily in South Carolina over the last 2 decades concurrent with increasingly warm winters. Although no cause and effect has been definitively identified, it is hypothesized that the species' recruitment mechanism requires relatively cold winters. On the other hand, the white shrimp (*Litopenaeus*

[104] Beaugrand G. 2009. Decadal changes in climate and ecosystems in the North Atlantic Ocean and adjacent seas. Deep Sea Research Part II: Topical Studies in Oceanography. 56:656-673.
[105] Grebmeier, J., J. Overland, S. Moore, E. Farley, E. Carmack, L. Cooper, K. Frey, J. Helle, F. McLaughlin and S. McNutt. 2006: A major ecosystem shift in the northern Bering Sea. Science, 311(5766):1461-1464.
[106] ter Hofstede, R., J. Hiddink, and A. Rijnsdorp. 2010. Regional warming changes fish species richness in the eastern North Atlantic Ocean. Mar. Ecol. Prog. Serv. 414:1-9.
[107] South Carolina Department of Natural Resources. 2007. State of South Carolina's coastal resources: Spotted seatrout. http://www.dnr.sc.gov/marine/mrri/pubs/yr2007/seatrout07.pdf. Last accessed Dec 2010.

setiferus), is a subtropical species that may benefit from warmer winters and may expand its range farther north.[108]

Shifting water temperatures in the nearshore and shelf-break can lead to a shift in the distribution of both larval and adult fish. Increasing water temperatures could lead to shifts in areas of maximal abundance and overall species range for species such as red snapper (*Lutjanus campechanus*), red grouper (*Epinephelus morio*), gag (*Mycteroperca microlepis*) and scamp (*Mycteroperca phenax*). Anecdotal evidence suggests that shifts in some species' ranges may have occurred already off South Carolina.[109]

Strong year classes of Atlantic croaker (*Micropogonias undulatus*) populations along the mid-Atlantic coast have been positively related to warmer-than-normal winters.[110] Presumably, a higher frequency of warmer winters could modify the relative abundance for other important species and could result in significant shifting of ecological relationships including trophic structure, food webs and others. A long-term study in Narragansett Bay has documented a progressive shift in the marine community from vertebrates to invertebrates and, especially since 1980, from benthic to pelagic species.[111] Populations of small, short-lived forage species of fish, in particular, can change rapidly in response to climate variation, which can affect the growth and survival of other fish, mammals[112] and birds[113] that consume them.

Some diadromous species are near the southern end of their ranges in South Carolina. Many of these species already are stressed by summer conditions including high temperatures and, in some cases, low dissolved oxygen and anthropogenic impacts.[114] Finfish examples include the shortnose sturgeon (*Acipenser brevirostrum*), federally listed as endangered, and the Atlantic sturgeon (*Acipenser oxyrinchus*), a species of concern that was recently petitioned for listing as endangered. Both of these fish previously were of great economic, nutritional and cultural value to the state.[115] Climate change could exacerbate management problems for these and other species including shad species and river herring (*Alosa spp.*), or even in some cases, limit or eliminate their occurrence in South Carolina. Recruitment failure may occur in severe drought conditions as a consequence of dewatering of gravel bars and absence of the

[108] D. Whitaker, personal observation.
[109] J. Ballenger, MRRI, DNR. Personal communication
[110] J. Hare and K. Able. 2007. Mechanistic links between climate and fisheries along the east coast of the United States: explaining population outbursts of Atlantic croaker (Micropogonias undulatus) Fish. Oceanogr. 16(1):31–45,
[111] Collie, J., A. Wood, and P. Jeffries. 2008 Long-term shifts in the species composition of a coastal fish community Can. J. Fish. Aquat. Sci. 65:1352–1365.
[112] McLeod, et al. 2007. Linking sand eel consumption and the likelihood of starvation in harbour porpoises in the Scottish North Sea: could climate change mean more starving porpoises? Biol. Lett. 3:185-188.
[113] Frederiksen, et al. 2004. Scale-dependent climate signals drive breeding phenology of three seabird species. Global Change Biol, 10:1214-1221.
[114] Jenkins, W.E., T.I.J. Smith, L.D. Heyward and D. M. Knott. 1995. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Proc. Southeast. Assoc. Fish and Wildl. Agencies. 47:476-484.
[115] Leland, J. 1968. A survey of the sturgeon fishery of South Carolina. Contribution from Bears Bluff Laboratories. No. 41. 27 pp.

seasonally elevated flows which serve as a cue for spawning migration. Results of preliminary modeling investigations suggest that local extinction can occur rapidly.[116]

Freshwater fish species also are likely to be affected by changes in temperature regimes. Eastern brook trout (*Salvelinus fontinalis*) are the most sensitive to temperature of the 3 trout species that occur in South Carolina. They require colder water than rainbow (*Oncorhynchus mykiss*) and brown (*Salmo trutta*) trout. DNR has monitored temperatures in brook trout streams on the Sumter National Forest and Jocassee Gorges streams. Currently, maximum summer temperatures in South Carolina brook trout streams routinely reach 68-70°F (20-21°C) during the hottest summer periods. Brook trout typically do not occur in streams where maximum temperatures exceed 70°F (21°C). Any increase in stream temperature as a result of climate change likely would result in the loss of the species in South Carolina.

Smallmouth bass (*Micropterus dolomieu*) are a popular temperature-dependant coolwater sport fish that are managed in a number of South Carolina waters. For example, if waters were to warm in the Broad River, this recreationally valuable fishery could become jeopardized.

No studies of the response of nongame fishes to projected climate change in South Carolina or the southeastern United States have been published, but research elsewhere has predicted decline in distribution of cool and cold-water fishes.[117] In South Carolina, likelihood of extirpation from the state is high for the suite of fishes that are endemic to the southern Appalachian highlands, as these populations which are restricted to the upper reaches of the Savannah and Saluda drainages are relics from historic stream capture from the Tennessee River system. It also is possible that other upland-endemic species noted in the CWCS as sensitive to environmental change could decline in abundance and distribution with climate change.

Even if the overall distribution of fish species or their center of abundances is unchanged due to warming water temperatures, climatic changes could affect fish populations in other ways. Blue catfish (*Ictalurus furcatus*) are a nongame species that was introduced to the state's waters decades ago. No adverse effects to other aquatic species have been documented as a result of this introduction, and a popular fishery has developed for blue catfish. However, increased average water temperatures could result in increased competition between blue catfish and other species for spawning resources. Blue catfish spawn in temperatures ranging from 70-84°F (21-29°C). A typical spawning could shift from May to April could occur if temperatures rise. Native catfish, which usually do not compete for resources with blue catfish, may compete for spawning sites. This competition could be more pronounced if climate change altered seasonal durations, creating a shorter spring and a more prolonged summer.

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[116] J. Hightower, USGS, Raleigh, NC. Personal communication.

[117] Lyons, J, J.S. Stewart and M. Mitro. 2010. Predicted effects of climate warming on the distribution of 50 stream fishes in Wisconsin, U.S.A. Journal of Fish Biology 77: 1867-1898.

Additionally, climatic changes could alter the timing of the spring phytoplankton blooms – affecting zooplankton populations that many larval and juvenile fish species depend on as prey during this critical period of development. Conversely, climatic changes could directly affect the maturation of fishes, causing a shift in the spawning season. In any case, this could lead to a mismatch in the temporal period for which prey are available to larval and juvenile fish species in any given year, leading to more sporadic recruitment events and a higher probability of recruitment failure in any given year. This effect is often referred to as the Cushing match-mismatch hypothesis.[118]

Evidence is emerging that variations in annual oceanographic events affect the phytoplankton distribution of productivity.[119] For example, studies in other areas indicate that the intensity and timing of seasonal upwelling events have shifted compared to previous decades. This can have major effects on coastal ecosystems and may change the species composition of phytoplankton.[120] For example, the relative proportion of dinoflagellates, which tend to prefer warmer and more stratified water columns, may increase with respect to diatoms.[121]

It is unknown if a longer growing season would affect South Carolina oysters (*Crassostrea virginica*), but it might be due to effects on species composition and abundance of phytoplankton.

Seasonal inshore-offshore and latitudinal distributions, timing of migration and duration of nesting season of loggerhead sea turtles appear to be greatly influenced by water temperature.[122] Satellite-tagged juvenile loggerhead sea turtles have been shown to demonstrate inshore-offshore movement coincidental with water temperatures of 17°C.[123] It also has been demonstrated that warmer sea-surface temperatures in at least some locations lead to earlier onset and longer duration of nesting seasons.[124] It is not known to what degree extended warm weather seasons may alter these life history dynamics, and what the consequences of these environmental changes could have on the recovery of this threatened species. Additionally, sea turtle sex ratios are known to be determined by incubation temperatures in the nest, with warmer

[118] Cushing, D.H. 1990. Plankton production and year-class strength in fish-populations – an update of the match mismatch hypothesis. Advances in Marine Biology 26:249-293.
[119] Hays, G., A. Richardson and C. Robinson. 2005. Climate change and marine plankton. Trends in Ecology and Evolution. 20(6):337-344.
[120] Barth, J. B. Menge, J. Lubchenco, F. Chan, J. Bane, A. Kirincich, M. McManus, K. Nielsen, S. Pierce and L. Washburn. 2007. Delayed upwelling alters nearshore coastal ocean ecosystems in the northern California current. Proc. of the Nat. Acad. of Sci. 104(10):3719-3724.
[121] Monterey Bay Aquarium Research Institute. 2006. Seeing the Future in the Stratified Sea. 2006 Annual Rept. http://www.mbari.org/news/publications/ar/chapters/06_timeseries.pdf. Last accessed Dec 2010.
[122] Bjorndal, K.A., A.B. Meylan and B.J. Turner. 1983. Sea turtle nesting at Melbourne Beach, Florida, I. Size, growth and reproductive biology. Biological Conservation, 26:65-77.
[123] Arendt, M., J. Byrd, A. Segars, P. Maier, J. Schwenter, D. Burgess, J. Boynton, D. Whitaker, L. Liguori, L. Parker, D. Owens and G. Blanvillain. 2009. Examination of local movement and migratory behavior of sea turtles during spring and summer along the Atlantic coast off the southeastern United States. SC DNR, Univ. GA and College of Charleston, Final Report to NOAA Fisheries, Contract Number NA03NMF4720281, 177 pp.
[124] Hawkes, L.A., A.C. Broderick, M.H. Godfrey and B.J. Godley. 2007. Investigating the potential impacts of climate change on a marine turtle population. Global Change Biology, 13(5): 923-932.

temperatures resulting in sex ratios skewed to females.[125] It is conceivable that climate change could cause additional bias in sea turtle sex ratios, and males might become the limiting resource. In a worst-case scenario, a warming local climate could lead to the elimination of male offspring production altogether.[126]

3.1.3.4 DNR Response and Recommendations

Continuation of long-term surveys and archiving, integrating and analyzing the data they produce are essential to understanding climate-related impacts on the state's wildlife and freshwater and marine fisheries resources.

Abundant data exist to explore climate-related issues in databases compiled by MRD, other DNR sections and other organizations including NOAA and the University of South Carolina Baruch Marine Research Institute (BMRI) but funds for analyses are lacking. The MRD databases archive information from numerous ongoing, long-term (10-30 year) biological surveys that cover a variety of key habitats, ranging from small estuarine creeks to offshore deep waters. Examples include an electrofishing survey of upper estuarine habitats, a trammel net survey of lower estuarine marshfront, an estuarine crustacean trawl survey, a coastal trawl survey, a coastal shark and adult red drum longline survey and an offshore live bottom survey. These surveys often complement one another because many species spend different parts of their life cycle in different habitats. Two of the surveys, which are federal programs administered and conducted by MRD staff, cover the entire South Atlantic Bight (SAB) from North Carolina to Florida. They include the Southeast Area Monitoring and Assessment Program (SEAMAP), which began a shallow water trawl survey of the near-coastal SAB in 1986, and the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program, which began research further offshore in 1973 and primarily covers live bottom habitat.

In addition to the various fishery-independent surveys mentioned above, the OFM compiles fishery-dependent databases that record harvest rates of recreationally and commercially important species such as shrimps, crabs, oysters and fish.

Continued support of these long-term surveys is critical for understanding climate-related changes in the marine system, and for predicting potential future scenarios for South Carolina's marine resources. The value of the surveys derives from the time periods covered and the use of standardized collection methodology enabling meaningful, comparable data across years. Support for the collection of additional important biotic and abiotic data, such as fish and crustacean community structure and densities, life history information, temperature and salinity is essential. Existing programs currently provide data for regional stock assessments, but lack resources for critical analyses and modeling of existing data to support climate change studies.

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[125] Mrosovsky, N, and C.L. Yntema. 1980. Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices. Biological Conservation 18:271-28

[126] Blanvillain, G., L. Wood, A. Meylan. and P. Meylan. 2008. Sex ratio prediction of juvenile hawksbill sea turtles from South Florida, USA. Herpetological Conservation and Biology 3(1):21-27.

In order to assess the impacts of climate change on freshwater fisheries, a model simulation is needed for various scenarios of climate change using stream assessment data recently collected across the state to provide an objective evaluation of risk to native upland fish species.

Monitoring of penaeid shrimp, crab, fish and oyster populations should continue with fishery-dependent and fishery-independent methods. Efforts should be made to determine relationships between climate change and population dynamics of important species, for instance the impact of warmer winters on brown shrimp recruitment.

Data from other sources are also available, such as the long-term monitoring projects conducted by the BMRI. The integration of data across surveys, across DNR sections and across other research institutes would be a powerful method of detecting long-term biological trends associated with climate change. To facilitate this, it would be useful to compile an easily accessible list of all data sources within the DNR as a whole to integrate marine, freshwater and climate data sources, as well as other organizations within the state that collect long-term data. Comparison of these data with information available from other regions along the Atlantic and Gulf coasts would be useful in order to detect regional patterns.

There is a need to compile and analyze water temperature records from multiple locations to determine if temperatures have increased significantly in the last decade along the Gulf of Mexico and South Atlantic Coast as related to nearshore loggerhead sea turtle foraging grounds. Also needed is repeated examination of the sex ratios in loggerhead sea turtle nests with respect to spatial and temporal variability. At-sea monitoring of sea turtles with trawls should be continued to document overall population trends of juveniles and adults.

Agencies and local communities should continue education and eradication campaigns to eliminate beach vitex, an invasive plant that restricts nest building by sea turtles.

Populations of diadromous species should be evaluated in all major coastal rivers to estimate populations and monitor trends.

3.1.3.5 Harmful algal blooms (HABs)

HABs are caused by certain species of microscopic photosynthetic algae (phytoplankton). They cause a wide range of detrimental effects that are species-specific. Examples include shading and destruction of estuarine grass habitat, shellfish poisoning and toxin production that can bioaccumulate up the food chain and induce sickness and death in wildlife and humans. There has been an increase in reported HAB events over recent decades,[127] partly because of improved monitoring, but also

[127] Anderson, D.M. 2004. The growing problem of harmful algae: Tiny plants pose potent threat to those who live in and eat from the sea. Woods Hole Oceanographic Institution. http://www.whoi.edu/page.do?pid=11913&tid=282&cid=2483. Last accessed Jan 2011.

because of increased aquatic nutrient loading from run-off, alteration in land use patterns and the introduction of exotic HAB species. Climate change may further affect the timing and intensity of HAB events, but the overall relationships among climate change and other factors affecting the HAB prevalence remain unclear. For example, blooms of toxic cyanobacteria and raphidophytes are common in South Carolina. These blooms can cause mass fish kills and often are associated with increased levels of certain nutrients, particularly nitrogen;[128] [129] however, the timing and duration of blooms may be augmented by climate change.

3.1.3.6 DNR Response and Recommendations

The South Carolina Algal Ecology Laboratory has been jointly operated by USC and DNR over the last decade. Additional collaborations exist with the National Ocean Services, Charleston Laboratory. The monitoring and research performed by these collaborative efforts should be encouraged. Examples of relevant questions concerning HABs and climate change include:

1. Does climate change lead to longer summer growing seasons, and if so, then how would HAB taxa that tend to be more responsive to warmer temperatures respond? How might these co-vary with land use patterns?
2. Would harmful blooms simply persist for longer timeframes under predicted climate change scenarios?
3. Or, would phytoplankton blooms eventually exhaust their supply of nutrients, die off, and subsequent microbial respirations adversely affect water oxygen levels, thus inducing hypoxia?

3.1.3.7 Hypoxia and Dead Zones

Increasing temperatures can reduce oxygen levels in coastal waters through a variety of mechanisms such as a decrease in the solubility of oxygen, an increase in productivity and stratification of the water column. Hypoxia-related events have been well-documented in other coastal regions after, for example, extended phytoplankton blooms including in the Gulf of Mexico and Long Island Sound in New York.[130] Hypoxia often is related to increased nutrient run-off coupled with a stratified water column. These combined processes often promote proliferation of phytoplankton biomass, including that of HAB species. Cessation of blooms is typically coupled with increased oxygen consumption by bacteria, and in extreme cases, this oxygen consumption causes hypoxic conditions or dead zones, where oxygen concentrations fall below levels supporting life. These hypoxic regions impact benthic or demersal species and can result in considerable losses to fisheries. The incidences of dead zones are increasing worldwide and are believed to be, in part, a result of increasing global temperatures

[128] Chorus I, Bartram J (1999) Toxic cyanobacteria in water. World Health Organization, London.
[129] Downing TG, Meyer C, Gehringer MM, Venter M (2005) Microcystin content of *Microcystis aeruginosa* is modulated by nitrogen uptake rate relative to specific growth rate or carbon fixation rate. Environ Toxicol 20:257-262
[130] Diaz, R.J. and R. Rosenberg. 2008. Marine ecosystems spreading dead zones and consequences for marine ecosystems. Science. 321:926-929.

promoting greater water stratification.[131] The phenomenon can be exacerbated by nutrient-laden freshwater runoff related to increasing impervious surfaces from coastal development and changes in rainfall patterns. Numerous dead zone events have occurred in South Carolina during the last 2 decades, but most have been confined to small estuarine creeks and were of short duration. In 2004 and in 2009, relatively large events occurred in coastal waters just off Horry County in Long Bay.[132] Preliminary studies indicate these events were caused by persistent southwest winds resulting in upwelling near the coast, thence causing the unusual effect of trapping nutrient-laden water near the beaches, leading to hypoxia. Climate-related changes in ocean and wind circulation patterns could result in a greater frequency of coastal hypoxia. [133]

3.1.3.8 DNR Response and Recommendations

The relationship between climate change, land use and phytoplankton bloom timing and intensity is virtually unstudied for coastal South Carolina, but should be an important focus of future research. Agencies and universities should continue to form partnerships to monitor coastal hypoxia. Permanent nearshore monitoring stations strategically located along the coast should be maintained to monitor physical and chemical aspects of coastal waters. Efforts should be made to develop mathematical models that can explain hypoxia events, including the oceanographic conditions that give rise to them. Anthropogenic causes of hypoxia should be addressed and corrected where possible.

3.1.3.9 Potential Effects of Ocean Acidification

Increasing ocean acidification apparently related to increasing CO_2 levels in the Earth's atmosphere raises concerns about the future of reef-building corals and other species that incorporate calcium carbonate into their skeletons including mollusks, crustaceans and some plankton.[134] While South Carolina does not have shallow-water coral reefs, the impact of ocean acidification on oysters and other species is of concern. It is expected that ocean pH will fall to about 7.8 over the next 300 years and this is within the range known to impact oyster growth. However, pH in estuaries typically ranges between 7.0-7.9, with the lower values known to impact a variety of physiological and

[131] Kelling, R, and H. Garcia. 2002. The change in oceanic O2 inventory associated with recent global warming. Proc. Nat. Acad. Sci. 99(12):7848-7853.

[132] Sanger, D. , D. Hernandez, S. Libes, G. Voulgaris, B. Davis, E. Smith, R. Shuford, D. Porter, E. Koepfler and J.H. Bennett. 2010. A case history of the science and management collaboration in understanding hypoxia events in Long Bay, South Carolina, USA. J. Environmental Manage. 46:340-350.

[133] Gregg, R.M. L.J. Hansen, K.M. Feifel, J.L. Hitt, J. M. Kershner, A.Score, and J. R. Hoffman The State of Marine and Coastal Adaptation in North America: A Synthesis of Emerging Ideas. Eco. Adapt. Bainbridge Island, WA. http://www.cakex.org/sites/default/files/EcoAdapt%20Synthesis%20Report%20January%202011.pdf. Last accessed May 2011.

[134] Orr, J.,, V. Fabry, O. Aumont, L. Bopp, S. Doney, R. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. Najjar, G. Plattner, K. Rodgers, C. Sabine, J. Sarmiento, R. Schlitzer, R. D. Slater, I. Totterdell, M. Weirig, Y. Yamanaka and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature. 437:681-686.

immune functions in oysters.[135] Further deceases in pH could result from increasing ocean acidification, acid rain and increasing development in the coast zone. The effects of low pH are amplified at higher temperatures. Whether the expected increases in ocean acidity, atmospheric CO_2 and temperature pose serious threats to oysters and other estuarine species is difficult to assess as the issue has not been well studied. Similar concerns exist for many crustaceans, as the molting process involves calcium demineralization and re-mineralization of the exoskeleton and this is influenced by both internal pH as well as external pH. Increased acidification also could impact phytoplankton bloom dynamics and regional primary productivity.

3.1.3.10 DNR Response and Recommendations

Agency and university researchers should cooperatively monitor pH in coastal waters. Support is needed for research on the potential ecological and physiological impacts of shifting salinity profiles and ocean acidification on mollusks, crustaceans and fishes.

3.1.4 Potential Effects Related to Changes in Terrestrial and Aquatic Habitats

3.1.4.1 Habitat Fragmentation

Habitat decline, shifting climate regime, increasing development, particularly in coastal areas, and rising sea level represent constraints and barriers to dispersal and migration of fish, wildlife and plant species.[136] Maintaining migratory corridors is essential for the ability of wildlife and fishes to find suitable habitat and for population maintenance. Over the past several decades, habitats within South Carolina have become increasingly fragmented. Natural areas have been developed and roads have been created or widened throughout much of the state. This development has disrupted traditional corridors and resulted in pockets of wildlife habitat that are isolated from one another. Dams and other barriers have fragmented entire river systems and impede migration of diadromous and freshwater fish as well as many invertebrate species. As climate changes, further habitat fragmentation will restrict movement of animals, limiting or preventing the critical ability to migrate to more favorable habitats.

3.1.4.2 DNR Response and Recommendations

The South Carolina Heritage Trust Program was created in 1976 to help stem the tide of habitat loss by protecting critical endangered species sites through acquisition and other means. Enabling legislation directed DNR, in concert with other state agencies, to set aside a portion of the state's rich natural and cultural heritage in a system of heritage preserves to be protected for the benefit of present and future generations (Sec. 51-17-20, 1976 *S.C. Code of Laws*).[137] Support for the Heritage Trust and other habitat

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[135] Gazeau, F., C. Quiblier, J. Jansen, J.P. Gattuso, J. Middelburg and C Heip. 2007. Impact of elevated CO2 on shellfish calcification. Geophysical Research Lett. 34 :L07603, doi:10.1029/2006GL028554.

[136] P. Opdam and D. Wascher. 2003. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. Biological Conservation 117:285–297. http://research.eeescience.utoledo.edu/lees/Teaching/EEES4760_07/Opdam.PDF Last accessed Sept 2010.

[137] http://www.scstatehouse.gov/code/statmast.htm. Last accessed Sept 2010.

protection programs is needed to identify, create and preserve important conservation corridors to allow migration and movement of affected species. In addition, the agency will need to investigate ways to partner with other agencies and non-governmental organizations to develop and maintain adequate migration corridors.

3.1.4.3 Loss and Alteration of Habitats

Temperature changes likely are to result in changes in vegetative structure of wildlife habitats throughout the state. In the event local temperatures warm, higher elevation habitats could suffer; cooling temperatures could affect lowcountry habitats. More rapid and extreme temperature fluctuations could stress populations and restrict thermal refugia. These changes could result in habitat loss and a change in both vegetative and animal community structure. Two examples of important freshwater fisheries at increased risk are trout (subfamily *Salmoninae*) and striped bass. Habitat loss not only affects the area in which the species can live, it also affects food availability and availability of suitable nesting/breeding areas. Impacts associated with temperature changes most likely will be greater in the higher elevations of the state.

Precipitation changes will affect both surface and groundwater levels and will result in impacts to both terrestrial and aquatic systems.[138] Wildlife depends on a variety of water sources within the state. All animals require water within their habitats, some more than others. Changes in wetland systems will affect many species of birds (particularly waterfowl), reptiles and amphibians that depend on these areas for foraging and breeding habitats. Isolated freshwater wetlands, small streams and seepage wetlands are critical to the survival of many of these species. Small wetlands and the species associated with them may be excellent indicators for the effects of climate change on larger systems.

Freshwater aquatic systems are susceptible to changes in precipitation. Streams, rivers, lakes and ponds are dependent upon both precipitation and groundwater recharge to maintain flow and water levels. Changes in surface and groundwater levels can affect the species assemblages and migration in freshwaters throughout the state.

3.1.4.4 DNR Response and Recommendations

There is the need to gather plant and animal baseline data for terrestrial and aquatic habitats and monitor the rate of change in both vegetative and animal community structures. The agency should use the information collected to determine appropriate management options in response to climate change and adapt management activities as climate changes occur in response to the changing habitat needs of wildlife and fish species. DNR should use these data to develop predictive models of the effects of temperature changes.

Monitoring the rate of water level and flow change in all surface waters and groundwater systems is vital to terrestrial as well as aquatic habitats. DNR should use the

[138] IPCC. 2007.

information collected to determine appropriate management options in response to climate change and adapt its management activities as climate changes occur in response to the evolving habitat needs of wildlife and fish species. The agency should use data collected to develop models that can assist in predicting water level and flow change and work with other entities to ensure adequate water levels and flow rates for wildlife and fish.

3.1.4.5 Habitat Impacts Related to New and Alternative Energy

As the nation strives to locate and utilize alternative, cleaner and more carbon-neutral sources of energy, it is important to understand that such sources may result in additional impacts to wildlife, fish and their habitats. Increased demand for biofuels can result in decreased wildlife habitat as forests and conservation areas are converted to production areas. Wind power, both on- and off-shore, can result in increased mortality to birds and bats. Hydropower can result in reduced flow in rivers and restrict movements of freshwater and diadromous fish as well as cause direct impacts through turbine impingement. Impacts to natural resources may be mitigated during planning, permitting and licensing for alternative energy projects.

3.1.4.6 DNR Response and Recommendations

The agency should work with all stakeholders including utilities, other agencies, NGOs, legislators, government planners and other experts as alternative energy sources are developed, licensed and brought on line to ensure natural resource needs are addressed during planning.

3.2 Potential Biological Effects Resulting from a Changing Climate

3.2.1 Species and Habitat Data

3.2.1.1 Insufficient Data for Species and Habitat

Although very detailed distribution and life history data exist for some harvestable species within the state and for a limited number of special status species (threatened and endangered species), these types of data are lacking for the majority of wildlife and freshwater fish. Without information about the distribution and abundance of species and their habitat requirements, reproductive abilities and longevity, it will be very difficult to understand and respond to impacts associated with climate change.

DNR has developed a plan to identify species of greatest conservation need in the state through its *South Carolina Comprehensive Wildlife Conservation Strategy* (CWCS) which includes recommendations to address threats to these species and their habitats.[139] A total of 1,240 species is identified in the CWCS, including marine species. Because these species currently are considered at risk, any additional impacts

[139] Kohlsaat, T., L. Quattro and J. Rinehart. 2005. South Carolina Comprehensive Wildlife Conservation Strategy. SC Dept. Nat. Resour. http://www.dnr.sc.gov/cwcs/index.html. Last accessed Sept 2010.

associated with climate change will exacerbate current threats; data needs identified for those species in the CWCS should be addressed as we manage for climate change.

In addition to those species identified in the CWCS, other wildlife and fish species are likely to experience impacts related to climate change. Habitat for local, migrating and wintering waterfowl, neotropical migrant birds, reptiles and amphibians as well as a number of freshwater fish species is particularly vulnerable to climate change impacts.

3.2.1.2 DNR Response and Recommendations

The agency should continue to collect baseline data for wildlife and fishes in South Carolina. Data collection projects should include abundance, distribution and life history studies. Data should be utilized to determine appropriate management options in response to climate change. Habitat management activities must be adaptive as climate changes occur in response to the changing needs of wildlife and fish species. DNR should use data collected to develop models that can assist in predicting species response to climate change.

3.2.1.3 Habitat Data and Characterization

As with information about wildlife and fish species in South Carolina, there is a lack of data concerning the historic and current condition of habitats. Without current or past baseline data, it will be very difficult to assess the vulnerability of habitats and to determine the rate of habitat loss. In addition to the need for baseline data, it will be critical to identify the climate change effects on wildlife and fish habitat.

3.2.1.4 DNR Response and Recommendations

DNR should collect baseline data on the condition of wildlife and fish habitat in South Carolina. This information should be used to determine appropriate management options in response to climate change. The agency should adjust management activities as climate changes occur in response to the changing habitat needs of wildlife and fish species. Data collected can be utilized to develop models that can assist in predicting habitat response to climate change.

3.2.2 Endangered, Threatened or Species of Concern

3.2.2.1 Declining Habitat for Endangered, Threatened or Species of Concern

Habitat loss is the most important factor contributing to species decline. Climate change may exacerbate habitat decline, particularly for rare or sensitive species such as amphibians. Nuisance and exotic species invasions, changes in plant and animal community structure and changes in abiotic factors such as hydrology, soil moisture and climate are areas of great concern relative to rare or sensitive species conservation.

3.2.2.2 DNR Response and Recommendations

DNR maintains and manages the South Carolina Rare, Threatened and Endangered Species Inventory. Much of the data in the Inventory is submitted to DNR by citizens and academic institutions, so data acquisition is driven by individual submissions rather than a comprehensive plan or strategy. Additional support for comprehensive and long-term monitoring of rare and sensitive plant and animal species is needed. This should involve development of a more modern inventory system with significant IT support. The current database should be screened and standardized with other systems in the region.

An improved monitoring strategy can provide vital data to guide conservation and habitat management activities. Again, there is opportunity to partner under the umbrella of existing and future conservation efforts. Potential conservation activities include translocation of species where appropriate, rare plant species propagation and identification and protection of important habitat. The management of natural resources will become increasingly difficult and complicated as climate change advances. The Conservation Section within the LWC can provide needed leadership and technical expertise to local, regional and statewide conservation and planning efforts.

3.2.3 Invasive Species

3.2.3.1 Potential for Introduction of Invasive Species

Increased temperatures, changes in rainfall and other environmental factors affected by climate shifts or change can create ideal conditions for proliferation of invasive plant and animal species, including parasites and pathogens. An increase in the number and diversity of native and non-indigenous invasive plant and animal species has been documented in South Carolina terrestrial, freshwater and marine habitats. Some of these species may have been released accidently or by well-meaning citizens, but others are likely migrating northward from more tropical climates as a result of warming temperatures. Regardless of the manner in which they have become established, these species already are impacting native animals and their habitats. As climate changes, an increasing number of exotic species likely will migrate to South Carolina. Habitats can be destroyed as resources are over-utilized. Invasive and non-indigenous species have the potential to outcompete native species for food and other resources.

Impacts of invasive species are second only to habitat loss for the significant decline and extirpation of both endangered and common species. The current environmental, economic and health costs of invasive species could exceed $138 billion per year in the United States, more than all other natural disasters combined. In 2006 alone, the United States spent $1.2 billion combating invasive species. That total does not even consider the numerous hours and dollars spent at regional, state and private levels to combat invasive species.[140]

[140] Pimental, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs associated with non-indigenous species in the United States. Biosci. 50(1):53-65.

Invasive species can completely overtake unique, sensitive and important habitats, such as those protected on lands dedicated as DNR Heritage Preserves, and out compete other established natives, forcing them into endangered, threatened or species of concern status. Stressed vegetation is vulnerable to attack by non-indigenous parasites and pathogens. The identification and acquisition of land for preserves often is based on the presence of unique native floral or faunal populations; however, if climate change alters local conditions in ways that allow invasive species to proliferate, the value of conservation lands as habitat for native species can become compromised.

Tilapia is a warmwater non-indigenous group of fish that extensively are stocked under permit in the state to control algae in private ponds. With few notable thermal refuges excluded, tilapia will die from cold stress in a typical South Carolina winter when water temperatures drop below 50°F (10°C). Historically, south coastal South Carolina water temperatures routinely drop to 45-50°F (7-10°C) during the winter. In the event that waters were to warm in the state, the potential for tilapia to overwinter is possible. Tilapia currently overwinters in Florida and has become an invasive species and a major management problem. If tilapia were to routinely overwinter in South Carolina it would result in direct competition with native and existing species for space, food, habitat and spawning areas, which could drastically alter natural fish communities.

The destruction that non-indigenous peacock bass (*Cichla* spp.) can cause to native fish communities is well documented.[141] In Florida, these fish currently are widespread, but, fortunately, these fish are very temperature dependant and do not typically survive in waters cooler than 60°F (16°C). Given current South Carolina winter low temperatures, tilapia is much more of an eminent threat than peacock bass. However, if winter temperatures increase, peacock bass could become a threat in South Carolina. Other invasive fish that are common in Florida and, like peacock bass, could become established in South Carolina, include various cichlids, pleco (*Hypostomus plecostomus*), Asian swamp eel (*Monopterus albus)*, walking catfish (*Clarias batrachus*), various piranha and oscar (*Astronotus ocellatus*). All of these fish could, like tilapia, compete with native species for habitat, food and spawning resources.

Despite the increased frequency of occurrence, and in some cases the establishment in South Carolina, of subtropical and tropical flora and fauna, including invertebrate fauna, with historic ranges once restricted to latitudes south of Cape Canaveral, little has been done to determine the impact of these species on the natural ecosystems of our state, or to assess whether or not their arrival and dispersal has been enhanced or accelerated by climate changes. Recently it has been demonstrated that changes in seasonal maxima and minima of water temperature may be more important than changes in means.[142] Examples of marine invertebrates that have extended their ranges northward include two millennia Andrew C. Kemp, Benjamin P. Hortona,,

[141] Pelicice, F.M. and A.A. Agostinho. 2009. Fish fauna destruction after the introduction of a non-native predator (*Cichla kelberi*) in a neotropical reservoir. Biol Invasions. 10.1007/s10530-008-9358-3.

[142] Stachowicz, J, J Terwin, R Whitlatc, and R. Osman. 2002. Linking climate change and biological invasions: Ocean warming facilitates nonindigenous species invasions. Proc. Natl. Acad. Sci. 99(24):15497-15500.

Jeffrey P. Donnellyc, Michael E. Mannd,species of callinectid crabs similar to native blue crabs (*Callinectes bocourti* and *C. exasperatus*); the spiny hands crab (*Charybdis hellerii*); the blue land crab (*Cardisoma guanhumi*); the green porcelain crab (*Petrolisthes armatus*); two pulmonate snails (*Creedonia succinea* and *Microtralia ovula*); an intertidal littorinid snail (*Echinolittorina placida*); the Asian green mussel and the charrua mussel (*Perna viridis* and *Mytella charruana*); the Asian tiger shrimp (*Penaeus monodon*); two acorn barnacles (*Megabalanus coccopoma* and *M. tintinnabulum*); and a caprellid amphipod (*Caprella scaura*).[143] In addition, lionfish (*Pterois volitans*) have colonized the southeastern United States from Florida to North Carolina over the past decade.[144] These represent some of the most recently discovered arrivals, although others are certain to arrive in the future. Invasive species can be extremely problematic because they may competitively displace existing species or cause radical habitat changes that affect entire populations or ecosystems. For example, beach vitex (*Vitex rotundifolia),* an introduced exotic plant from Hawaii, recently has taken over sand dune areas on some beachfronts in northern Georgetown and Horry counties. Its aggressive growth and impenetrable roots quickly cover dunes, making them unsuitable for loggerhead sea turtle nesting.[145] Species such as *Phragmites australis*, *Hydrilla verticillata* and *Eichhornia crassipes* are aquatic plants with similar impacts to brackish and freshwater areas in the United States where they create monocultures outcompeting native species and drastically altering the ecology of entire ecosystems. Another example is the nematode *Anguillicoloides crassus*, a parasitic worm originally located only in Asian eels (*Anquilla japonica*). The first record of *A. crassus* in wild-caught American eels (*Anguilla rostrata*) was from Winyah Bay in 1996,[146] having been introduced by the transport of live Asian eels. The parasite is much more detrimental to the health of American eels than its natural host, and it may exacerbate problems in this already declining species by interacting with other sources of stress, such as climate change. (Martin Vermeere, and Stefan Rahmstorff www.pnas.org/cgi/doi/10.1073/pnas.1015619108)

The recent range expansions of native North American mammals, specifically coyotes (*Canis latrans*), into South Carolina raise questions about the role climate change has played or may play in this phenomenon. Obviously, ranges have expanded and contracted over time but, more recently, it has become clear that transport and release by humans have placed animals and plants in new areas, and these species have occupied available habitats. In many cases they then compete directly with native species, to their detriment. The principal of natural range expansion is difficult to detect and describe and naturalization is difficult to determine.

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143 South Carolina aquatic invasive species management plan. Prepared in coordination with the South Carolina Aquatic Invasive Species Task Force by the South Carolina Department of Natural Resources. September 2008. 94 pp.

144 Albins, M. and M. Hixon. 2008. Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. Mar Ecol. Prog. Ser. 367:233–238.

145 Murphy, S. and D. Griffin. 2005. Loggerhead turtle - *Caretta caretta.* 2006. http://www.dnr.sc.gov/cwcs/pdf/Loggerheadturtle.pdf. Last accessed Dec 2010.

146 Fries, L.T., D.J. Williams and S.K. Johnson. 1996. Occurrence of *Anguillicola crassus*, an exotic parasitic swim bladder nematode of eels, in the SE United States. Trans. Am Fish. Soc. 125:794-797.

Recently, the armadillo (*Dasypus novemcinctus*) expanded its range into South Carolina from points south and west, and the federally endangered wood stork (*Mycteria americana*), that historically nested in Florida, now nests in significant numbers in this state. The available literature does not describe climate change as a factor in this expansion. Habitat loss and alteration for nesting and foraging are most often described as the major factors for range expansion of the wood stork.

Of greater threat are species currently located in Florida and South Georgia that come from more temperate parts of the world but have been historically limited to ranges south of South Carolina by cold winters. Significant climate change could allow northward and eastward range expansion in these species that would be detrimental to native species. Plants, birds, reptiles (especially large constrictors), amphibians and a few mammals are now reproducing in areas south of South Carolina. Inventory and monitoring is essential to determine and describe any changes in range of these exotic species.

3.2.3.2 DNR Response and Recommendations

DNR should continue monitoring wildlife and fish populations and their habitats for evidence of new invasive and non-indigenous species. Through existing programs within DNR, South Carolina needs to consistently fund and expand control activities to eliminate or reduce concentrations of those species where possible. DNR and others should seek to strengthen State laws regulating importation and transportation of non-native species and to implement the action items delineated under the goals and objectives of the South Carolina Aquatic Invasive Species Management Plan.

DNR is a partner in the South Carolina Aquatic Invasive Species Task Force and, through the Aquatic Nuisance Species Program, collaborates with the South Carolina Aquatic Plant Management Council to annually develop a South Carolina Aquatic Plant Management Plan. DNR also is active on regional levels with the Gulf States and South Atlantic Panel and on state levels with the South Carolina Exotic Plant Pest Council. Similar strategies to address nuisance and exotic species, particularly on conservation lands should be expanded within the state. Support is needed to develop and implement a comprehensive, prioritized monitoring strategy for the early detection of non-indigenous species. DNR also should seek to partner and collaborate with others working in this area.

Support of taxonomic expertise is an important component of any successful invasive species monitoring program. The Southeastern Regional Taxonomic Center (SERTC), located in the MRRI, has developed a curated collection of marine and estuarine animals from the SAB and maintains a searchable library of regionally relevant peer-reviewed taxonomic literature. Through collaborations with other labs and museums, SERTC has collected and preserved representative specimens from numerous habitats throughout the southeastern United States, documenting northern range extensions along the Atlantic Coast. Continued funding for this program needs to be secured. The

Center played an important role in developing the management plan for South Carolina aquatic invasive species.[147]

Prevention may be the best adaptive strategy to minimize the impact of invasive species. Enforcement of existing statutes related to intentional importation of non-indigenous species, such as apple snails (family *Ampullariidae*), is essential. Enforcement mechanisms should be strengthened; however, a review of all statutes and regulations regarding importation of non-indigenous organisms is recommended, with the legislative goal of a consolidated, comprehensive state law to minimize intentional and accidental introduction. A rapid response plan to eradicate, contain or control invasive species also is an essential tool to curtail the spread of invasive species.

3.2.4 **Potential for Increased Incidence of Pathogens**

3.2.4.1 Increased Incidence of Pathogens

Climate warming has been linked with a general increase in pathogens, which may have negative effects on host populations.[148]

The oyster disease Dermo (*Perkinsus marinus*) has been determined to be ubiquitous in South Carolina oysters although infection intensities are relatively low.[149] Infection intensities have consistently been relatively low, perhaps because Palmetto State oysters are almost exclusively intertidal and exposed to high summer temperatures that may inhibit the disease.[150] Another oyster disease, MSX (*Haplosporidium nelson*) has been infrequently detected in South Carolina and it is not known how climate change may affect the prevalence of this pathogen.

An apparent outbreak of disease caused by the hemolymph-infecting dinoflagellate *Hematodinium* in the late 1990s in Georgia reportedly led to substantial mortalities in blue crabs and other crustaceans. It is believed that the outbreak was initiated by a prolonged drought that resulted in higher salinities in estuaries, thus favoring the growth of *Hematodinium*.[151] In many South Carolina estuaries, blue crabs can escape to lower salinity refuges, but in the northern part of the state these refuges may not be available. Knowledge of the dynamics of hosts and pathogens in the marine environment is limited, but where disease outbreaks occur, they often are associated with unusual

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[147] South Carolina Department of Natural Resources. 2008. South Carolina aquatic invasive species management plan. http://www.dnr.sc.gov/invasiveweeds/aisfiles/SCAISplan.pdf. Last accessed Dec 2010.

[148] Harvell et al. 2002. Climate warming and disease risks in terrestrial and marine biota. Science 296: 2158-2162. Hereafter Harvell et al. 2002.

[149] Bobo, Y., D. Richardson, L. Coen and V. Burrell. 1997. A report on the protozoan pathogens *Perkinsus marinus* (Dermo) and *Haplosporidium nelson* (MSX) in South Carolina shellfish populations. SC DNR Mar. Res. Div. Tech. Rept. No. 86. 50 pp.

[150] Bushek, D. 1997. Chlorine tolerance of the eastern oyster pathogen, *Perkinsus marinus*: Standards for sterilization and quarantine. Grant # P/M-2A, SC Sea Grant Consortium Final Rept.

[151] *Hematodinium* Continues - No Let-Up in Sight. 2002. The Georgia Blue Crab Journal. http://crd.dnr.state.ga.us/assets/documents/BlueCrabNewsletterapr02.pdf. Last accessed Dec 2010.

climatic events.[152] The potential for outbreaks of new pathogens is high because of the expectation of greater variation in climate over the next few decades and invasion of species carrying non-native pathogens.

Large-scale disease mortality in wild penaeid shrimp has not been observed in South Carolina; however, disease and mortality in nonnative shrimps in aquaculture farms within the state has been documented. Cultured shrimp are vulnerable to a number of viruses with susceptibility varying among species, but thus far, no known mortality has occurred in the wild populations of South Carolina. Because pathogenic viruses are known to exist and shrimp are more vulnerable when exposed to multiple stresses, including high temperature and salinity, additional stresses caused by climate change may have a negative effect on wild populations.[153] [154] A pathogen that is known to affect wild shrimp is the black gill (brown gill) syndrome. This condition is caused by an apostome (protozoan) that attaches to shrimp gills and causes melanization, or a darkening of the chitinized exoskeleton. This disease typically is most common when coastal waters are warmest in August and September.[155] Although no directly related mortality has been documented, it is clear that shrimp stamina, ability to escape predators and probably resistance to disease are compromised by the condition. The lowest incidence of the disease since 1999 occurred in 2001 following a relatively cold winter. These apparent relationships to water temperature may suggest that warmer winters and summers associated with climate change may amplify the disease.

Changes in temperature regimes may result in an increase in wildlife and fish diseases that are adapted to warmer conditions. Warmer temperatures can increase the potential for invasion by new pathogens, or increase risk of more serious invasions by existing pathogens. Not only could such pathogens affect wildlife and fish, effects to native vegetation could alter habitats and make them unsuitable for native species. Sudden oak death and the hemlock wooly adelgid infestations are already changing the landscape of some of South Carolina forests, making them potentially more vulnerable to invasion.

3.2.4.2 DNR Response and Recommendations

A proactive program monitoring the health of aquatic animals is not feasible. The potential pathogen pool is large and resources and tools are limited. The most adaptive approach is vigilance for potential pathogens and collaboration with the Clemson Veterinary Diagnostic Center. Advances in molecular technologies have developed a broad range of diagnostic tools that allow scientists to assess thousands of known pathogens in a single assay. It is not known if similar tools for other species are available. Efforts to monitor interstate movement of potentially infected animals should

[152] Harvell et al. 2002.
[153] Zein-Eldin, Z. and M. Renaud. 1986. Inshore environmental effects on brown shrimp, *Penaeus aztecus,* and white Shrimp, *P. setiferus,* populations in Coastal waters, particularly of Texas. Mar. Fish. Rev. 48(3):9-19.
[154] Zhan, W., Y. Wang, J. Fryer, K. Yu, H. Fukuda and Q. Meng. 1998. White spot syndrome virus infection of cultured shrimp in China, J. of Aquatic Animal Health 10:405-410.
[155] Whitaker, D., J. Powers, B. Gooch, N. West and A. Von Harten. 2009. Cooperative research in South Carolina – SC DNR Final Report to National Marine Fisheries Service NOAA, Grant Number NA04NMF4720306. p 45-49.

be continued and enhanced. Research should continue for the development of diagnostics, particularly field tests that can be used to identify pathogens.

Continued support is needed to monitor wildlife and fish populations and their habitats for evidence of new disease and parasite infestations. DNR should maintain and strengthen regional and national contacts and interactions related to disease and parasite challenges, including participation in the Southeastern Cooperative Wildlife Disease Study.

3.3 Impacts to Commercial and Recreational Fishing and Hunting and Other Public Uses of Natural Resources Resulting from a Changing Climate

3.3.1 Potential for Changes in Recreational and Commercial Opportunity

Wildlife and fish populations likely are to be altered as climate change occurs. Such changes may result in reduced commercial and recreational hunting and fishing opportunities of some species, although opportunities may increase with others. As populations are monitored, it may become necessary to alter seasons or bag limits on some species. It will be important to keep the public notified of changes as they occur in order to reduce the potential for conflict between human and natural resource needs and values.

3.3.2 DNR Response and Recommendations

Long-term monitoring of harvested species should be conducted in order to detect temporal and spatial changes in numbers and prevent unsustainable population declines. Research is needed to model and understand the relationship between climate change and population dynamics of important species. Outreach and education are required so that South Carolina residents, city and county officials and legislators understand changes in natural resources resulting from climate change. Strategies and policies are needed to establish compromises that balance needs of the resource with human needs and uses.

3.4 Natural Resources Education and Outreach Needed as a Result of a Changing Climate

3.4.1 Needs for Climate Change Impacts Education and Outreach

Climate change potentially will cause significant alterations to the nature and structure of habitats and species distributions in the southeastern United States including South Carolina. Coastal communities, in particular, will become increasingly vulnerable to a wide range of hazards including hurricanes, shoreline erosion, flooding and storm surge. The impact of these hazards is compounded by coastal development as coastal population increases and coastal ecosystems are degraded. A resilient community understands the potential impacts of these hazards and prepares itself to respond with timely and holistic management strategies. This gives communities the ability to recover after hazard events and adapt to future conditions.

3.4.2 DNR Response and Recommendations

A critical element of the DNR response to climate change is to increase public awareness of the potential adverse, and positive, effects resulting from these changes. Agency efforts at outreach and education are threefold:

1. DNR should strengthen and increase partnerships with other agencies and organizations involved in climate change research and policy and planning. For example, the Southeast Natural Resource Leadership Group (SENRL), an interagency collaboration established to improve communication on natural resource issues, has recognized the need for natural resource agencies to proactively guide policy, management and socioeconomic decision making regarding climate change.[156] The DNR should seek opportunities to participate in national and local networks such as the SENRL and the recently established Southeastern Climate Science Center. National and local networks are a rich source of information, ideas, research and funding opportunities. Participation in such efforts can greatly increase the efficiency and effectiveness of a state climate change response plan.
2. DNR must assist local communities in planning for change and providing coastal resiliency to reduce overall vulnerability of economic and ecological systems to climate variations. The agency's education programs can help inform decision making in the state regarding climate change by strengthening regional and local partnerships for improved community response. Communities will need assistance planning for their response to potential hazards by considering institutional capacity, land development patterns and natural resource conservation. DNR alone cannot respond to the needs of these communities; however, DNR regularly works with partners that can provide access to information and tools designed to help communities identify critical linkages and understand how decisions impact their community and the environment. By strengthening regional and local partnerships, DNR can help respond to the needs of communities by linking them with the information they require.
3. DNR will play an important role in communicating information on climate change to citizens of South Carolina. Through partnerships with educators and policy makers, DNR research and management staff can work with these groups to translate scientific information into action. The agency will use the World Wide Web to publish reports, news articles and other information involving climate change as well as to provide a mechanism for public comment and input into the process. By involving the public in the research process, DNR will build buy-in from the community and capacity at the local level to respond adaptively to future conditions. The importance of resilient communities will increase as the impacts of climate change are felt. In addition, substantial

[156] Southeast Natural Resource Leadership Group. 2008. Meeting notes. 14 pp.

efforts should be made by agency staff to publish their research data and analysis in peer-reviewed scientific journals.

Climate change is a global concern with potentially significant impacts to South Carolina. To understand and assess the impacts to the human and natural resource populations of this state will involve the cooperative efforts of many agencies, scientists and planners as well as the local community. Education of the state's citizens on the negative and positive impacts of climate change is an essential component of this process. Each of these outreach initiatives is critical to improving the state's capabilities to respond and adapt to climate change. Through regional, state and national partnerships, DNR can help communities protect themselves and the important natural resources surrounding them.

3.5 Technologies Needed to Mitigate and Protect Natural Resources as a Result of a Changing Climate

3.5.1 Technologies Needed to Monitor Physical and Biological Change

Understanding and monitoring climate change impacts on the state's natural resources will require the enhancement of the agency's technology infrastructure, database and analysis and modeling capabilities. Various DNR programs have collected natural resource data for the state, and these historic and recent data are maintained in disparate database systems. For example, the South Carolina Climate Office records hourly and daily temperature, precipitation, storm event and other meteorological data from numerous weather stations throughout the state. These data are stored in Oracle and are used by staff in regional drought analysis and monitoring studies. Similarly, the South Carolina Geological Survey and the USGS established cooperative programs to record surface and ground water and lithologic data from various river/stream gauges and well monitoring stations. These data primarily are maintained in Oracle with some tables residing in Microsoft Access. WFFD maintains numerous fisheries, wildlife, botanical and other habitat-related databases in a variety of mainframe, server and PC-based database management systems.

MRD has a variety of long-term data sets containing both physical and biological data. For example, MRRI maintains several long-term fishery and water-quality databases that are relevant to evaluating the effects of climate change on those resources. These include: the MARMAP fishery independent monitoring program of offshore (deepwater) reef fish that extends back 20+ years and the SEAMAP fishery independent monitoring program of nearshore non-reef finfish and crustacean species that also extends back 20+ years. Both of these programs collect data from Cape Hatteras to Cape Canaveral that includes basic water quality measures and both use standardized sampling programs that facilitate long-term trends analysis. MRRI also maintains a 10-year database of juvenile loggerhead sea turtle distribution and density that extends from about Winyah Bay south to and including the northern portion of Florida.

To facilitate inshore monitoring, the MRRI conducted a standardized trammel netting program to assess the composition and abundance of the state's recreational finfish species for 20+ years, and another standardized sampling program to assess the relative abundance and distribution of shrimp and blue crabs that is also 20+ years in duration. The MRRI also participates in several programs to determine and assess environmental measures affecting coastal resources. In cooperation with DHEC, the MRRI has conducted an annual statewide assessment of water quality, sediment quality and biological resources for bottom invertebrate fauna, fish and crustaceans since 1999. The ACE Basin NERR program also has nearly continuous water quality and weather data extending back to 1995 and this program is expected to continue to be maintained in the future.

Mining these various data sets for long-term trends is a critical need, but the data are stored in a variety of formats and in many cases are not in advanced information management systems. Therefore, it is strategically important to develop a comprehensive spatial and tabular database of existing natural resources data and integrate various analytical, statistical and modeling tools to forecast trends and project changes in the distribution of these resources in response to climate change.

DNR also has extensive natural resources spatial data in the agency's geographic information system. These data include statewide soils, wetlands and land use, hydrography, known threatened and endangered species locations, road centerlines, administrative boundaries, contours, digital elevation models, agency owned and/or managed lands and boat ramps, surface and subsurface geology, multi-temporal digital orthophoto quarter quadrangles and Landsat Thematic Mapper satellite imagery. Statewide land cover data was classified from Landsat TM data for the 1985/86, 1992/93, 1997/98, 2002/03 and 2008/09 time periods. These data can be used to provide baseline trends in habitat change and to project potential future impacts from climate change and sea-level rise. Similarly, MRD has developed new oyster maps that provide detailed base imagery and shape files of intertidal shellfish resources. These imagery products also could be used to evaluate changes in wetland vegetation extent and distribution over time which has tremendous potential value in evaluating loss of wetlands and shellfish due to sea-level rise. More recently, the agency initiated a statewide program to develop high resolution elevation data using Light Detection and Ranging (LiDAR) technologies. These data provide digital elevation models with a vertical accuracy of 15.0 to 18.5 cm in open terrain which is essential for sea-level rise and wetland change modeling.

3.5.2.1 DNR Response and Recommendations

In order to meet the agency's long-term needs for responding to climate change impacts in South Carolina, numerous additional strategies and technologies will be required to include:

1. DNR needs to implement a resource inventory and monitoring program to track trends in resource abundance and distributions at the species and landscape

levels as determined to be viable and appropriate to the agency mission. This inventory will require input from all sections and groups, and should expand upon existing data collection and monitoring programs as discussed in Section 3.5.1. Further, it should include the use of various satellite image processing data and tools to systematically assess changes to the vegetative structure and man-made landscape features of the state. Access to accurate, long-term monitoring databases is critical for developing strategies to respond to climate change impacts; therefore, implementation of these comprehensive monitoring programs should be considered a priority.

2. The agency must expand its existing technology infrastructure to support the climate change studies. This includes the implementation of various direct and remotely-sensed measurement platforms to provide *in situ* documentation of sea-level rise, temperature and precipitation, stream flow and other critical data and the integration of all data collected through agency resource inventories in a comprehensive Oracle database. Coupled with various data mining and warehousing technologies, this would enable examination of data for trends and patterns useful for understanding climate change impacts. Further, as these long-term data and information are recorded and analyzed, additional network bandwidth, data storage and computational processing capabilities will be required to support the volume and complexity of scientific, graphic, GIS, imagery and video applications. Additionally, partnerships should be established with other southeastern states and academic institutions to develop a standardized data schema and information delivery platform that will facilitate sharing/exchange of regional data, analysis results and reports.
3. DNR also must develop appropriate data access, scientific analysis (statistical, biometric, image processing, spatial modeling and forecasting, etc.) and resource management decision-support tools to assess the impacts of climate change and develop appropriate management strategies. These tools must include business intelligence and data mining technologies to discover patterns inherent in the data and extensive use of the World Wide Web to disseminate relevant information to the public regarding climate change and its impacts to the state's natural resources. Where available, the agency should implement commercial-off-the-shelf (COTS) solutions that can be augmented with software and applications developed by agency programming staff that address issues specific to natural resources management in South Carolina. For example, the Sea Level Affecting Marshes Model (SLAMM) developed by the United States Fish and Wildlife Service can be adapted from its general visualization modeling application to incorporate high resolution LiDAR elevation and soils data to model potential impacts of sea-level rise on salt and brackish marshes along the coast. Other software tools appropriate to the needs of the DNR are available from various federal and state governments including numerous sea-level rise and biodiversity impact assessment technologies developed by the NOAA Coastal Services Center. These assessment tools should be evaluated for application to the needs of the DNR for determining climate change impacts in the state.

4. Finally, DNR must develop the expertise required to meet the challenges of understanding and addressing the vast array of environmental impacts and natural resource management issues associated with climate change. Staff training in various analytical, modeling and geographic information systems software and associated technologies is essential. Similarly, sponsorship and participation in various regional programmatic workshops and technical committees are critical for developing and maintaining strategic climate change response initiatives.

The creation of long-term monitoring programs, implementation of new technologies and establishment of regional partnerships are essential components of the DNR's response to climate change in South Carolina. The efforts required to accomplish these key objectives may be facilitated by outside funding sources, as many grant opportunities now support or require the development of digital data and implementation of innovative technologies. Additionally, cooperative partnerships facilitate information sharing, which increases the efficiency and effectiveness of programs and opens opportunities for additional funding sources.

4.0 NATURAL RESOURCES LAW ENFORCEMENT DURING AN ERA OF CLIMATE CHANGE

The Law Enforcement Division (LED) is responsible for enforcement of state and federal laws governing hunting, recreational and commercial fishing, recreational boating and other natural resources conservation concerns; promoting safety and developing public support through education and outreach. Additionally, the LED is tasked with assisting other state and federal agencies with varying security missions dealing with non-natural resource issues and events.

Climate change can no longer be considered solely an environmental issue. The physical effects of climate change will have both natural resources impacts as well as socio-economic impacts including the loss of infrastructure, resource scarcity and displacement of life and property. In turn, these impacts could produce security consequences to include civil unrest and instability, presenting new challenges to law enforcement agencies and governments attempting to maintain order and rule of law.[157]

[157] Abbot, C. 2008. An uncertain future: Law enforcement, national security and climate change. Oxford Research Group. http://www.bvsde.paho.org/bvsacd/cd68/uncertain.pdf. Last accessed May 2010.

Table 4.1 Anticipated public safety effects related to climate change in South Carolina.[158]

Weather Event	Public Safety Issue	Population Affected	Public Safety Burden
Heat waves	Heat stress	Elderly, socially isolated, poor, those already health impacted	Low to moderate
Increase in mean temperature	Heat stress, increased disease	Outdoor workers, elderly, poor, outdoor recreationalists	Low to moderate
Extreme weather events	Injuries, drowning	Coastal and Lowcountry dwellers, the poor, outdoor recreationalists	Moderate
Severe winter weather	Injuries, hypothermia, drowning,	Elderly, poor, outdoor recreationalists	Moderate
Sea-level rise	Injuries, drowning, water and soil salinization, ecosystem and economic disruption	Coastal and Lowcountry dwellers, outdoor recreationalists	Moderate
Drought, ecosystem migration	Water shortage, low rivers and lakes, boating accidents, food shortage	Elderly, children, poor, outdoor recreationalists, multiple populations	Moderate to high
Floods	Excess water, dam failures, crop losses, livestock loses, loss of pollution containment, loss of human life	Multiple populations	Moderate to high
Severe climate change	Heat stress, drowning, water shortage, limited food availability, human conflict	Multiple populations	High

4.1 Marine Law Enforcement

4.1.1 Marine Law Enforcement Issues

Marine law enforcement primarily is responsible for enforcing recreational and commercial fishing laws, promoting boating safety and investigating boating incidents in the marine environment. DNR officers regularly conduct search and rescue missions in outlying areas and assist other law enforcement agencies in investigations. The LED has officers trained in underwater diving to assist in law enforcement, search and rescue and evidence recovery missions. The Division also utilizes aircraft for law enforcement patrol, search and rescue and other department missions. The LED is called upon to provide homeland security missions related to waterborne activities including, but not limited to, commercial ship escorts and port security.

[158] Balbus, J.M. and M. L. Wilson. 2000. Human health and global climate change: A review of potential impacts in the United States. Washington, DC: Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/human_health.pdforg/global-warming-in-depth/all_reports/human_health. Last accessed Oct 2010.

As certain species adapt to climate change some will shift ranges creating additional opportunity for commercial and recreational fishing in the marine environment. These shifts in range and availability will be magnified by human population growth and additional resource pressure. Sensitive habitats may be threatened, requiring additional monitoring and patrols to stem illegal activities and overharvests. The need for conservation enforcement will become apparent as this process unfolds. In view of the possible decline of food resources there will be ever increasing pressure to push the boundaries of conservation to meet economic and food supply needs. In the case of a catastrophic event these issues will manifest themselves at the most basic level, where everyday citizens stressed by poor economic and environmental conditions will begin subsistence fishing by harvesting whatever is available to meet daily needs. Law enforcement will be the only line of defense between these individuals and overharvesting of species. Additionally, alternative energy development will usher in a new set of law enforcement issues in order to monitor and protect marine energy development infrastructure.

In addition to resource protection, the LED may be faced with an increasing recreational boating population along our coastline as a result of higher temperatures and possible longer boating seasons. As a result, enforcement of recreational boating may not be readily available if the current trend of reducing officer positions continues.

4.1.2 DNR Response and Recommendations

Funding for an adequate, if not expanding, natural resource law enforcement presence in the marine environment will be necessary. Partnerships with federal and other state and local law enforcement agencies will be required.

4.2 Inland Law Enforcement

4.2.1 Inland Law Enforcement Issues

As in the marine environment, the LED is responsible for enforcing recreational and commercial fishing laws, promoting boating safety and conducting boating incident investigations on inland surface water bodies. DNR officers regularly conduct search and rescue missions in the air and on or under the surface of rivers, lakes and ponds assisting other law enforcement agencies in investigations. The LED performs homeland security missions related to waterborne activities near hydroelectric dams, nuclear facilities and other energy production facilities. Additionally, the LED is tasked with protecting land-based game and non-game species as well as investigation of hunting related incidents.

Climate change may shift ranges of popular species pursued through recreational hunting and fishing, bringing pressures on sensitive species and habitats; such as the threat that warming and drought imposes on aquatic species, for example, trout and anadromous fish. These threats will be magnified by human population growth and additional resource pressures. Sensitive habitats may be threatened, requiring additional monitoring and patrols to stem illegal activities and over harvests.

As within the marine environment, the need for conservation enforcement will be apparent as this process unfolds. With ever increasing pressure to push the boundaries of conservation to meet economic and food supply needs, every day citizens stressed by poor economic and environmental conditions will begin subsistence fishing and hunting by harvesting whatever is available to meet daily needs. Law enforcement will be the only line of defense between these individuals and the overharvesting of species.

Additionally, as higher temperatures and longer seasons become stabilized, the LED will be faced with an ever increasing recreational boating population. As a result, enforcement of recreational boating activity may not be readily available if the current trend of reducing officer positions continues.

4.2.2 DNR Response and Recommendations

Funding for an adequate, if not expanding, natural resource law enforcement presence in inland areas will be necessary. Partnerships with federal and other state and local law enforcement agencies will be required.

4.3 Public Safety

4.3.1 Public Safety Issues

The potential public safety effects of climate change have been extensively reviewed.[159] Many are health and safety related. Principal public safety concerns include those related to severe weather events and heat waves. Indirect concerns, for which data to support projections are less available and uncertainties are greater, include human competition for available resources, population dislocation and civil conflict/unrest. In addition, changes in the patterns of pests, parasites, and pathogens may affect wildlife, agriculture, forests and coastal habitats and can alter ecosystem composition and functions. Climate change may disrupt these life-support systems and carry implications for public safety.

Very few public safety laws and regulations currently have a direct bearing on climate change. However, public safety officials can provide science-based input regarding laws and regulations affecting the environment, natural resources and alternative energy arenas. As policies are codified, there may be roles for state and local public health agencies in enforcing such policies including water quantity and quality regulations as an example.

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[159] Frumkin, H., J. Hess, G. Luber, J.Malilay and M. McGeehin. 2008. Climate Change: The Public Health Response. Am. J. Public Health. 98:435-445. http://www.bvsde.paho.org/bvsacd/cd68/HFrumkin2.pdf. Last accessed Sept 2010.

4.3.2 DNR Response and Recommendations

There is widespread scientific consensus that climate is changing and it also is being reported in the public safety arena.[160] Mounting evidence suggests there will be future impacts on public safety, including illnesses and injuries associated with heat stress and exposure. Other future impacts will include incidents related to drought caused by shallow surface waters, severe weather events and floods. Finally there are likely to be public safety impacts to surface- and ground-water supplies. Indirect effects may include the consequences of mass migration and human conflicts over available resources. Addressing these occurrences to public safety will be a pressing challenge for natural resource and other law enforcement agencies. Although the scope and complexity of the challenges may be unprecedented, the conceptual framework for responding will draw on long-standing public safety policy. An effective public safety response to climate change is essential to preventing injuries and illnesses, enhancing preparedness, and reducing risk. Science-based decision-making will help manage uncertainty and optimize environmental outcomes.[161]

As climate change evolves, the role of natural resources law enforcement will be required to adapt. There will be a need for additional emphasis on protecting dwindling resources requiring the need for enhanced conservation enforcement. Also, public ambivalence to natural resources will become apparent as the need for gathering food becomes a priority at an unknown cost to all fish and wildlife resources. In either case, the role of the LED will evolve with a greater focus on resource enforcement or a greater focus on more traditional roles of law enforcement where public safety is the priority. In either instance, the LED, in the face of an ever-changing world, will continue to play an increasing role in traditional public safety.

[160] IPCC. 2007.
[161] IPCC. 2007.

5.0 SUMMARY AND PRIORITY LIST OF CLIMATE CHANGE ISSUES

5.1 Overarching Issues and DNR Recommendations

This first report from DNR sets the foundation for actions needed to address climate change impacts to natural resources in South Carolina. The report identifies the overriding natural resource issues and provides recommended actions to keep South Carolina at the forefront of conserving natural resources during an era of changing climate. These overarching issues include the potential for:

1. Detrimental change in habitat,
2. Detrimental change in abundance and distribution of species,
3. Detrimental change to biodiversity and ecosystem services,
4. Detrimental change on the traditional uses of natural resources including hunting, fishing, other compatible public uses, forestry and agriculture,
5. Detrimental change in the abundance and quality of water, and
6. Detrimental change in sea level.

Specific tasks identified by DNR in order to move forward in an era of climate change while protecting natural resources include:

1. Spatial mapping,
2. Monitoring and establishing baselines on
    a. Living resources,
    b. Non-living resources, and
    c. Climate trends.
3. Habitat acquisition,
4. Adaptation strategies on DNR-titled properties,
5. Integration and analysis of data,
6. Outreach and education,
7. Developing additional partnerships and collaborating with others, and
8. DNR leading by example.

5.2 DNR Leading by Example

DNR is making climate change an integral part of the agency's ongoing mission. A Climate Change Impacts Technical Working Group (CCI-TWG) was formed with representatives from each division. The CCI-TWG reports directly to the Executive Office and was charged with the completion of this comprehensive report addressing the potential impacts of a changing climate to natural resources in South Carolina. The CCI-TWG developed recommendations that will lead to integrating climate change into the DNR organizational culture, its structure and all aspects of its work. These key steps include:

1. Develop an approach that will incorporate climate change into DNR strategic and operational plans and existing structure that can be used as a vehicle for internal and external communication,
2. Ensure that all levels of agency staff are aware of, and appropriate staff engaged in, climate-change initiatives,
3. Update and align DNR actions with regional and national climate-change initiatives as appropriate,
4. Work with stakeholders and partners on fish and wildlife adaptation and mitigation,
5. Prepare an internal and external outreach strategy to communicate climate change issues, and
6. Develop clear and measurable indicators to track the results of DNR climate change efforts.

To accomplish its mission, DNR recommends the following core climate change foci of effort:

1. Policies and Opportunities – focus on grants, legislation, partnerships and strategic planning,
2. Research and Monitoring – focus on standardized monitoring protocols and state-specific data (including gaps) and predictive modeling,
3. Communication and Outreach – focus on the DNR messages and a climate change communication plan,
4. Adaptation – focus on the activities related to unavoidable climate-change impacts on fish and wildlife, and
5. Operations – focus on positioning DNR as a leader by reducing the agency's carbon footprint, improving its energy efficiency and decreasing operational costs by accomplishing the following:
    a. Achieve increased fuel economy through fleet reduction, use of more efficient vehicles as well as implementing efficient wildlife and fisheries management and law enforcement where combustion engines are required,
    b. Achieve increased energy efficiency through obtaining energy audits for agency buildings and adoption of practicable energy audit recommendations,
    c. Implement practicable water efficiency measures for agency buildings, and
    d. Implement paperless internal communications and document management.

DNR is taking a lead role among South Carolina state agencies to advance the scientific understanding of the vulnerability of South Carolina's vital natural resources during an era of changing climate. These actions and advocacy for sound planning should enable the agency, its partners, constituents and all Palmetto State citizens to avoid or minimize the anticipated impacts. The agency will strive to lead by example, work to create ecosystem resiliency and partner with others to preserve and protect South Carolina’s natural resources.

Appendix 3. Details of dredging occurring near Charleston, SC.

DEPARTMENT OF THE ARMY
CHARLESTON DISTRICT, CORPS OF ENGINEERS
69A HAGOOD AVENUE
CHARLESTON, SOUTH CAROLINA 29403-5107

FINDING OF NO SIGNIFICANT IMPACT

CHARLESTON HARBOR ADDITIONAL ADVANCED MAINTENANCE DREDGING

CHARLESTON HARBOR, SOUTH CAROLINA

September 22, 2009

The National Environmental Policy Act (NEPA) requires the U.S. Army Corps of Engineers, Charleston District (The Corps) to evaluate the effect of proposed projects on both the environment and human health and welfare. This Finding of No Significant Impact (FONSI) summarizes the results of The Corps' evaluation and documents The Corps' conclusions.

The Corps has prepared an Environmental Assessment (EA) that covers maintenance dredging practices in Charleston Harbor. Charleston Harbor is located midway along the South Carolina coastline approximately 140 statute miles southwest of the entrance to Cape Fear River, North Carolina and approximately 75 statute miles northeast of the Savannah River (see Figure 1). The EA discusses dredging depths not addressed in the 1996 Feasibility Report and 1996 EA for deepening and widening the Charleston Harbor Federal Navigation Channel. The 1996 Report/EA indicated an authorized depth of 45 feet (47-foot deep entrance channel) plus 2 feet of advanced maintenance and 2 feet of allowable overdepth for a total potential dredging depth of 49 feet. Allowable overdepth dredging is to assure the project is constructed to the authorized depth, and advanced maintenance dredging is conducted in high shoaling areas to enable the project to remain at the authorized depth for a longer period of time.

During the harbor deepening project (1999 through 2004), portions of several reaches were dredged 2 to 4 feet deeper (additional advanced maintenance) because of historically higher shoaling rates. This resulted in potential dredging depths of either

51 feet or 53 feet in those areas. Since completion of the harbor deepening project in 2004, maintenance dredging, including the additional advanced maintenance, has been performed on a 12 to 18 month frequency. This additional advanced maintenance in the higher shoaling areas was not addressed in the 1996 Report/EA and is the reason for the Charleston Harbor Additional Maintenance Dredging EA, 2009.

Based on recent dredging projects, the anticipated average annual maintenance dredging needs for Charleston Harbor are approximately 2,200,000 cubic yards. About 1,360,000 cubic yards of this total go to the EPA designated Charleston Ocean Dredged Material Disposal Site (ODMDS), of which, about 310,000 cubic yards is from the additional advanced maintenance areas. About 840,000 cubic yards of the total go to the Clouter Creek Disposal Area, of which, about 330,000 cubic yards are from the additional advanced maintenance areas. These annual volumes should average the same for the foreseeable future.

The Corps evaluated two alternatives in the EA: No Action and the Proposed Project. Both alternatives will use the same dredging methods and the same disposal locations and are expected to result in the same quantity of material being dredged.

- **No Action** – The no action alternative is what was discussed in the 1996 Report/EA. As indicated above, those documents covered a project depth of 45 feet plus 2 feet of advanced maintenance and 2 feet of allowable overdepth (45+2+2) for a total potential dredging depth of 49 feet (2 feet deeper in the entrance). However because of higher shoaling rates in certain areas, a portion of the harbor would need to be dredged as frequently as twice per year to maintain the authorized depth and allow efficient ship navigation. This would result in an increased annual cost of about $2,085,000 primarily due to more frequent mobilization of dredging equipment and a higher unit cost.

- **Proposed Project** – For the proposed project, most of the project would be maintained to a project depth of 45 feet plus 2 feet of advanced maintenance and 2 feet of allowable overdepth (45+2+2). Due to higher shoaling rates, portions of the following reaches would continue to be maintained to either 45 feet plus 4 feet of advanced maintenance and 2 feet of allowable overdepth (45+4+2) or 45 feet plus 6 feet of advance maintenance and 2 feet of allowable overdepth (45+6+2): Ordnance Reach and Turning Basin, Lower Wando River, Wando Turning Basin, and Lower Town Creek Reach are all dredged 2 feet deeper (i.e. 45+4+2); and Drum Island Reach is dredged 4 feet deeper (i.e. 45+6+2). These areas with higher shoaling rates are indicated in Figure 2. The additional advance maintenance dredging will enable the harbor to continue to be maintained on a 12-18 month frequency. This will result in a decreased annual cost of about $2,085,000 compared to the no action alternative primarily due to less frequent mobilization of dredging equipment and a lower unit cost.

The Corps' criteria for evaluating the effect of both the no action alternative and the proposed project included the following:

- **Wetlands**: No adverse affect on wetlands are expected as a result of implementing either the no action alternative or the proposed project.
- **Water Quality**: A short-term increase in turbidity will occur during dredging activities associated with both alternatives. However, because of the more frequent dredging associated with the no action alternative, these turbidity increases would occur more often if the proposed project is not implemented. The temporary impact to water quality resulting from the proposed project was determined to be of short duration and cause minimal temporary disturbance to water quality.
- **Cultural Resources**: No effects on cultural resources are expected as a result of implementing either the no action alternative or the proposed project.
- **Threatened and Endangered Species**: There is a minor risk to threatened and endangered species as a result of implementing either the no action alternative or the proposed project. Either alternative may affect but is not likely to adversely affect threatened and endangered species. However, the risk is slightly higher resulting from the more frequent dredging associated with the no action alternative.
- **Benthic Organisms**: There will be impacts to benthic organisms associated with both the no action alternative and the proposed project. However, the impacts to benthic organisms will be greater as a result of the no action alternative. The impact to benthic organisms resulting from the proposed project was determined to cause a temporary disturbance that would result in short term minimal impacts to benthic populations.
- **Fisheries**: There is a potential impact to fisheries associated with both the no action alternative and the proposed project. However, the impacts to fisheries will be greater as a result of the no action alternative. The impact to fisheries due to the proposed project was determined to result in minimal impacts to overall fisheries populations.
- **Socioeconomic**: No adverse affect on socioeconomic conditions are expected as a result of implementing either the no action alternative or the proposed project.
- **Air Quality**: There will be a minor impact to air quality as a result of implementing either the no action alternative or the proposed project. However, the impact is slightly higher resulting from the more frequent dredging associated with the no action alternative.
- **Cumulative Impacts**: There are some cumulative impacts associated with both the no action alternative and the proposed project. However, the cumulative impacts will be greater as a result of the no action alternative. The cumulative impacts resulting from the proposed project were determined to be negligible.

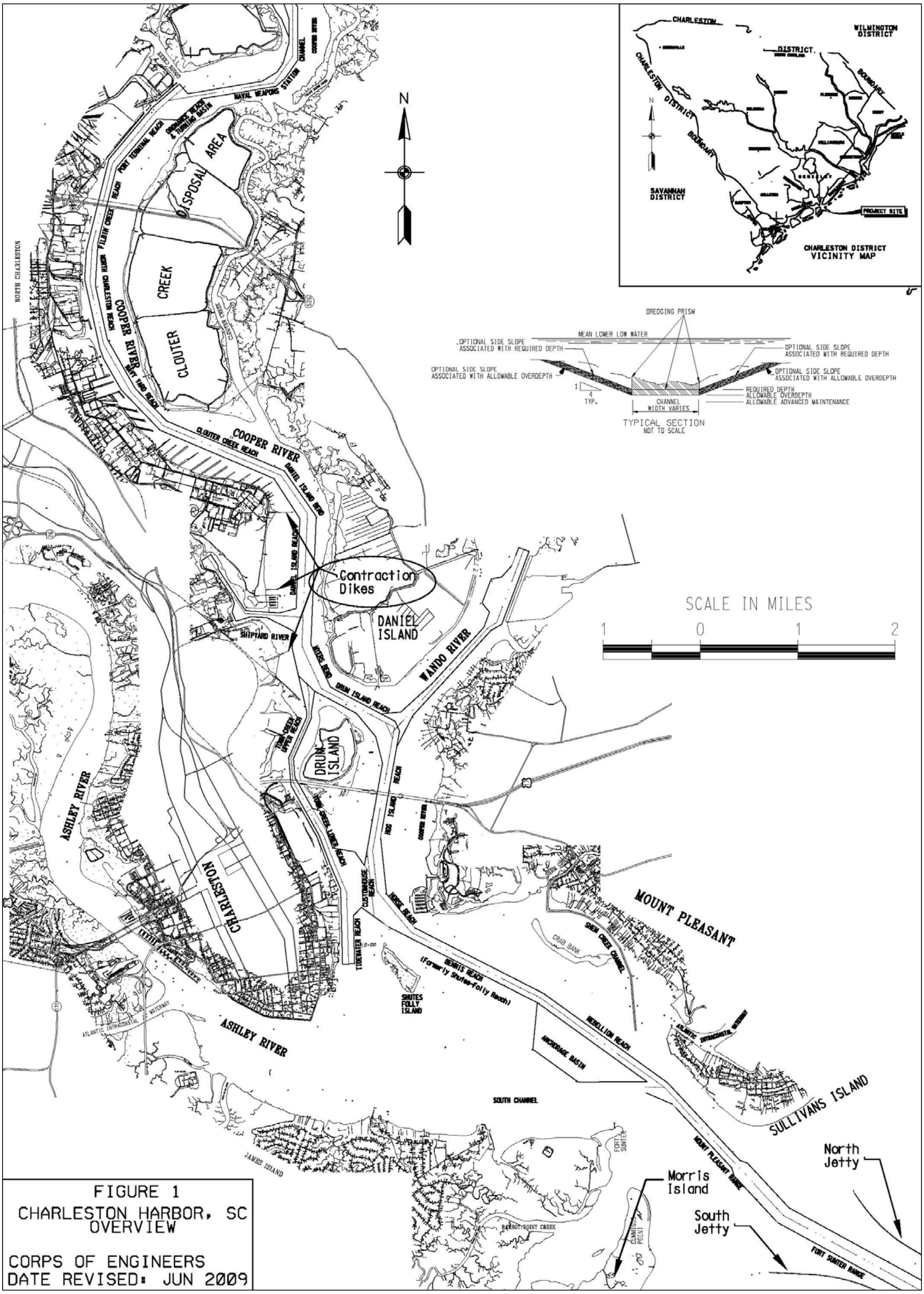
Because the additional advanced maintenance areas have already been dredged and have been maintained at the same time as routine maintenance events, no significant environmental impacts are expected from continuing this dredging practice. In addition, if the proposed project is implemented, dredges will be in the harbor less frequently, resulting in fewer impacts compared to the no action alternative.

Implementing the proposed action will also result in an average annual savings in dredging costs of approximately $2,085,000 compared to the no action alternative. Therefore, the proposed project is recommended for long-term maintenance of Charleston Harbor.

A draft EA and FONSI were distributed in July 2009 for a 30 day comment period. No substantial adverse comments were received. Therefore, the Corps' findings are that the proposed project does not significantly adversely affect the environment or human health and welfare and, therefore, preparation of an Environmental Impact Statement is not warranted. The full Environmental Assessment can be downloaded from the internet at *http://www.sac.usace.army.mil/?action=environmental.assessment* or a copy may be obtained by contacting Mr. Alan Shirey by telephone at (843) 329-8166 or by e-mail at *alan.d.shirey@usace.army.mil*. The 1996 Feasibility Study and 1996 EA can also be downloaded from the internet at the same site listed above.

Date 24 September 2009

Jason A. Kirk, P.E.
Lieutenant Colonel, EN
Commander, U.S. Army Engineer District, Charleston


Contraction Dikes
DANIEL ISLAND
WANDO RIVER
COOPER RIVER
CLOUTER CREEK DISPOSAL AREA
DRUM ISLAND
ASHLEY RIVER
CHARLESTON
MOUNT PLEASANT
SULLIVANS ISLAND
Morris Island
North Jetty
South Jetty
SCALE IN MILES
1 0 1 2
TYPICAL SECTION
NOT TO SCALE
CHARLESTON DISTRICT VICINITY MAP
FIGURE 1
CHARLESTON HARBOR, SC
OVERVIEW
CORPS OF ENGINEERS
DATE REVISED: JUN 2009

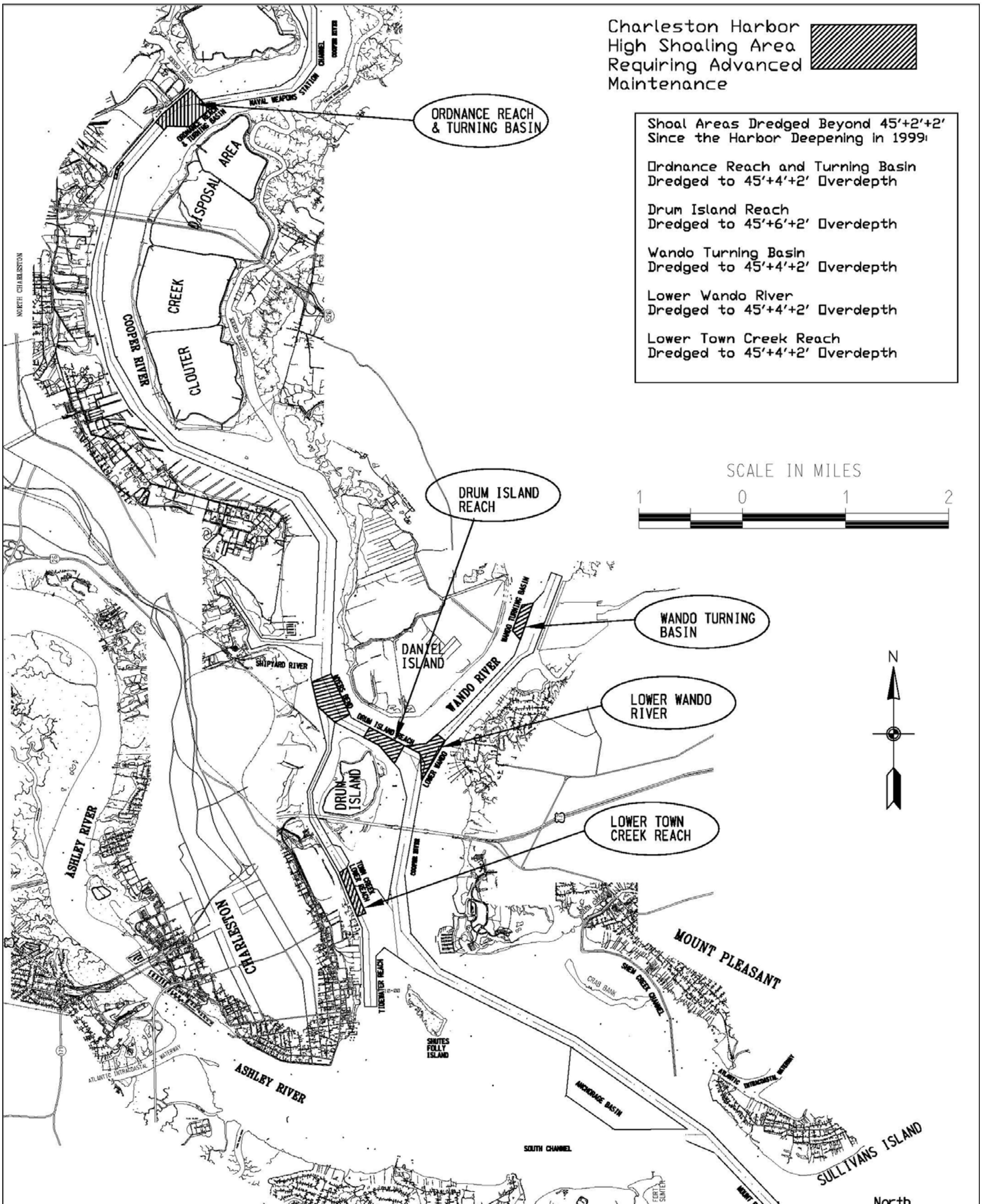


FIGURE 2
CHARLESTON HARBOR, SC
HIGH SHOAL AREAS

CORPS OF ENGINEERS
DATE REVISED: JUN 2009

Enclosure 1

Dredged Material Management Plan
Preliminary Assessment

Charleston Harbor
Charleston, South Carolina

POC – Brian R. Wells, PE, SAC
Economic Assessment – George Ebai, SAC

23 June 2009

DREDGED MATERIAL MANAGEMENT PLAN PRELIMINARY ASSESSMENT FOR CHARLESTON HARBOR

CHARLESTON, SOUTH CAROLINA

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DREDGED MATERIAL MANAGEMENT PLAN
PRELIMINARY ASSESSMENT
FOR
CHARLESTON HARBOR

CHARLESTON, SOUTH CAROLINA

PROJECT NAME AND DESCRIPTION

Charleston Harbor (CWIS - 02980) is a natural tidal estuary located at Charleston, South Carolina. The harbor covers an area of approximately 14 square miles and is formed by the confluence of the Ashley, Cooper, and Wando Rivers. The entrance to Charleston Harbor is flanked by a dual weir-jetty system 2900 feet apart. Construction of the rubble mound jetties was completed in 1895. The south jetty, which springs from Morris Island, is 19,104 feet in length. The north jetty extends seaward from the southern tip of Sullivans Island and is 15,443 feet in length. The elevation of the jetties is approximately 12 feet above mean low water (MLW) with the ends extending from station 0+00 to station -112+00 of the Federal navigational channel. The existing 45-foot Federal navigational channel extends from the 47-foot ocean contour through the jetties to the North Charleston Terminal on the Cooper River, a distance of 26.97 miles. An additional 2.08 mile 45-foot channel extends up the Wando River to the Wando Welch Terminal belonging to South Carolina States Ports Authority. The existing Federal channel varies in width from 400 feet in Town Creek and Wando River to 1000 feet wide in the entrance channel, Fort Sumter Range. A small 110-foot wide by 12-foot deep navigational channel also extends through the harbor, behind Crab Bank and up Shem Creek to Mount Pleasant. The mean and spring tidal ranges in the entrance channel are 5.1 feet and 5.9 feet, respectively.

Charleston Harbor also includes Shipyard River. Shipyard river was originally a separate authorization, but was incorporated into the Charleston Harbor Project as part of the 1996 WRDA. Shipyard River provides an entrance channel 300 feet wide and 45 feet deep from deep water in the Cooper River to Basin A, and then a 200 foot wide by 30 feet deep channel to Basin B. Basin A and Basin B are 45 and 30 feet deep, respectively. The mean range of tide at Shipyard Creek, 0.8 miles above the entrance is 5.3 feet above mean low water, and the spring tide is 6.1 feet above mean low water.

The maximum sailing draft of the fleet using Charleston Harbor is 45 feet. Nominal project dimensions for the project are listed by segment in Table 1. A map of each project is contained on Figures 1 and 2.

South Carolina State Ports Authority (SCSPA) sponsored the recent deepening and widening of Charleston Harbor from 40 feet to its present depth of 45 feet. Deepening to 45 feet was essentially completed in May 2004. The existing 30-foot project in Shipyard River was completed in 1951.

In April 2007, the U.S. Army Corps of Engineers issued permits for a new three-berth, 280-acre container terminal on the former Charleston Naval Complex. The state permits were issued in late 2006. The $600-million project is supported by SCSPA and will boost capacity by 1.4 million TEU. Demolition of buildings and structures on the site was approved in August 2007 and other preliminary work to prepare the site for consolidation and construction is well underway. The terminal's 171-acre first phase is slated to open in 2017.

The Project Cooperation Agreement (PCA) for the Charleston Harbor 45-foot Deepening/Widening project was signed on June 5, 1998. No project cooperation agreement is presently required for the upper portion of Shipyard River, because it is part of the Charleston Harbor Project. Shipyard River is combined into this Charleston Harbor report as both projects use the same disposal areas and are combined into the same dredging contracts for convenience and efficient use of funds. The sponsor, South Carolina States Ports Authority, has furnished necessary funds and disposal areas in a timely manner. The mailing address of South Carolina States Ports Authority is P. O. Box 22287, Charleston, South Carolina 29413-2287.

TABLE 1

PROJECT DIMENSIONS:

CWIS Number	Reach or Segment	Nominal Depth (as maint.)	(as auth.)	Nom. Chan. Width (as maint.)	(as auth.)	Max. Sailing Draft[1]	Project Sponsor (Y/N)
02980 (Chas Harbor)	Entrance Channel	47/42	47/42	42' at 1000' 47' at 800'	42' at 1000' 47' at 800'	47	Y
	Mount Pleasant Range	45	45	600-1000	600-1000	45	Y
	Rebellion Reach	45	45	600	600	45	Y
	Bennis Reach	45	45	600	600	45	Y

CWIS Number	Reach or Segment	Nominal Depth (as maint.)	(as auth.)	Nom. Chan. Width (as maint.)	(as auth.)	Max. Sailing Draft[1]	Project Sponsor (Y/N)
02980 (Chas Harbor)	Horse Reach	45	45	800	800	45	Y
	Hog Island Reach	45	45	600	600	45	Y
	Drum Island Reach	45	45	600	600	45	Y
	Myers Bend	45	45	VARIES	VARIES	45	Y
	Daniel Island Reach	45	45	880	880	45	Y
	Daniel Island Bend	45	45	700-780	700-780	45	Y
	Clouter Creek Reach	45	45	600	600	45	Y
	Navy Yard Reach	45	45	600-675	600-675	45	Y
	North Charleston Reach	45	45	500	500	45	Y
	Filbin Creek Reach	45	45	500	500	45	Y
	Port Terminal Reach	45	45	600	600	45	Y
	Ordnance Reach	45	45	1400	1400	45	Y

TABLE 1
(CONT.)

PROJECT DIMENSIONS:

CWIS Number	Reach or Segment	Nominal Depth (as maint.)	(as auth.)	Nom. Chan. Width (as maint.)	(as auth.)	Max. Sailing Draft[1]	Project Sponsor (Y/N)
02980 (Chas Harbor)	Custom House Reach	45	45	Varies	Varies	45	Y
	Upper Town Creek	16	16	500	500	16	Y
	Lower Town Creek	45	45	400	400	45	Y
	Town Creek Turning Basin	35	35	300	300	35	Y
	Tidewater Reach	40	40	650	650	40	Y
	Wando Channel	45	45	400	400	45	Y
	Wando Turning Basin	45	45	1400	1400	45	Y
	Anchorage Basin	35	35	2250	*	35	Y
	Shem Creek Channel	12	12	110	110	12	Y
(Shipyard River)	Entrance Channel	45	45	300	300	45	Y
	Basin A	45	45	700	700	45	Y

TABLE 1
(CONT.)

PROJECT DIMENSIONS:

CWIS Number	Reach or Segment	Nominal Depth (as maint.)	(as auth.)	Nom. Chan. Width (as maint.)	(as auth.)	Max. Sailing Draft[1]	Project Sponsor (Y/N)
(Shipyard River)	Connector Channel	45	45	200	200	45	Y
	Basin B	30	30	600	600	30	Y

Project Sponsor Reach(s) A -- X:		
Name: South Carolina State Ports Authority		
Address: P. O. Box 22287		
City: Charleston	State: South Carolina	ZIP: 29413-2287
Point of Contact: Tim Sherman	Phone #: (843)856-7055	

NOTE: [1] For vessels currently using the harbor.
* Maintenance discontinued due to lack of use.

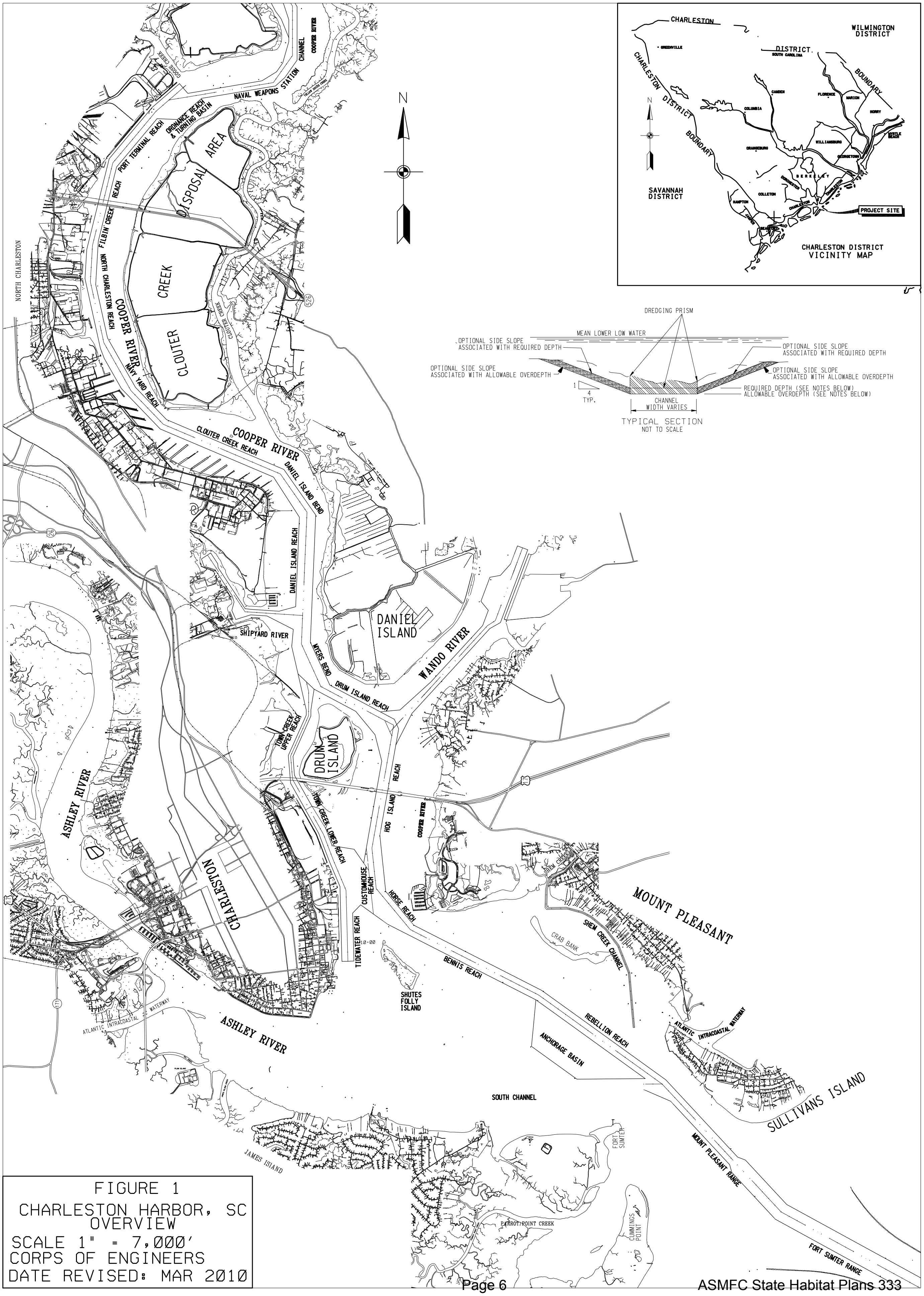


FIGURE 1
CHARLESTON HARBOR, SC
OVERVIEW
SCALE 1" = 7,000'
CORPS OF ENGINEERS
DATE REVISED: MAR 2010

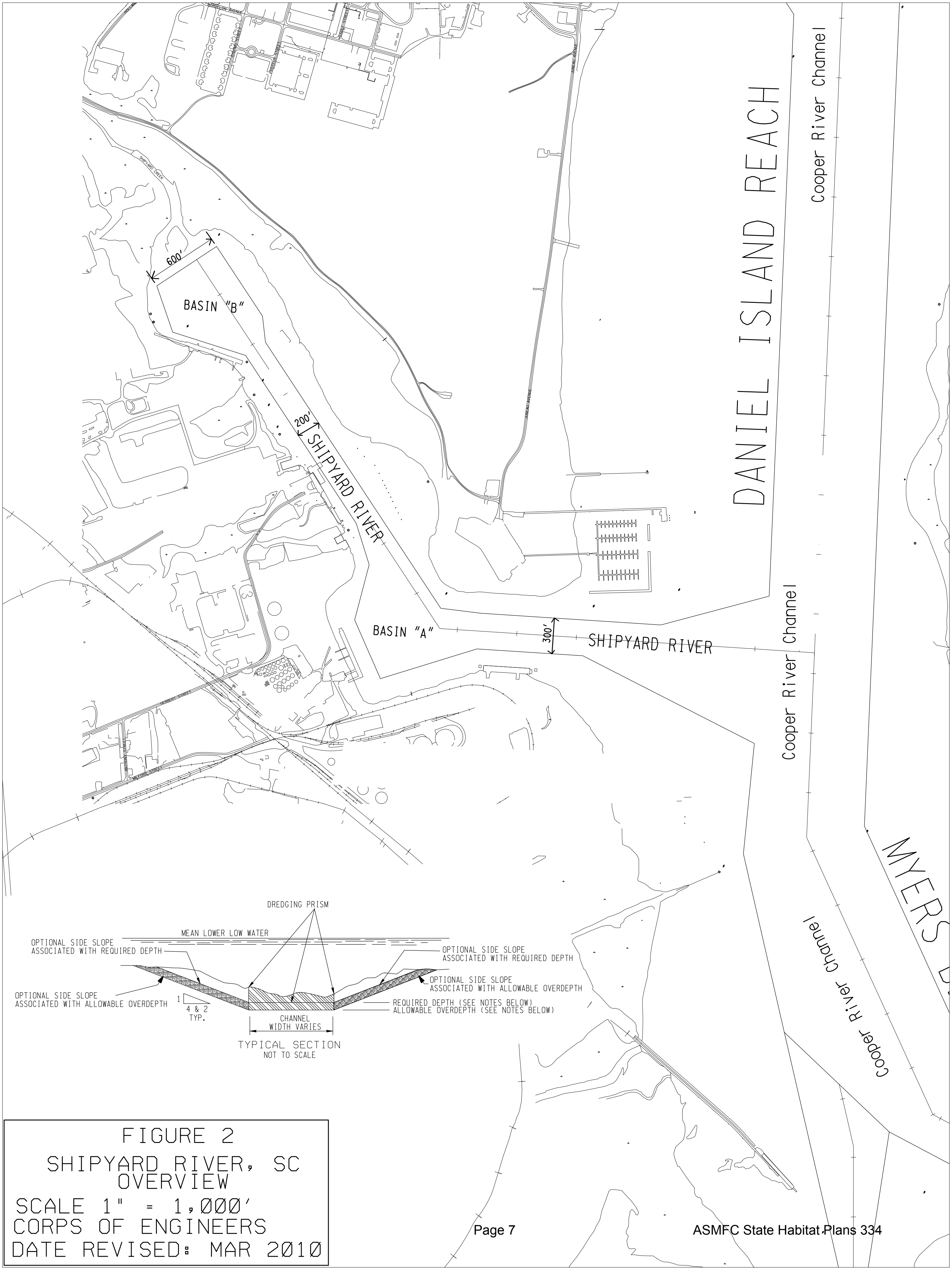


FIGURE 2
SHIPYARD RIVER, SC
OVERVIEW
SCALE 1" = 1,000'
CORPS OF ENGINEERS
DATE REVISED: MAR 2010

PROJECT AUTHORITY

Charleston Harbor, SC (CWIS - 02980) has had numerous authorizations beginning with the River and Harbor Act of June 18, 1878, and continuing through to the present. The latest authorization, the 1996 Water Resources Development Act (WRDA96) (Sec 101 of WRDA96 PL 104-303) provided for deepening the harbor to its current 45-foot depth and other modifications as follows:

- A 16.3 mile long entrance channel 47 foot deep. This is a trapezoidal channel – 47’ deep in the center 800’ and 42’ on the edges – full width is 1000’.
- 45-foot deep interior channels and turning basins
- The Bennis Reach (FormerlyShutes/Folly Reach) of the Lower Harbor was realigned
- The Town Creek Channel from Cooper River bridges to Myers Bend was reduced to 16 feet deep by 250 feet wide
- The Daniel Island Reach channel was widened to 875 feet beginning at the conjunction of Myers Bend and tapering to a width of 600 feet at the Daniel Island Bend
- Existing training dikes were restored and a contraction dike on Daniel Island was removed
- An additional contraction dike was constructed just north of Shipyard River and the Navy degaussing pier
- Construction of a 1,400 by 1,400 foot turning basin

All of the authorized 1996 authorized changes have been completed with the exception of the Daniel Island Turning Basin as constitution of the turning basin was contingent upon the construction of the new six-berth terminal on Daniel Island.

Shipyard River, SC was initially authorized by the River and Harbor Act of July 25, 1912 to provide a depth of 18 feet. The 1986 Water Resources Development Act authorized deepening the lower portion of Shipyard River to 38 feet as part of the Charleston Harbor improvements under the same authority. (See page 1-2 for more information on Shipyard River).

ECONOMIC ASSESSMENT

The purpose of this dredged material management plan (DMMP) preliminary assessment (PA) is to document the continued economic viability of Charleston Harbor and to determine whether there is dredged material placement capacity sufficient to accommodate 20 years of maintenance dredge. If this PA determines that there is insufficient capacity to accommodate maintenance dredging for the next 20 years, then a Dredged Material Management Plan (DMMP) study will be recommended.

This DMMP PA is provided under the authority of U.S. Army Corps of Engineers (USACE) Engineering Regulation ER 1105-2-100, Planning Guidance Notebook, dated 22 April 2000.

The recommended DMMP for the Charleston Harbor is justified by confirming that over the next 20 years, transportation savings (benefits) resulting from the authorized dredging program in that segment of the harbor exceed the cost of maintenance. Benefits and costs were obtained from the 1996 Charleston Harbor Final Feasibility Report (FR96). Comparisons between commodity traffic and fleet projections and actual commodity growth and fleet composition were used as the basis for determining whether or not the expected average annual benefits computed in FR96 are still applicable to the project.

Existing and Without Project Conditions

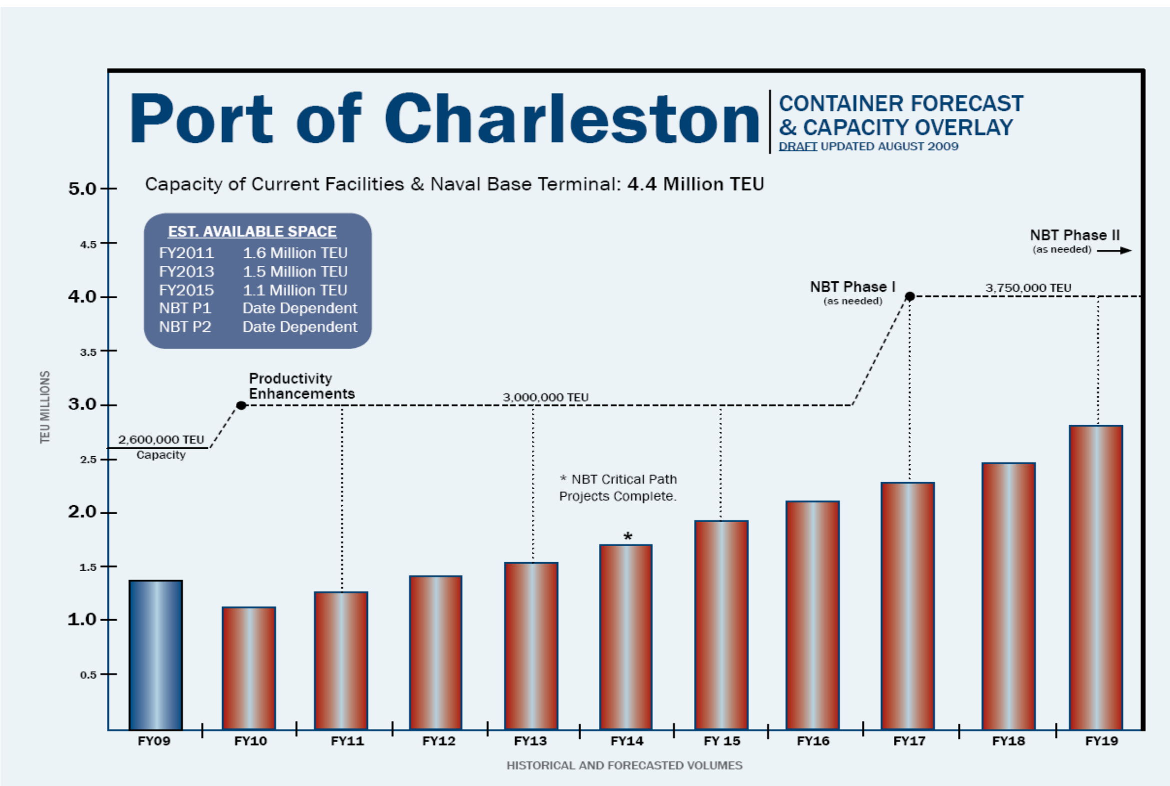
Port Commerce

The Charleston Harbor project was originally authorized by the River and Harbor Act of 1878. The last economic analysis for the harbor was completed in February 1996 as part of FR96, which recommended deepening the main channels to 45 feet, widening and realigning selected reaches, and constructing a turning basin. Construction of the authorized project, recommended in FR96, began in 1998.

At the time of FR96, Charleston Harbor was the second largest container port on the East and Gulf coasts of the United States and the sixth largest in the nation, with more than 10,830,000 short tons of waterborne commerce moving through the harbor in 1994. Two-thirds of the harbor's traffic was containerized cargo. Today, Charleston Harbor ranks fourth nationwide and remains the second busiest container port along the East and Gulf coasts. According to the Waterborne Commerce of the United States, between 1999 and 2006, the Port's waterborne commerce increased from 19,916,000 to 26,425,000 short tons representing a 33% rise in total tonnage and an average annual growth rate of approximately 4.2%. This tonnage movement was comprised mainly of petroleum products, followed by bulk and containerized tonnage. The port's top imports are furniture, auto parts, fabrics, pulp and paperboard, logs and lumber, and machinery. Top exports are paper and paperboard, wood pulp, poultry, auto parts, kaolin and china clay, and fabrics.

In 1994, 7.5 million tons of containerized cargo was handled in Charleston Harbor, with about 65 percent being export traffic. With the recent completion of additional berthing space and landside facilities at the Wando Terminal, Charleston Harbor has the capacity to handle about 11.5 million tons of containerized cargo annually. The South Carolina State Ports Authority (SCSPA) currently has plans underway to construct a new containerized terminal that could potentially double the existing capacity. The chart below is a container forecast and capacity overlay for Charleston Harbor from 2009 to 2019.

Table 2 Container Forecast and Capacity Overlay for Charleston Harbor



Commodity Traffic Projections

Projections of containerized cargo traffic measured in tons for the years 1997 to 2002 were included in FR96 as one of the major inputs into the economic analysis. The projections were given in a 5-year increment, 1997 to 2002, and 10-year increments for the remaining years. Actual container traffic data was available from the State Ports Authority (SPA) for the years 1997 and 2002; however, the data was quantified in twenty-foot equivalent units (TEU's) per year and not tons. Based on the conversion ratio[1] given in FR96, the 1997 and 2002 actual TEU's as reported by the SPA were converted to approximate actual tons and then compared to the 1997 and 2002 projected tons as shown below in Table 3. It was determined that the actual growth in containerized cargo traffic in Charleston Harbor far exceeded the growth projections in FR96.

Table 3
Projected vs. Actual Tons of Commerce in Charleston Harbor

	Projected Tons	Actual Tons
1997	8,951,700	12,633,919
2002	11,368,700	14,906,250

Therefore, it was assumed that the estimated project benefits[2] from the channel modifications to Charleston Harbor calculated in the 1996 report are still valid and in fact, that actual project benefits are probably greater than the estimated benefits due to more commodity traffic than was predicted. Therefore, benefits computed in FR96 can be used in the economic justification of this DMMP.

Current Economic Indicators

A report prepared by the Gulf Engineers & Consultants predicted an increase in containerized goods. Tonnage growth was shown to exceed that which was presented in the 1996 Feasibility Report. The most important containerized imports, by tonnage, are chemicals, machinery and textiles. More than 2,100 vessels from ports around the world called at the Port of Charleston in 2007. Of these, 74 percent were container ships, 8 percent were tankers, 4 percent were dry-bulk carriers, and 4 percent were general cargo vessels. The major commodity handled at the port included agricultural products, consumer goods, machinery, metals, vehicles, chemicals, and clay products.

[1] 7.5 million tons is equivalent to approximately 800,000 TEU's
[2] Project benefits or transportation savings computed by

However, since 2007containerized traffic and break-bulk have experienced a decline. According to the SCSPA containerized traffic is reported to be down by 6.8% between 2007 and 2008 and vessel calls have also declined by 4% within the same period. Table 2 presents trends in pertinent indicators between 2007 and 2008.

The recent decline in container traffic is likely related to the global current economic conditions. The current economic recession has impacted commerce in many sectors of the economy both nationally and internationally. It should be noted that this trend is a snapshot of activities from 2007 to 2008 and is likely to change when the economy recovers from its recession. Data obtained from Port Container Traffic from December 2008 to December 2009 reveal that other major ports in the US have experienced a significant decline in container traffic. However, note that vessel draft has increased since the project deepened to 45 feet.

TABLE 4 Port of Charleston Trends (based on CY2008 SCSPA)

Reach or Segment	Benefit Indicators[1]	Current Operations	Trend (Up, Down) from previous year	Summary/ Remarks
PROJECT	COMMODITY TYPES	Container Breakbulk Petroleum	Down Down *Not Applicable at* ***public*** *facilities*	
	VOLUME (TEUs)	1,635,535	Down	Total for Port of Charleston's containerized cargo in 2008
	TONNAGE (Breakbulk Cargoes)	587,389 pier tons	Down	Breakbulk cargo handled for SCSPA Charleston facilities only
	GROWTH RATES	-6.8%	Down	As reported by SCSPA from 2007 to 2008, containerized cargo only
	VESSEL COUNTS (calls)	Containership Deep draft bulk Tankers Ro-Ro	Down	As reported by SCSPA in 2008, 4% fewer vessel calls than prior year
	VESSEL SIZES	Range: 280 – 965 feet LOA (draft 20 – 47 foot)	Up	Vessel draft increased since project deepened to -45 feet MLW.
	RECREATIONAL VESSEL TYPES	Cabin Cruisers, Sail Boats	Unknown	
	RECREATIONAL VESSEL SIZES	Unknown	Unknown	
	COMMERCIAL FISHING, CHARTER	Unknown	Unknown	
	COMMERCIAL	shrimp boats	Unknown	

	FISHING, OTHER			

NOTE: [1] Include only pertinent indicators
Trend in last 5 years has been up but has gone down since 2007
Table is a snapshot of commerce traffic from 2007 to 2008

Current and Projected Traffic

The historic tonnage retrieved from Waterborne Commerce show an increase in tonnage Bulk commodities – gasoline, distillate fuel oil, residual fuel oil, lubricating oil, grains, coal, and iron carbide. In 2005, gasoline receipts at Charleston Harbor totaled 1.6 million tons and have remained relatively stable from 1999 through 2005 with the exception of a significant drop in 2003. In 2005, approximately 25,439,000 million short tons of waterborne commerce were moved through the harbor. The primary exports are chemicals, paper and wood pulp. Petroleum products, coal, chemicals, cement, bauxite, non-ferrous metal products and primary iron and steel products are the major commodities for Charleston harbor. Increases in tonnage are attributable especially to expected increases in tonnage in Petroleum, break-bulk, and containerized cargo. The 1996 Report forecasted gasoline tonnage of 1,388,600 for 2002 and 1,530,400 for 2012. Actual tonnage for 2002 was 1,549,000 and 1,601,000 for 2005, larger than the forecasted amounts.

Between 1999 and 2005, receipts of distillate fuel oil have increased in recent years, exceeding the historical highs in the late 1970's near 700,000 tons. Tonnage increased from 607,000 tons in 1999 to 832,000 tons in 2005 but dipped in 2002 to 508,000 tons. Tonnage in 2004 reached an all-time high of 906,000 tons. In the 1996 report, projections of distillate fuel oil tonnage were also based on Department of Energy projections, of 457,000 tons in 2002 and 558,000 tons in 2012, which were largely underestimated. Table 5 presents the expected total tonnage and vessel calls for the harbor through the year 2012.

Table 5
Total Tonnage & Forecasts
(FY00 – FY12)

.

Year	Tonnage	Vessel Calls
FY 00	21,082,000	2057
FY 01	23,250,000	2122
FY 02	24,993,000	1947
FY03	25,199,000	1865
FY 04	24,739,000	1992
FY 05	25,439,000	1959

FY 06	26,425,000	1956
FY 07	22,616,000	1861
FY 08	20,936,000	1782
FY 09*	23,904,722	1592
FY 10*	23,915,022	1688
FY 11*	23,925,322	1647
FY 12*	23,935,622	1606

*Forecasted values

Future Outlook

Shipping trends in Charleston show adherence to projections for considerable growth in ship size, in all three dimensions, draft (depth below water required to float), beam (width), and length. As economics and technologies have driven ship sizes larger, the world's port infrastructure is rapidly expanding in capacity to accommodate larger ships. The number of deep draft ports around the world is growing, and, most importantly, the Panama Canal is currently expanding lock capacity to handle ships of 25 % greater draft (up to 50 ft), 52% greater beam (up to 60 feet), and 30% greater length. Ships have been under construction for several years to be ready for the new canal capacity when the new Panama Canal locks open in 2014.

In February 2010, Mediterranean Shipping Company (MSC), the World's second largest container carrier, had a ship with a draft of 47.5 feet, called the Port of Charleston on its Golden Gate Service (GGS). The service between the U.S. East Coast and Asia currently deploys 12 Post-Panamax vessels with capacity of 6,050 20-foot equivalent units (TEU). Typically, a vessel with a capacity of 6,000 TEU's draws a draft of 46 feet when fully loaded. According to industry statistics from Drewry, 72% of current vessels on order are Post-Panamax (5,000+ TEU) and 55% are over 8,000 TEU, which reflects future vessel fleets. Most of these container ships draw deepest draft and mostly carry break –bulk.

Charleston has the deepest channels on the South Atlantic coast, routinely handling Large ships and vessels drawing up to 47 feet of water. However, as shown in Table 6, to receive 24-hour access in Port of Charleston, ships have to be drafting 43 feet and will be constrained by tide beyond that.

Table 6 Port of Charleston Vessel Draft

Hours/Day Available for Inbound Transit	Vessel Draft
24	**38**
24	**39**
24	**40**
24	**41**

24	**42**
24	**43**
16	**44**
12	**45**
8	**46**
6	**47**
2	**48**

According to the SCSPA, 495 ships of design draft 43 feet or greater called the Port of Charleston from December 2008 to December 2009. Without additional depth Charleston Harbor will continue to impose a constraint on the use of larger vessels. Vessels with deeper draft will be able to take advantage of deeper channel and reduce transportation costs from tidal delays.

Of the 37,242 commercial ships listed by Lloyds Register of sufficient size to require a pilot entering Charleston, 5914 have full load drafts in excess of 43 ft (Charleston's current 24 hour draft limit), and 2494 have full load drafts greater than 48 feet (Charleston's current high tide draft limit). Thus, 16% of the world's ocean going ships are currently restricted either by tide or cargo carriage to trade in Charleston, and 7% cannot trade when fully loaded on any stage of tide.

The port of Charleston currently serves container, bulk, break bulk, general cargo, heavy load, roll-on roll-off, vehicle carrier, tank, specialty cargo carriers, and cruise ships. Of these, container, bulk, and tank ships have been tide restricted in Charleston. Trends in these segments of shipping indicate continued expansion of ship size. The other vessel classes trading in Charleston have yet to be restricted by channel depth, and trends in these segments of shipping show that these ships will continue to require less depth than container, bulk, and tank ships. Thus, channel depth targets are driven by container, bulk, and tank shipping characteristics.

Dredging Cost

Dredging quantities and total costs were estimated by information obtained from Charleston District. Unit costs were determined by taking the total cost of the dredge contract and dividing by the total cubic yards (CY) dredged. Costs were adjusted to the 2008 dollars using the CWCCIS-CWBD-Feature Code 12-Navigation Ports and Harbors.

Dredging

Frequent shoaling is a problem in particular reaches of Charleston Harbor: Lower Town Creek Reach and Turning Basin, Drum Island Reach, Ordnance Reach and Ordnance

Reach Basin. Advanced maintenance of four to six feet is accomplished in some of the rapidly shoaling reaches. Shoaling in the Entrance Channel typically occurs between -132+00 and -292+00. Dredging records from 1994 to 2008 indicate the average annual maintenance quantities to be 1.9 million cubic yards from Federal Channels and 400,000 cubic yards from private berth maintenance dredging. The yearly average for the three entrances is as follows: Entrance Channel 630,000 CY, 731,000 CY from Charleston Lower Channel, and 425,000 CY from the Charleston upper Channel. This material is placed in an EPA approved ocean disposable site (ODMDS). Table 7 presents the historical cost of dredging for the three channels

Table 7 (Data from Table 8)
Historical Costs of Dredging for the 3 Segments of the Harbor

	Entrance Channel	Lower Harbor	Upper Harbor
FY 94	$ 45.00	$2,607.00	-
FY 95	$2,011.00	$ 719.80	-
FY 96	-	$1,267.50	$1,267.50
FY 97	$2,032.50	$1,242.40	-
FY 98	-	$1,538.50	$1,538.50
FY 99	$4,119.70	$ 998.40	-
FY 00	$1,519.00	$1,797.00	-
FY 01	$3,069.70	$2,709.20	$1,861.00
FY 02	-	$1,089.60	$2,728.50
FY 03	$1,811.30	$5,190.00	$1,595.00
FY 04	$2,526.30	$2,392.60	$1,421.80
FY 05	-	$1,701.20	$2,397.40
FY 06	$3,490.20	-	($ 294.20)
FY 07	-	$5,740.80	$4,469.60
FY 08	$2,524.80	$5,949.00	$ 520.00

The Entrance channel is typically dredged every two years; the Lower Harbor is dredged every 12 to 15 months; and the Upper Harbor dredged every 18 to 21 months. Although CY costs remain relatively stable through time, the mob-and de-mob costs vary significantly from year to year due to variances in the location of the dredge both before and after the dredging.

Economic Assessment Conclusion:

The economic analysis of the 1996 Feasibility Report concluded that the optimal channel depth of 45 ‘ is economically justified for the main channel and for each separable increment of the total deepening project. Net benefits will be maximized by deepening the harbor to 45 feet, yielding a benefit/cost ratio of 1.88.

Based on the above analysis, continued maintenance of Charleston harbor, including Shipyard River are warranted on the basis of project usage and indicators of economic productivity. Based on the costs of dredging and the benefits derived from the current tonnage the project is still economically justified.

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Table 8

Channel Maintenance Cost History: Charleston Harbor

Reach or Segment	Dredging Cost (Thousands of Dollars Per Fiscal Year)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Yearly Avg.
Entrance Channel	Dredging (1)		$ 2,011.0		$ 2,032.5		$ 4,119.7	$ 1,519.0	$ 3,069.7		$ 1,811.3	$ 2,526.3		$ 3,490.2		$ 2,524.8	$ 23,105	$ 1,540
	Env. Studies	$ 45.0															$ 45	$ 3
	Total	$ 45.0	$ 2,011.0	$ -	$ 2,032.5	$ -	$ 4,119.7	$ 1,519.0	$ 3,069.7	$ -	$ 1,811.3	$ 2,526.3	$ -	$ 3,490.2	$ -	$ 2,524.8	$ 23,150	$ 1,543
Lower Harbor, Wando, & Shem Creek	Dredging (1)	$ 2,607.0	$ 719.8	$ 1,267.5	$ 1,242.4	$ 1,538.5	$ 998.4	$ 1,797.0	$ 2,709.2	$ 1,089.6	$ 5,190.0	$ 2,392.6	$ 1,701.2		$ 5,740.8	$ 5,949.0	$ 34,943	$ 2,330
	Env. Studies																$ -	$ -
	Total	$ 2,607.0	$ 719.8	$ 1,267.5	$ 1,242.4	$ 1,538.5	$ 998.4	$ 1,797.0	$ 2,709.2	$ 1,089.6	$ 5,190.0	$ 2,392.6	$ 1,701.2	$ -	$ 5,740.8	$ 5,949.0	$ 34,943	$ 2,330
Upper Harbor Incl. Shipyard and TC	Dredging (1)			$ 1,267.5		$ 1,538.5			$ 1,861.0	$ 2,728.5	$ 1,595.0	$ 1,421.8	$ 2,397.4	$ (294.2)	$ 4,469.6	$ 520.0	$ 17,505	$ 1,167
	Env. Studies																$ -	$ -
	Total	$ -	$ -	$ 1,267.5	$ -	$ 1,538.5	$ -	$ -	$ 1,861.0	$ 2,728.5	$ 1,595.0	$ 1,421.8	$ 2,397.4	$ (294.2)	$ 4,469.6	$ 520.0	$ 17,505	$ 1,167
Total Project	Dredging (1)	$ 2,607.0	$ 2,730.8	$ 2,535.0	$ 3,274.9	$ 3,077.0	$ 5,118.1	$ 3,316.0	$ 7,639.9	$ 3,818.1	$ 8,596.3	$ 6,340.7	$ 4,098.6	$ 3,196.0	$ 10,210.4	$ 8,993.8	$ 75,553	$ 5,037
	Eng and Desgn (2)	$ 902.1	$ 1,174.9	$ 998.5	$ 1,165.6	$ 839.1	$ 741.3	$ 472.8	$ 1,380.6	$ 1,504.3	$ 1,661.2	$ 1,802.8	$ 1,367.0	$ 1,034.4	$ 766.7	$ 898.3	$ 16,710	$ 1,114
	Env. Studies	$ 45.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 45	$ 3
	Other O&M (3)	$ 49.7	$ 489.3	$ 579.5	$ 748.0	$ 451.6	$ 1,210.4	$ 2,308.8	$ 834.8	$ 1,078.5	$ 356.7	$ 715.9	$ 206.6	$ 96.2	$ 168.2	$ 1,461.4	$ 10,756	$ 717
	Total (4)	$ 3,603.8	$ 4,395.0	$ 4,113.0	$ 5,188.5	$ 4,367.7	$ 7,069.8	$ 6,097.6	$ 9,855.3	$ 6,400.9	$ 10,614.2	$ 8,859.4	$ 5,672.2	$ 4,326.6	$ 11,145.3	$11,353.5	$ 103,063	$ 6,871

NOTES:

1. Dredging Costs are the Contract Prices for the actual Dredging and it also includes any claim payments or payments for requests for equitable adjustments relating to the dredging contract

2. Eng and Design costs include the following: Develop Plans and Specs, Drafting, Perform Volume Calculations, Plotting, Printing, Surveying, etc.

3. Other O&M include Costs for the following: Ditching, Diking, Mosquito Abatement, etc.

4. This Table Excludes new work dredging quantities - maintenance only

5. The numbers on this sheet reflect the total of both Federal and State Sponsor Funds.

Table 9

Channel Maintenance Cost Projections: Charleston Harbor

Reach or Segment	Dredging Cost (Thousands of Dollars Per Fiscal Year- TCY)												
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	Yearly Avg.
Entrance Channel	Dredging (1)		$ 3,700		$ 4,100		$ 4,500		$ 5,000		$ 5,500	$ 22,800	$ 2,280
	Env. Studies											$ -	$ -
	Total	$ -	$ 3,700	$ -	$ 4,100	$ -	$ 4,500	$ -	$ 5,000	$ -	$ 5,500	$ 22,800	$ 2,280
Lower Harbor, Wando, & Shem Creek	Dredging (1)		$ 7,000	$ 7,350	$ 7,717	$ 8,103		$ 8,934		$ 9,850	$ 10,342	$ 59,296	$ 5,930
	Env. Studies											$ -	$ -
	Total	$ -	$ 7,000	$ 7,350	$ 7,717	$ 8,103	$ -	$ 8,934	$ -	$ 9,850	$ 10,342	$ 59,296	$ 5,930
Upper Harbor Incl. Shipyard and TC	Dredging (1)	$ 6,000	$ 6,400		$ 7,056		$ 7,779	$ 8,168		$ 9,005		$ 44,408	$ 4,441
	Env. Studies											$ -	$ -
	Total	$ 6,000	$ 6,400	$ -	$ 7,056	$ -	$ 7,779	$ 8,168	$ -	$ 9,005	$ -	$ 44,408	$ 4,441
Total Project	Dredging (1)	$ 6,000	$ 17,100	$ 7,350	$ 18,873	$ 8,103	$ 12,279	$ 17,102	$ 5,000	$ 18,855	$ 15,842	$ 126,504	$ 12,650
	Eng and Desgn (2)	$ 1,114	$ 1,170	$ 1,228	$ 1,289	$ 1,354	$ 1,421	$ 1,493	$ 1,567	$ 1,645	$ 1,728	$ 14,009	$ 1,401
	Env. Studies	$ 120	$ 126	$ 132	$ 139	$ 146	$ 153	$ 161	$ 169	$ 177	$ 186	$ 1,509	$ 151
	Clouter Ditching	$ 1,000			$ 1,158	$ 1,215			$ 1,407	$ 1,477		$ 6,257	$ 626
	Clouter Diking		$ 2,000	$ 2,000			$ 2,315	$ 2,431			$ 2,814	$ 11,560	$ 1,156
	Other O&M (3)	$ 100	$ 105	$ 110	$ 115	$ 122	$ 128	$ 134	$ 141	$ 148	$ 155	$ 1,258	$ 126
	Total	$ 8,334	$ 20,501	$ 10,820	$ 21,574	$ 10,940	$ 16,296	$ 21,321	$ 8,284	$ 22,302	$ 20,725	$ 161,097	$ 16,110

NOTES:

1. Dredging Costs are projected Contract Prices for the actual Dredging.

2. Eng and Design costs include the following: Develop Plans and Specs, Drafting, Perform Volume Calculations, Plotting, Printing, Surveying, etc.

3. Other O&M include Costs for the following: Mosquito Abatement, etc.

4. Assumed 5% inflation/cost growth per year.

5. Dredging Estimate Computational Details
Entrance Channel Historical Last Dredging Contract in Dec 2007 was for $2.6M for 967 TCY (Thousand Cubic Yards). FY 10 Estimate for 1,260 TCY (Table 12) is **$3.7M**
Charleston Lower Dredging FY10. CWE (Current Working Estimate) is **$7.0M** for 1,013 TCY (Table 12)
Charleston Upper Channel Historical Last Dredging Contract in Dec 2008 was for **$6.0M** for 1,843 Yards. FY 10 Estimate is **$6.4M**

6. Costs are shown in the year where the majority of the work will take place. Contract awards might be in the year prior to the majority of the actual dredging, so this should not be used for requesting funds. Check with the Project Manager for a more detailed Budget.

MAINTENANCE DREDGING HISTORY

Until 2004, the existing Charleston Harbor project was maintained to the authorized project depth of 40 feet MLW (42 feet for the Entrance Channel) and 38 feet MLW in Shipyard River. To accommodate the larger container ships serving world trade, the $148-million Charleston Harbor Deepening & Widening Project was commenced in 1999 and completed in May 2004. Channels leading to all container terminals are now 45 feet (13.7 m) at mean low water, while the entrance channel has been deepened to 47 feet (14.3 m). In addition, two feet of advance maintenance and two feet of allowable overdepth are authorized. Rapid shoaling occurs in certain reaches: Lower Town Creek Reach (and Turning Basin), Drum Island Reach, Wando River Turning Basin, Shipyard River, Daniel Island Reach, Ordnance Reach and Ordnance Reach Turning Basin. Advanced maintenance of four to six feet is accomplished in some of the rapidly shoaling reaches. Dredging of either the “Lower Reaches” of Charleston Harbor or the “Upper Reaches” of the Cooper River, or both, is done every year.

Shoaling in the Entrance Channel typically occurs between stations -132+00 and -292+00. Dredging records from 1994 to 2008 indicate the average annual maintenance dredging quantities to be approximately 1.9 million cubic yards from the Federal channels plus another 400,000 cubic yards from private berth maintenance dredging. Material dredged from the Upper Reaches of the Cooper River (Upper Harbor) is placed in the Clouter Creek Disposal Area. Maintenance dredging of the Upper Harbor and Shipyard River is done by cutterhead hydraulic pipeline dredge. Maintenance dredging of the Lower Reaches (Lower Harbor) is done by Mechanical (Clamshell) Dredge and the material is transported via scow to the Offshore Dredged Material Disposal Site (ODMDS). The Entrance Channel is dredged by hopper dredge and the material is transported to the ODMDS. Table 10 shows the maintenance yardage dredged for the last fifteen years for Charleston Harbor. Table 11 shows yardage removed during the past fifteen years from private berthing areas and placed in the Federal project disposal areas. Table 12 and 13 respectively shows the anticipated yardage to be dredged over the next 10 years from both the Federal channel and private berthing areas. The yearly averages from these ten year projections are used to ensure that the 20 year capacity requirement is met. See Table 14 for 20 Year Disposal Site Capacity Projection.

In April 2007, the U.S. Army Corps of Engineers issued permits for a new three-berth, 280-acre container terminal on the former Charleston Naval Complex. The state permits were issued in late 2006. The $600-million project is supported by SCSPA and will boost capacity by 1.4 million TEU. Demolition of buildings and structures on the site was approved in August 2007 and other preliminary work to prepare the site for consolidation and construction is well underway. The terminal’s 171-acre first phase is slated to open around 2014.


NWS DISPOSAL AREA
YELLOW HOUSE DISPOSAL AREA
NAVAL WEAPONS STATION CHANNEL
COOPER RIVER
ORDNANCE REACH & TURNING BASIN
PORT TERMINAL REACH
FILBIN CREEK REACH
NORTH CHARLESTON REACH
NORTH CHARLESTON
CLOUTER CREEK DISPOSAL AREA
NAVY YARD REACH
CLOUTER CREEK REACH
DANIEL ISLAND BEND
DANIEL ISLAND REACH
SHIPYARD RIVER
DANIEL ISLAND
WANDO RIVER
MYERS BEND
DRUM ISLAND REACH
TOWN CREEK UPPER REACH
DRUM ISLAND
HOG ISLAND REACH
TOWN CREEK LOWER REACH
CUSTOMHOUSE REACH
HORSE REACH
TIDEWATER REACH
ASHLEY RIVER
CHARLESTON
MOUNT PLEASANT
CRAB BANK
SHEM CREEK CHANNEL
BENNIS REACH
SHUTES FOLLY ISLAND
REBELLION REACH
ANCHORAGE BASIN
ATLANTIC INTRACOASTAL WATERWAY
SOUTH CHANNEL
SULLIVANS ISLAND
FORT SUMTER
JAMES ISLAND
MOUNT PLEASANT RANGE
PARROT POINT CREEK
CUMMINGS POINT
MORRIS ISLAND
FORT SUMTER RANGE
N
HIGH SHOALING AREA
FIGURE 3
CHARLESTON HARBOR, SC
HIGH SHOAL AREAS
SCALE 1" = 7,000'
CORPS OF ENGINEERS
DATE REVISED: MAR 2010

Table 10

Dredging History: Federal Channel Maintenance Dredging

Reach or Segment	Primary Dredge Method	Dredging History (Thousand CY per Fiscal year)																	Disposal Site(s) Used (Identifier)
		1994	1995	1996 (5)	1997 (5)	1998 (5)	1999	2000 (3)	2001	2002 (3)	2003	2004	2005	2006	2007	2008	Total	Yearly AVG	
Entrance Channel	1		1,735.0		775.4		1,562.7	1,147.3		708.4		1,377.0		1,178.7		967.3	**9,452**	**630**	ODMDS
Fort Sumter and Mt. Pleasant Ranges	2																**0**	**0**	ODMDS
Mount Pleasant Range	2																**0**	**0**	ODMDS/Daniel Isl
Rebellion Reach	2	40.6						12.8									**53**	**4**	ODMDS/Daniel Isl/Morris
Shem Creek Access	2	198.1										140.8					**339**	**23**	Morris Island
Anchorage Basin	2	707.7															**708**	**47**	Daniel Isl/Morris
Folly Reach	3							9.3									**9**	**1**	ODMDS
Shutes Reach	3							5.3									**5**	**0**	ODMDS
Horse Reach	3							34.0									**34**	**2**	ODMDS
Tidewater Reach	3	297.1				163.3					202.9						**663**	**44**	ODMDS
Custom House Reach	3			66.1		10.2		43.8			191.4	92.5			127.4	64.2	**596**	**40**	ODMDS
Town Creek Lower (w/tb)	3	351.6		358.8	77.3	414.7		135.5			621.5	181.9			326.3	404.0	**2,872**	**191**	ODMDS
Hog Island Reach	3	209.5		168.8		220.6		106.4			188.2	188.6			245.5	163.6	**1,491**	**99**	ODMDS
Town Creek Upper	3																**0**	**0**	ODMDS
Drum Island Reach	3			243.7	141.5	316.8		68.7			127.1	127.4			185.9	159.9	**1,371**	**91**	ODMDS
Wando River Lower Reach	3			120.5		126.4		74.3			156.7	119.8			136.8	92.6	**827**	**55**	ODMDS
Wando Uppper TB	3			285.9		240.9		185.7			214.1	185.5			186.1	175.1	**1,473**	**98**	ODMDS
Wando Upper Reach	3			222.4		167.9		181.9			225.1	115.9			182.6	134.3	**1,230**	**82**	ODMDS
Totals for Charleston Lower (4)	3	**1,096.9**	**0.0**	**1,466.2**	**218.8**	**1,660.8**	**0.0**	**857.7**	**0.0**	**0.0**	**1,927.0**	**1,152.4**	**0.0**	**0.0**	**1,390.6**	**1,193.7**	**10,964**	**731**	Varies
Total for Morris Isl. Disp Site		946.4										415.2					**1,362**	**91**	**Total Morris**
Total for Drum Isl. Disp Site								381.0									**381**	**25**	**Total Morris**
Total for Daniel Isl. Disp Site		858.2		2,054.2	218.8	2,191.6		34.0									**5,357**	**357**	**Total Daniel Island**
Total for ODMDS Disp Site		**0.0**	**1,735.0**	**0.0**	**775.4**	**0.0**	**1,562.7**	**2,215.0**	**0.0**	**708.4**	**1,927.0**	**2,190.9**	**0.0**	**1,178.7**	**1,452.0**	**2,161.0**	**15,906**	**1,060**	**Total ODMS**
Myers Bend	3			48.4				89.7				76.7			61.4		**276**	**18**	Clouter Creek
Shipyard River (w/ub & lb)	2			387.2		428.9		381.0	240.1	150.0			285.1		183.1		**2,055**	**137**	Clouter Creek
Daniel Island Reach	2			152.4		101.9		154.3	202.6	104.0			364.9		517.4		**1,598**	**107**	Clouter Creek
Daniel Island Bend	2																**0**	**0**	Clouter Creek
Clouter Creek Reach (w/pp)	2									102.0							**102**	**7**	Clouter Creek
Navy Yard Reach	2									51.3					56.1		**107**	**7**	Clouter Creek
North Charleston Reach	2																**0**	**0**	Clouter Creek
Filbin Creek Reach	2																**0**	**0**	Clouter Creek
Port Terminal Reach	2									22.0					22.6		**45**	**3**	Clouter Creek
Ordinance Reach	2			311.2		215.0		162.2	171.6	150.0			198.7		231.4		**1,440**	**96**	Clouter Creek
Ordinance Reach TB	2			424.4		337.3		297.5	417.2	150.0			432.2		581.8		**2,640**	**176**	Clouter Creek
Total for Clouter Disp Site		**0.0**	**0.0**	**735.6**	**0.0**	**552.3**	**0.0**	**459.7**	**1,031.5**	**729.3**	**0.0**	**0.0**	**1,280.9**	**0.0**	**1,592.4**	**0.0**	**6,382**	**425**	**Total Clouter**
TOTALS		**1,804.6**	**1,735.0**	**2,789.8**	**994.2**	**2,743.9**	**1,562.7**	**3,089.7**	**1,031.5**	**1,437.7**	**1,927.0**	**2,606.1**	**1,280.9**	**1,178.7**	**3,044.4**	**2,161.0**	**29,387**	**1,959**	

NOTES:

1. Select one of the following types of Dredging Methods:
   - 1 - Hopper Dredge
   - 2 - Pipeline Dredge
   - 3 - Mechanical (Clamshell)

2. All quantities are based on required pay prism and not gross yardage.

3. New Work Quantities were excluded from these numbers

4. Calculatons:
Yearly Average for Entrance Channel from Table 5A is **630** x 10years = **6,300 Thousand Cubic Yards (TCY)**. (This will be used in Table 12 projections for the entrance Channel)
Yearly Average per Shoal of only those Shoals that are currently dredged will be used in Table 12 Lower Reaches Projections (We no longer Dredge the Anchorage Basin)
To get Yearly Average for future ODMDS Disposal: Yearly Avg of Ent Channel + Yearly Avg of Chas Lower (Anchorage Basin Removed - no longer dredged) . 630+731 = **1,361 TCY** (To be used in table 12)
Yearly Avg for Clouter from Table 10 is 425 However, we will only consider the average since the 2002 dredging, we have had 3 actual dredging events since then. 1,280(2005)+1,592(2007)+1,843(2009) = 4,715 / 6 years = **786 TCY** per year or **1,572 TCY** per dredge cycle. These numbers will be used in Table 9 (Cost Projection) and Table 12 (Anticipated Federal Dredging)

5. During the 1996, 1997, 1998 Dredging events, all Lower Harbor shoals and some Upper Harbor Shoals were deposited in Daniel Island, with the exception of Ordnance Reach and Ordnance Reach TB, which were deposited in Clouter.

Table 11

Dredging History: Private Work

Approximate area -Reach or Segment	Primary Dredge Method (1)	Dredging History (Thousand CY per Fiscal year)																	Disposal Site(s) Used (Identifier)
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	TOTAL	YEARLY AVG	
Shipyard River	2	50.0	7.3	46.0	25.6	40.0			76.0	56.0	54.9		56.3		89.9		**502**	**33**	Clouter Creek
Clouter Creek Reach (includes Pier Papa)	2			23.0	162.0		178.0	339.0	381.4	166.0		689.4	351.4	116.6	60.0	499.5	**2,966**	**198**	Clouter Creek
Navy Yard Reach	2				162.0		178.0	339.0	169.0	166.0		148.5	242.5	48.9	30.0		**1,484**	**99**	Clouter Creek
North Charleston Reach	2			40.9							8.7		15.6	7.0	6.0		**78**	**5**	Clouter Creek
Filbin Creek Reach	2	9.0	8.7		9.3	22.8		14.6	16.0		30.6		12.8	5.5	19.2	9.8	**158**	**11**	Clouter Creek
Port Terminal Reach	2			11.3		13.8				52.0		46.1	16.0	30.4		9.8	**179**	**12**	Clouter Creek
Ordinance Reach	2										335.4		35.3		259.1	25.0	**655**	**44**	Clouter Creek
TC Dock	2		49.0	57.0		46.0	44.0		44.0		57.0	57.4	56.0	49.2	30.6	51.8	**542**	**36**	Clouter Creek
TOTALS		**59.0**	**65.0**	**178.2**	**358.9**	**122.6**	**400.0**	**692.6**	**686.4**	**440.0**	**486.6**	**941.4**	**785.9**	**257.6**	**494.8**	**595.9**	**6,565**	**438**	
		0	0	735.6	0	552.3	0	459.7	1031.5	729.3	0	0	1280.9	0	1592.4	0			
		59.0	65.0	913.8	358.9	674.9	400.0	1,152.3	1,717.9	1,169.3	486.6	941.4	2,066.8	257.6	2,087.2	595.9			

NOTES:

1. Select one of the following types of Dredging Methods:
   - 1 - Hopper Dredge
   - 2 - Pipeline Dredge
   - 3 - Mechanical (Clamshell)

2. All quantities are based on required pay prism and not gross yardage.

3. Calculation Notes:
Historical Averages for Private work = **438 TCY** per year (to be used in Table 13).

Table 12

Anticipated Dredging: Federal Channel Maintenance

Reach or Segment	Primary Dredge Method	Programmed Dredging Maint (Thousand CY per fiscal year) (1,2,3) (Consistent with 10-yr O&M Maintenance Plan)												Disposal Site(s) to be Used (Identifier)
		2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Totals**	**Yearly AVG**	
Entrance Channel	1		1,260.0		1,260.0		1,260.0		1,260.0		1,260.0	**6,300**	**630.0**	ODMDS
Fort Sumter and Mt. Pleasant Ranges	3											**0**	**0.0**	ODMDS
Mount Pleasant Range	3											**0**	**0.0**	ODMDS
Rebellion Reach	3											**0**	**0.0**	ODMDS
Shem Creek Access	3		40.0	40.0	40.0	40.0		40.0		40.0	40.0	**280**	**28.0**	ODMDS
Anchorage Basin	3											**0**	**0.0**	ODMDS
Folly Reach	3											**0**	**0.0**	ODMDS
Shutes Reach	3											**0**	**0.0**	ODMDS
Horse Reach	3											**0**	**0.0**	ODMDS
Tidewater Reach	3		62.9	62.9	62.9	62.9		62.9		62.9	62.9	**440**	**44.0**	ODMDS
Custom House Reach	3		61.4	61.4	61.4	61.4		61.4		61.4	61.4	**430**	**43.0**	ODMDS
Town Creek Lower (w/tb)	3		272.9	272.9	272.9	272.9		272.9		272.9	272.9	**1,910**	**191.0**	ODMDS
Hog Island Reach	3		141.4	141.4	141.4	141.4		141.4		141.4	141.4	**990**	**99.0**	ODMDS
Town Creek Upper	3											**0**	**0.0**	ODMDS
Drum Island Reach	3		130.0	130.0	130.0	130.0		130.0		130.0	130.0	**910**	**91.0**	ODMDS
Wando River Lower Reach	3		78.6	78.6	78.6	78.6		78.6		78.6	78.6	**550**	**55.0**	ODMDS
Wando Uppper TB	3		140.0	140.0	140.0	140.0		140.0		140.0	140.0	**980**	**98.0**	ODMDS
Wando Upper Reach	3		117.1	117.1	117.1	117.1		117.1		117.1	117.1	**820**	**82.0**	ODMDS
TOTALS FOR ODMS (4)			**2,304.3**	**1,044.3**	**2,304.3**	**1,044.3**	**1,260.0**	**1,044.3**	**1,260.0**	**1,044.3**	**2,304.3**	**13,610**	**1,361.0**	**ODMDS TOTALS**
Myers Bend	2			29.5	29.5		29.5	29.5		29.5		**148**	**14.8**	Clouter Creek
Shipyard River (w/ub & lb)	2	334.5		224.3	224.3		224.3	224.3		224.3		**1,456**	**145.6**	Clouter Creek
Daniel Island Reach	2	594.2		387.9	387.9		387.9	387.9		387.9		**2,534**	**253.4**	Clouter Creek
Daniel Island Bend	2											**0**	**0.0**	Clouter Creek
Clouter Creek Reach (w/pp)	2											**0**	**0.0**	Clouter Creek
Navy Yard Reach	2	59.1		31.6	31.6		31.6	31.6		31.6		**217**	**21.7**	Clouter Creek
North Charleston Reach	2											**0**	**0.0**	Clouter Creek
Filbin Creek Reach	2											**0**	**0.0**	Clouter Creek
Port Terminal Reach	2	26.3		13.4	13.4		13.4	13.4		13.4		**93**	**9.3**	Clouter Creek
Ordinance Reach	2	255.3		187.9	187.9		187.9	187.9		187.9		**1,195**	**119.5**	Clouter Creek
Ordinance Reach TB	2	574.0		435.4	435.4		435.4	435.4		435.4		**2,751**	**275.1**	Clouter Creek
TOTALS FOR CLOUTER (5)		**1,843.4**		**1,310.0**	**1,310.0**		**1,310.0**	**1,310.0**		**1,310.0**		**8,393**	**839.3**	**CLOUTER TOTALS**
TOTALS		**1,843.40**	**2,304.30**	**2,354.30**	**3,614.30**	**1,044.30**	**2,570.00**	**2,354.30**	**1,260.00**	**2,354.30**	**2,304.30**	**22,004**	**2,200.4**	

NOTES:

1. All quantities are based on required pay prism and not gross yardage.

2. Average Dredge Cycles: Entrance Channel is once per 24 Months
Charleston Lower Channel is once per 18 Months
Charleston Upper Channel is once per 21 Months

3. Number of Dredging Cycles over the next 10 years:
Entrance Channel 120 Months / 24 Months = 5 Dreding Events - **5 total**
Lower Charelston 120 Months / 18 Months = 6.7 Dredging Events - Round t **7 Total**
Upper Charleston 120 Months / 21 Months = 5.7 Dredging Events - Round t **6 Total**

4. Calculations for ODMDS:
Annual Average for Entrance Channel = Yearly Average for Entrance Channel (From Table 10) is 630 x 10years = 6,30 TCY. 6,300 / 5 Dredging Events = **1,260 TCY** per Dredge
Annual Average for the Shoals that we currently Dredge in Charleston Lower (From Table 10) 731 x 10years = 7,310. 7,310 / 7 Dredging Events = **1,044 TCY** per Dredge
Total Projected Yardage for ODMDS (From Note 4, table 10) = 13,610 TCY over the next 10 years. Projected Disposal at the ODMDS is **1.361 MCY** per year (To be used in Table 14)

5. Calculations for Clouter:
Total Projected Federal Yardage for Clouter (From Table 10) was 786 **TCY** Anually. **786 x 10 Years = 7,860 TCY** over the next 10 years.
For 6 Dredges in the Upper Harbor, the average Dredge Amounts are 7,860 / 6 = **1,310 TCY** Per Dredge Cycle
We currently have a contract in progress in FY09 for dredging in the upper Chas Harbor of **1,843 TCY**, the **1,310 TCY** will be used on the remaining 5 Dredge Cycle Projections.
Revised Projected Total Cubic Yardage for Chas Upper / Clouter Creek = **8,393 TCY** (To be used in Table 15)

Table 13

Anticipated Dredging: Private Work

Reach or Segment	Primary Dredge Method	Programmed Dredging (Thousand CY per Fiscal year) (1,2) (Consistent with 10-yr O&M Maintenance Plan)												Disposal Site(s) to be Used (Identifier)
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Totals	Yearly AVG	
Shipyard River	2	33	33	33	33	33	33	33	33	33	33	**330**	**33**	Clouter Creek
Clouter Creek Reach (w/pp)	2	198	198	198	198	198	198	198	198	198	198	**1980**	**198**	Clouter Creek
Navy Yard Reach	2	99	99	99	99	99	99	99	99	99	99	**990**	**99**	Clouter Creek
North Charleston Reach	2	5	5	5	5	5	5	5	5	5	5	**50**	**5**	Clouter Creek
Filbin Creek Reach	2	11	11	11	11	11	11	11	11	11	11	**110**	**11**	Clouter Creek
Port Terminal Reach	2	12	12	12	12	12	12	12	12	12	12	**120**	**12**	Clouter Creek
Ordinance Reach	2	44	44	44	44	44	44	44	44	44	44	**440**	**44**	Clouter Creek
TC Dock	2	36	36	36	36	36	36	36	36	36	36	**360**	**36**	Clouter Creek
TOTALS		**438**	**438**	**438**	**438**	**438**	**438**	**438**	**438**	**438**	**438**	**4380**	**438**	

NOTES:
1. All quantities are based on required pay prism and not gross yardage.

2. Calculation Notes:
Historical Averages for Private work from table 11 = **438 TCY** per year.

3. Revised Projected Total Cubic Yardage for Clouter Creek Disposal = **438 TCY per year** (To be used in Table 15)

DREDGED MATERIAL DISPOSAL SITE CAPACITY AND USAGE

At one time, the inside channels of Charleston Harbor were served by four upland diked containment sites: Morris Island, Drum Island, Daniel Island, and Clouter Creek Disposal Areas (see Figure 5). Currently, only Drum Island and Clouter Creek Disposal Areas are actively used. The Naval Weapons Station Disposal Area (see Figure 5), is used for maintenance material dredged from the Naval Weapons Station channels and wharves, but may also be used for maintenance of the Federal channels under a license from the Navy (see page 33 for more details). Yellow House Creek Disposal Area is used solely for maintenance of the Naval Weapons Station. The Charleston Harbor Ocean Dredged Material Disposal Site (ODMDS) is used for disposal of material removed from the Entrance Channel as well as from the "Lower Reaches" of Charleston Harbor.

The Charleston, South Carolina, Ocean Dredged Material Disposal Site is one of the most active, frequently used sites in the South Atlantic Bight (part of EPA's Region 4 area of responsibility). The general site has been in use since 1896 for disposal activities. The original management plan for ocean dredged materials disposal associated with the Charleston Harbor complex (1987) called for two sites. The permanently designated ODMDS was approximately 2.8 x 1.1 nautical miles in size (Figure 4.1, labeled "smaller ODMDS"). This site was designated to receive all dredged material emanating from maintenance dredging activities in the harbor and entrance channels. Surrounding the permanent smaller ODMDS was a larger ODMDS. This site encompassed an area of approximately 5.3 x 2.3 nautical miles (Figure 4.1, labeled "larger ODMDS"), and was designated for one time use, only, for placement of material obtained during the Charleston Harbor Deepening Project. This larger ODMDS was designated for a seven year period of use (1987-1994) for placement of material obtained during the 1987-1994 Charleston Harbor Deepening Project.

In the fall/winter of 1989-1990, local fishermen reported that disposal operations occurring in the permanently designated, smaller ODMDS were impacting a live bottom area within the western quarter of that area. Until that time, no significant live bottom areas were known to exist within or near either the larger or small disposal area. Due to the discovery of live bottom habitat, a line was immediately put in place by the EPA that was located on the eastern edge of the smaller ODMDS, in an effort to protect these valuable resources (Figure 4.1, labeled "EPA line"). The final rule regarding this line was published in the Federal Register in 1991, and stated that "All dredged material, except entrance channel material, shall be limited to that part of the site east of the line between coordinates 32º39'04"N, 79º44'25"W and 32º37'24"N, 79º45'30"W unless the materials can be shown by sufficient testing to contain 10% or less of fine material (grain size of less than 0.074 mm) by weight and shown to be suitable for ocean disposal."

Video mapping of the seafloor was conducted during this same time period (1990) by the EPA in the vicinity of the ODMDSs in an effort to precisely map the location and extent of live bottom within and beyond the boundaries of both the smaller and larger ODMDSs. Based on the results of the video survey, the interagency Site Management and Monitoring Plan (SMMP) Team (EPA, SCDNR, COE, and SCSPA) jointly decided in 1993 that the area actively used for disposal should be moved to a new location within the larger ODMDS to avoid future disposal of materials on sensitive live bottom habitat. This location was four square miles in size, and agreed upon by all agencies (Figure 4.1, four square mile Disposal Zone). The creation of this four square mile Disposal Zone within the larger ODMDS required the development of a Management Plan which included a comprehensive Monitoring Plan for the site. The monitoring plan was regarded as a flexible strategy with the various task and techniques applied as appropriate and as dictated by disposal activities. The four square mile Disposal Zone and surrounding areas were divided into three zones (Figure 4.2, disposal zone, inner boundary, and outer boundary), which formed 20 discrete areas (or strata) of comparable size (one square mile). Based on the Site Management Plan, the COE began building an L-shaped berm on the western side of the four square mile Disposal Zone using material from the 42-ft deepening project. The berm was to be constructed of harder materials and was designed to serve as a barrier, with finer materials to be placed to the east of the barrier.

In 1995, the smaller ODMDS was officially de-designated in the Federal Register due to the presence of live bottom habitat in the area. The language describing the larger ODMDS was modified such that the site could be used for all disposal materials permitted for offshore disposal, which meant that the site was no longer limited for the disposal of deepening materials. In addition, the time limit restricting the use of the larger disposal area to a seven year period was removed, and the site was permitted for “continued use.”

The U.S. Congress authorized the most recent Charleston Harbor Deepening Project in 1996. The project was planned to deepen the entrance channel from 42 ft to 47 ft, and the inner harbor channel from 40 ft to 45 ft. Approximately 20-25 million cubic yards of sediments were planned for disposal in the four square mile Disposal Zone selected by the Task Force in 1993.

On October 10, 2001, a proposed rule was published in the Federal Register [66 FR 51628] to modify the site name and restriction of use. The proposed action was (1) to define the four square mile Disposal Zone as the only area in which disposal can continue, (2) to shorten the official name of the site from the Charleston Harbor Deepening Project ODMDS to the Charleston ODMDS and (3) to remove the line that restricts the disposal of fine-grained material. The only letter received during the 45 day comment period came from the Office of Ocean and Coastal Resource Management, South Carolina Department of Health and Environmental Control. Upon receipt of the consistency determination for the Coastal Zone Management Act, EPA proceeded with the final rule which became effective on June 6, 2002. **Based on projected future use for maintenance material the current ODMDS has more than 20 years (Table 14) remaining capacity at a clearance elevation of -25' MLLW.**

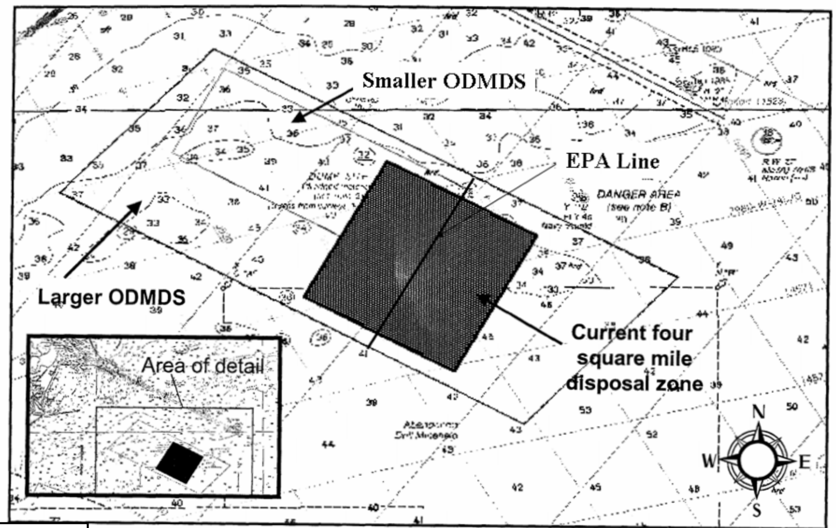

Figure4.1 Location of the larger ODMDS, smaller ODMDS, and the currently designated four square mile disposal zone.

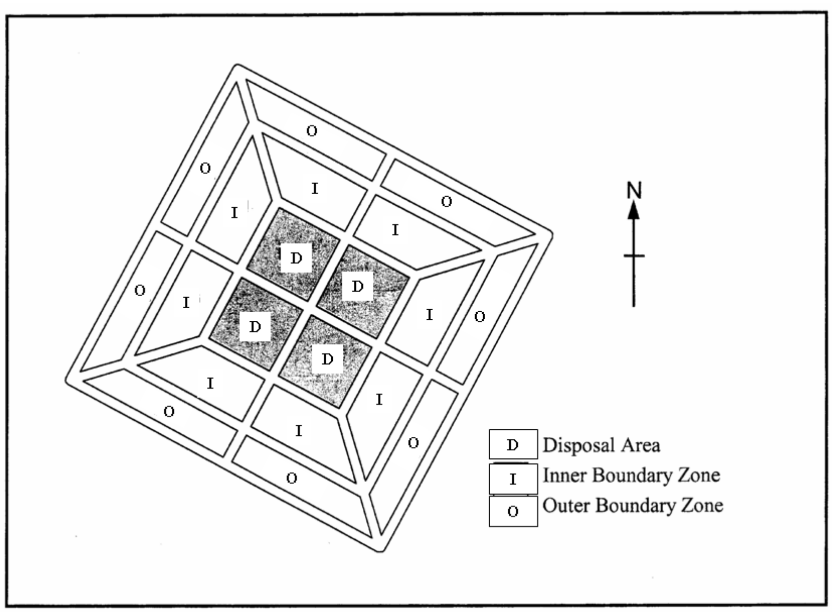

Figure4.2 Designated disposal zone within the Charleston ODMDS and the surrounding boundary zones.

FIGURE 4 ODMDS

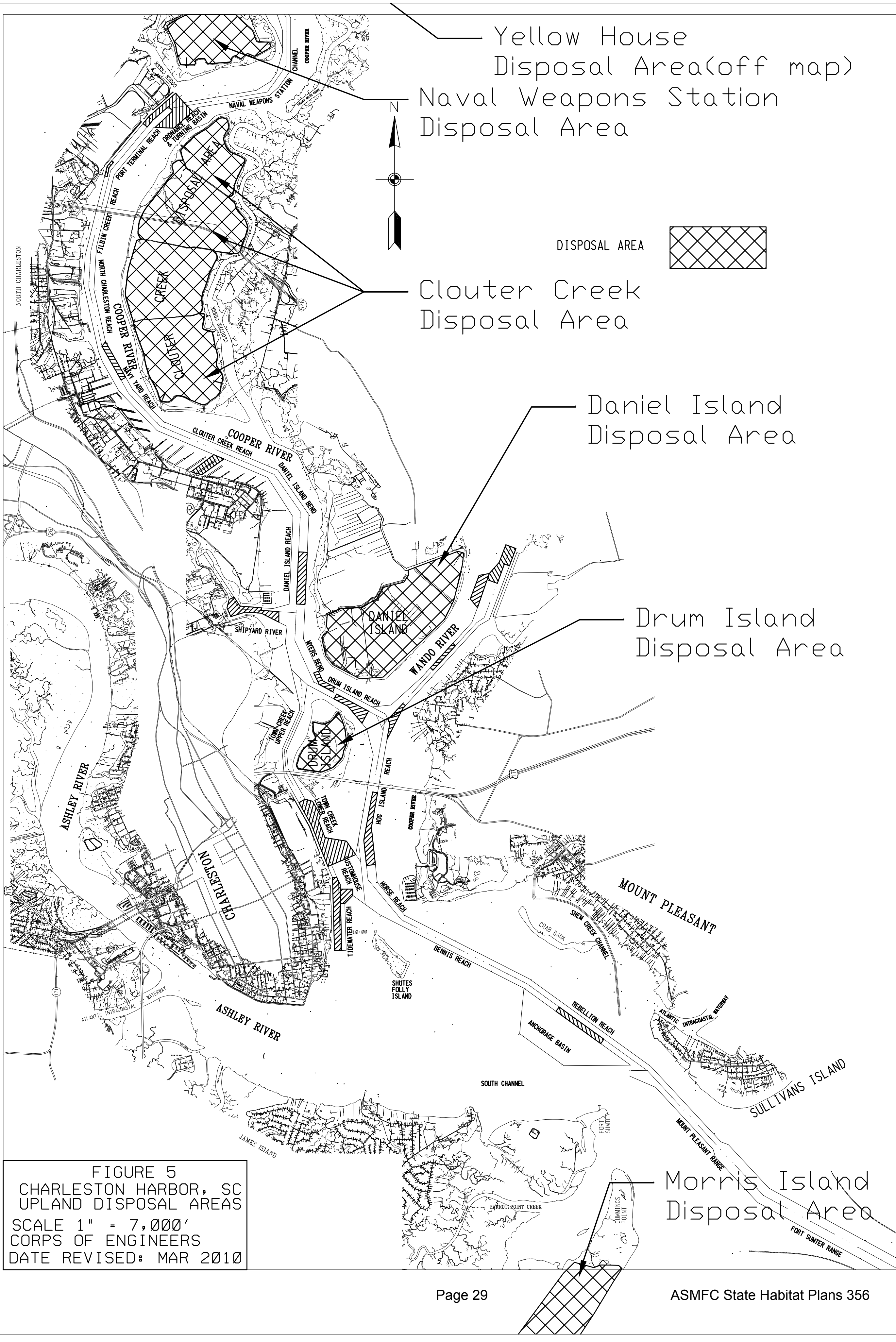

FIGURE 5
CHARLESTON HARBOR, SC
UPLAND DISPOSAL AREAS
SCALE 1" = 7,000'
CORPS OF ENGINEERS
DATE REVISED: MAR 2010

Morris Island is a barrier island south of Charleston Harbor and southwest of the entrance to Charleston Harbor. It is owned by the South Carolina State Ports Authority (SCSPA), which has renewed the disposal easement to the Government until August 2017. The site contains about 525 acres total and is divided by a cross dike into two cells. The North Cell contains approximately 165 acres and the South Cell contains approximately 360 acres.

The North Cell was last pumped in 2004. The North Cell dikes vary between elevation 19.0 and 20.0 NAVD88 and the interior elevation varies between 14.0 and 16.0+ NAVD88. The North Cell therefore currently has average freeboard of approximately four feet (4'), resulting in a gross capacity of about 1.0 MCY. Allowing for two feet of ponding and freeboard, and assuming a bloat factor of 2.0, there would be capacity for only about 266 KCY if placed all at one time.

The South Cell dikes vary between 16.0 and 20.0 NAVD88 and the interior elevation varies between about 5.0 and 14.0 NAVD88. The South Cell therefore currently has average freeboard of approximately eight feet (8'), resulting in a gross capacity of about 4.6 MCY. Allowing for two feet of ponding and freeboard, and assuming a bloat factor of 2.0, there would be capacity for about 1.7 MCY if placed all at one time. Unfortunately, the ocean has severely eroded the dike along the ocean side of the South Cell and the remaining capacity cannot be utilized without first repairing the dike. It is only a matter of time before the entire disposal area is reclaimed by the ocean. Severe erosion effects about 5000 linear feet of dike facing the ocean and is now impacting the North Cell as well.

Due to the long distance of this site from the inner harbor channels, it was historically used to contain maintenance material dredged from Rebellion Reach, the Anchorage Basin, and Shem Creek only. The site was not deemed to be within an economical pumping distance from other inner harbor shoals. However, the area has been used to contain new work material dredged from other reaches of the harbor. Maintenance of the Anchorage Basin has been discontinued due to lack of use after closure of the Charleston Navy Base. If eroded dikes were repaired and stabilized, Morris Island could be a valuable disposal asset to Charleston Harbor.

Drum Island is located in lower Charleston Harbor, northeast of the City of Charleston, and opposite the confluence of the Wando and Cooper Rivers. It is bounded by Town Creek to the west and the Cooper River to the east. It is owned by the South Carolina State Ports Authority (SCSPA) and the Federal Government has a disposal easement until January 2012. The central diked area contains approximately 138 acres, and the dikes, which were raised by SCSPA around 2005 provide an estimated 8 feet of freeboard. The area is used by SCSPA for maintenance of their Lower Harbor berths.

The site was historically used in conjunction or rotation with Daniel Island Disposal Area for maintenance material dredged from the Lower Harbor reaches between Tidewater and Hog Island Reaches northward to Shipyard River and Daniel Island Reaches (from about channel Mile 5 to Mile 10), but principally from Tidewater Reach and Shoal 6A (Town Creek). Due to the relatively small size of this area, it cannot be used to contain large quantities of material during a single dredging cycle. It is well-suited to off-cycle maintenance of the State Ports berths and high-shoaling areas of the Federal channel, during which quantities are relatively small. Currently, the Corps - by informal agreement - does not exercise its easement. We are not currently disposing material into this area.

A North Cell was used for dredged material up until about the late 1960's or early 1970's. It was frequented by nesting waterfowl and became known as the North Rookery. Bird populations declined and the SCSPA granted the Corps a disposal easement to use the area between 1987 and 1990. This cell is small but would nonetheless be valuable for containing the relatively small quantities dredged from the SPA Columbus Street Berths or as an emergency disposal area. Erosion exists along the Drum Island Reach side and part of the dike is now gone, along with some of the spillway pipe.

A South Cell, also a former bird rookery, was used for deposit of dredged material up until about the mid-1960's. The birds no longer use the site and it would be worthwhile to investigate the possibility of reactivating the cell. Just like the North Cell, it would be useful for containing the relatively small quantities dredged from the SPA Columbus Street Berths or as an emergency disposal area.

Update from SCSPA: There are areas to the north and south that are not part of the main cell. The southern part, below the old bridges received dredge material infrequently to supposedly kill vegetation and predators in an effort to enhance the rookery. The single cell that is used now is somewhere between 100 and 150 acres and lies entirely above the Ravenel Bridge. The southern dike was reconfigured with the construction of the Ravenel Bridge. As part of mitigation for the Navy Base Port Terminal, the SCSPA has plans to return a portion of the south end of the island to marsh

Daniel Island Disposal Area is located at the southern tip of Daniel Island, about three miles northeast of Charleston, at the confluence of the Wando and Cooper Rivers. The site is owned by the South Carolina State Ports Authority. The Ports Authority did not renew the easement to the Federal Government after January 1998. Ports Authority plans to develop a new shipping terminal on this site were rejected by the SC Legislature. Similarly, plans for development of the former disposal area have not yet materialized. The site is divided into three cells: the West Cell contains 177 acres, the Middle Cell contains 198 acres, and the Wando Cell contains 300 acres. The site was used between 1969 and 1997 to contain maintenance and new work material dredged from about Mile 5 to Mile 10 of the Lower Harbor channels, which includes Town Creek, Wando River, and Shipyard River. Daniel Island is a large disposal area centrally located with respect to the rapid-shoaling areas of the Lower Harbor reaches. It was actively managed by the Charleston District in order to extend its useful life, and the loss of this centrally-located disposal area was a severe blow to continued economic maintenance of the Lower Harbor channels. Most of the material that previously was placed in Daniel Island is now transported to the ODMDS. Material from Shipyard River and Daniel Island Reach that previously was placed in Daniel Island is now pumped upstream to Clouter Creek Disposal Area. These alternatives to Daniel Island are more costly than use of Daniel Island due to increased pumping and/or haul distances using dump scows.

Clouter Creek Disposal Area is located on the east bank of the Cooper River to the east of North Charleston, South Carolina. It is bounded on the north, west and south by the Cooper River and on the east by Clouter Creek. Approximately the southern two-thirds of the area (formerly owned by the U.S. Navy) are now owned by the Corps of Engineers, while the northern third is owned by the South Carolina State Ports Authority (SCSPA). The Federal Government enjoys a perpetual easement on the state-owned portion. During the 1980's, the area was subdivided by the construction of cross dikes into four cells. Their names and approximate contained acreages, from south to north are:

South Cell (415 acres)
Middle Cell (410 acres)
Highway Cell (460 acres)
North Cell (190 acres)

The South and Middle Cells currently service maintenance dredging needs of the Federal channels from Shipyard River and Daniel Island Reach northward to North Charleston Reach, including the former navy base piers and slips. The North and Highway Cells are currently used for maintenance dredging of the channels at the upper end of the Federal project, from Filbin Creek Reach to Ordnance Reach, including Ordnance Reach Turning Basin and the TC Dock. With proper management, the total capacity of the Clouter Creek Disposal Area exceeds anticipated needs well beyond next twenty years.

The **Naval Weapons Station** Disposal Area, located at the south end of the Naval Weapons Station, is bounded to the south and east by the Cooper River and to the west by Goose Creek. It is to the north of Clouter Creek Disposal Area and the upstream limit of the Federal project at the mouth of Goose Creek. In 1985, the Navy granted the Army a 25-year license to use the area for disposal of material dredged from the Navy Channel as well as from the commercial channel. The license will expire in 2010. The Charleston district is pursuing renewal of this license. The area contains about 300 acres. The area has been used to contain maintenance material from the Naval Weapons Station as well as new work material from the previous deepening of Ordnance, Port Terminal, and Filbin Creek Reaches. The Navy pays all diking costs and the site is managed by the Corps for maintenance of the Naval Weapons Station channel and berths.

Yellow House Creek Disposal Area is owned by the State (SCSPA) and the Government enjoys a perpetual easement. The diked area contains approximately 600 acres. Currently, the Navy pays all diking costs and the site is used solely for maintenance of the Naval Weapons Station channel and berths.

Table 14

Disposal Site Data

Disposal Site(s) (Name or Identifier)	Site Type (1)	Disposal Site Capacity		Beneficial Uses (CY/Year)		Other Uses (3)	Disposal Site Sponsor (Y/N)
		Original (MCY)	Percent Filled (2)	Existing	Ancicipated		
ODMDS (5,6,7)	2	77.4	68% (5)	None	None	D	Y
Morris Island (8)	6	N/A	N/A	None	None	D	Y
Drum Island (9)	6	N/A	N/A	None	None	D	Y
Daniel Island (7)	6	34.2	79%	None	Development	D	Y
Clouter Creek (4)	6	33.5	71%	None	None	D	Y

Sponsor for Disposal Site (s)		
Name: South Carolina State Ports Authority (SCSPA)		
Address: P.O. Box 817	City: Charleston	State: SC
Point of Contact: Tim Sherman	Phone # (843) 856-7055	

Notes:

1. Select one of the following types of disposal sites: (1) Open Water, unrestrained; (2) Designated Open Water; (3) Near Shore (surf zone); On Shore (beach renourishment); (5) Near Shore Confined (in water CDF); (6) Upland Confined; (7) Upland Unconfined

2. Based on existing diking

3. Select one of the following types of Non-Corps Users:
   - A - None, (Corps has exclusive use)
   - B - Authorized (Other parties allowed to use, with or without Corps consent)
   - C - Allocated (Space available for project related non-Corps dredging at no cost)
   - D - Permitted (Space available for non-Corps dredging in the area at a cost)

4. See Table 15 for a more detailed breakout of Clouter Capacity and Ditching/Diking Plans

5. The State Ports Authority plans on Removing 4-6 MCY of material from the ODMDS Site for use as fill for the upcoming construciton of the New North Charleston Navy Base Port Site. This will futher extend the life of the ODMDS.

6. We estimate that as of FY09, there is approximately **25 MCY** of capacity at the ODMDS Site. Based on State Port removing **4-6MCY** from the ODMDS within the next 5 years for the Navy Base Terminal Construction, assume current capacity is **29 MCY.** Projected Maintenance Material Disposal at ODMDS site is **1.361 MCY** (Table 12) per year = **21.3 Years** of Capacity Remaining.

7. There is the potential that the project sponsor will renew our inactive easment on Daniel Island for 10 years or longer. Use of the Daniel Island Disposal site in lieu of the ODMDS would further prolong the life of the ODMDS Site.

8. Severe Erosion from the ocean has destroyed oceanside dike. No current capacity at the Morris Island Disposal Site.

9. Drum Island is reserved for use by Project Sponsor (SC State Ports Authority) berthing areas. Not used for Federal Channels per agreement with the Project Sponsor.

Table 15

Clouter Creek Disposal Area 10 Year Plan

Reach or Segment								Programmed Dredging (Thousand CY per Fiscal year) (1,2) (Consistent with 10-yr O&M Maintenance Plan)												Disposal Site(s) to be Used (Identifier)
	2008 West Side Dike Elevations	2008 East Side Dike Elevations	SF of Disposal Area	Acres	Ht of Disposal Availabe (ft) (5)	2008 Disposal Capacity (CY)	2008 Activities	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Totals	Yearly AVG	
Clouter North Cell 190 Acres	25	23	8,276,400	190	6	1,839,200	Disposal	729.9	140.2	559.4	Ditching	Ditching	Diking	Diking	140.2	559.4	140.2	2,269	226.9	Clouter North
Clouter Highway Cell 460 Acres	22	19	20,037,600	460	0	0	Ditching	Ditching	Diking	Diking	874	219	874	874	Ditching	Ditching	Diking	2,841	284.1	Clouter Highway
Clouter Middle Cell 410 Acres	26	25	17,859,600	410	6	3,968,800	Disposal	1,551.1	297.8	1188.6	Ditching	Ditching	Diking	Diking	297.8	1188.6	297.8	4,822	482.2	Clouter Middle
Clouter South Cell 415 Acres	30	29	18,077,400	415	0	0	Ditching	Ditching	Diking	Diking	874	219	874	874	Ditching	Ditching	Diking	2,841	284.1	Clouter South
TOTALS FOR CLOUTER 1,475 Acres				1,475		5,808,000		2,281.0	438.0	1,748.0	1,748.0	438.0	1,748.0	1,748.0	438.0	1,748.0	438.0	12,773	1,277.3	Clouter Total

NOTES:

1. All quantities are based on required pay prism and not gross yardage.

2. Calculation Notes

Projected Disposal numbers are based on Anticipated Federal (Table 12) of **8,393** and **4,380** Private (Table 13). Total anticipated Disposed at Clouter over the next 10 years is **12,773 TCY**
Programed dredging amounts for each year come from Table 12 (Anticipated Federal) plus Table 13 (Anticipated Private)

3. Total Breakout of Areas: North Cell = 13%, Hwy Cell = 31%, Middle Cell = 28%, South Cell = 28%

4. Cycle Breakdowns:

North Cell and Middle Cell Disposal Cycles: 32% in North Cell, 68% in Middle Cell
Highway Cell and South Cell Disposal Cycles: 50%, 50%

5. Height of Disposal Area dikes are as of today, and will be raised as Ditching/Diking occurs over the next 50-75 years.

6. Based on current disposal projections, and given our success at ditching/diking at the site, we do not anticipate having any capacity issues at Clouter over the next 20 years.

Table 16

Dredging History: Maintenance Placement in Disposal Areas

Reach or Segment	Primary Dredge Method (1)	Dredging History (Thousand CY per year)																	Disposal Site(s) Used (Identifier)
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Yearly AVG	
ODMDS	3		1,735.0		775.4		1,562.7	2,215.0			2,635.3	2,190.9		1,178.7	1,452.0	2,161.0	15,906.0	1,060.4	ODMDS
MORRIS ISLAND	2	946.4										415.2					1,361.6	90.8	MORRIS ISLAND
DRUM ISLAND	2							381.0									381.0	25.4	DRUM ISLAND
DANIEL ISLAND	2	858.2		2,054.2	218.8	2,191.6		34.0									5,356.8	357.1	DANIEL ISLAND
CLOUTER CREEK	1	59.0	65.0	913.8	358.9	674.9	400.0	1,152.3	1,717.9	1,169.3	486.6	941.4	2,066.8	257.6	2,087.2	595.9	12,946.6	858.8	CLOUTER CREEK
TOTALS		1,863.6	1,800.0	2,968.0	1,353.1	2,866.5	1,962.7	3,782.3	1,717.9	1,169.3	3,121.9	3,547.5	2,066.8	1,436.3	3,539.2	2,756.9	35,952.0	2,396.8	

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NOTES:

1. Select one of the following types of Dredging Methods:
   - 1 - Hopper Dredge
   - 2 - Pipeline Dredge
   - 3 - Mechanical (Clamshell)

2. Data for this table comes from Tables 10 and 11

3. All quantities are based on required pay prism and not gross yardage.

4. Calcuations

Double check of quantities - Table 10 Total Quantity was 29,387 TCY (Federal) + Table 11 Total Quantity 6,565 (Private) = **35,952 TCY**

ENVIRONMENTAL COMPLIANCE

The existing Charleston Harbor project requires maintenance dredging of the navigational channel which extends from the 47-foot ocean contour to a point 26.97 miles up the Cooper River. In addition to the main channel, maintenance dredging is also needed in the Tidewater Reach, Upper and Lower Town Creek Reaches, Wando Channel, and the Shipyard River channels. Frequent shoaling is a problem in particular reaches, such as in the vicinity of Drum Island where dredging occurs on almost a six-month cycle.

Charleston Harbor has been broken up into three reaches commonly known as the Entrance Channel, the Lower Harbor and the Upper Harbor, based on the type of equipment used for transportation and the disposal location. Material from the Entrance Channel is dredged using a hopper dredge and is taken to the ODMDS. A clamshell dredge transports material from the Lower Harbor to the ODMDS and the dredged material from the Upper Harbor is disposed of in Clouter Creek Disposal Area by a pipeline dredge.

Historically, dredged material removed from Charleston Harbor has been placed within four upland disposal sites located throughout the study area and the Ocean Dredged Material Disposal Site (ODMDS). The four upland disposal sites include Morris Island, Drum Island, Daniel Island and Clouter Creek. Morris Island is rarely used due to its removed distance; however the area has been used to contain dredge material when deepening and widening have occurred. Drum Island is owned by the South Carolina State Ports Authority and is not often utilized but is a disposal option in emergency situations. The Daniel Island disposal easement expired in January of 1998 and therefore is no longer utilized. Clouter Creek disposal site is currently used for disposal material in the Upper Harbor.

Beneficial Use of Dredge Material. With the recommendation of SCSPA, the Charleston District plans to investigate potential beneficial uses of dredge material for the Charleston federal navigation project with a study under the authorization of Section 204. The goal of the study is to identify alternatives for managing/distributing the sediment resources within the federal project in order to protect, restore, and/or create coastal and estuarine resources in the region surrounding the federal project. The plan will address how Regional Sediment Management will be included in the operation and maintenance of the federal project.

In order to comply with environmental laws and regulations, the following is a list of documents, permits, and certifications that have been obtained for Charleston Harbor:

August 1975, Final Environmental Statement for Charleston Harbor Deepening Project for Charleston Harbor and Shipyard River, prepared by the U.S. Army Corps of Engineers, Charleston District. This environmental impact statement (EIS) was developed to identify any environmental impacts that would likely occur with the deepening of various channels in Charleston Harbor, enlarging the Shipyard River and Anchorage Basins and the turning basins at Goose Creek and Columbus Street, widening the North Charleston and Filbin Creek reaches, and relocating the channels near terminals to provide better clearance between piers and the edge of the channel. Environmental impacts associated with these actions included water quality changes; adverse effects on plankton and primary productivity; minor losses of larval and juvenile fishes; detraction of visual appearance of the harbor by the presence of the dredge boats and pipelines; and minor air and noise pollution.

March 1976. Final Environmental Statement for Maintenance Dredging of Charleston Harbor, Ashley River and the U.S. Navy Channels and the Cooper River, prepared by the U.S. Army Corps of Engineers. This EIS identified environmental impacts associated with maintenance dredging in Charleston Harbor, Shipyard River, Ashley River, and the Navy channel, piers and slips. The identified environmental impacts include short term increase in turbidity; smothering of plant and animal communities in disposal areas; temporary reduction of phytoplankton and zooplankton; possible oxygen reduction; short-term reduction in benthic organism populations; increase in mosquito populations; and stimulation of the local, State and national economy.

September 18, 1978. Water Quality Certification for Federal Projects, issued by the South Carolina Department of Health and Environmental Control, no expiration. This certification stated that the Charleston Harbor Entrance Channel and Charleston Harbor and Shipyard River Maintenance Dredging projects are consistent with applicable provisions of Sections 301, 302, 303, 306, and 307 of the Federal Water Pollution Control Act of 1972.

March 10, 1995. Federal Consistency for Charleston Harbor Deepening/Widening Project, P/N 94-1R-498, issued by SC Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (OCRM), no expiration. This Federal Consistency is in response to a public notice issued on December 9, 1994 describing proposed new work to deepen, widen and/or realign the Charleston Harbor federal navigation channel and diked upland disposal area return waters. The Consistency determination stated that the project is consistent with the Coastal Zone Management Program to the maximum extent practicable and serves as the final approval by OCRM.

May 2, 1995. Certification in Accordance with Section 401 of the Clean Water Act, as amended, Dredging Charleston Harbor P/N 94-1R-498, issued by SC Department of Health and Environmental Control, no expiration. This certification was also in response to the public notice described above. This water quality certification stated that there is reasonable assurance that the proposed project will be conducted in a manner consistent with the certification requirements of Section 401 of the Federal Clean Water Act. It also certifies that there are no applicable effluent limitations under Sections 301 (b) and 302, and that there are no applicable standards under Sections 306 and 307. The certification is subject to the following conditions:

1. Dredging must be limited, when possible, to the winter months when D.O. concentrations are highest and biological activity is lowest (Nov1 through Mar 31).
2. Monitoring reports from the chosen disposal sites should be routinely submitted to the Department's Division of Water Quality for review.

February 1, 1996. Federal Consistency for the Amendment to Charleston Harbor Deepening Widening Project, issued by SC Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (OCRM), no expiration. This certification was in response to public notice 95-1R-406 that included additions to the original project. These included the refurbishment of two existing contraction dikes and the construction of a new contraction dike and turning basin. The additional work was necessary to reduce shoaling in the Daniel Island Reach. The certification stated that the project was consistent with the Coastal Zone Management Program and that except as indicated on the plans submitted, there was to be no construction in any wetland areas. The plans did not include approval for the construction of the proposed Daniel Island Terminal Facility.

March 8, 1996. Environmental Assessment and Findings of No Significant Impact, Charleston Deepening/Widening Project in Charleston County, South Carolina, completed by the Charleston District Corps of Engineers. The Environmental Assessment included in the *Final Feasibility Report for Charleston Harbor* concluded that there would be no significant environmental effects from the deepening and widening of Charleston Harbor. It was determined that wetlands, air quality and water quality would not change; no land use would change; the project would have a negligible impact on fish and wildlife resources; construction activities would enhance shipping traffic and result in no significant effect on recreational boating and the proposed action is in full compliance with the Endangered Species Act.

March 21, 1996. Certification in Accordance with Section 401 of the Clean Water Act, as amended, Permit to refurbish two contraction dikes and to construct a new contraction dike and dredging to create a turning basin, P/N 95-1R-406, issued by the SC Department of Health and Environmental Control, no expiration.

This water quality certification stated that there is reasonable assurance that the proposed project will be conducted in a manner consistent with the certification requirements of Section 401 of the Federal Clean Water Act, as amended. In accordance with the provisions of Section 401, it was also certified that, subject to the indicated conditions, the work is consistent with the applicable provisions of Section 303 of the Federal Clean Water Act, as amended. It also certifies that there are no applicable effluent limitations under Sections 301 (b) and 302, and that there are no applicable standards under Sections 306 and 307. The certification is subject to the following conditions:

1. Dredging must be limited, when possible, to the winter months (November 1 through March 31).
2. If natural revegetation of the excavated corridor is not successful, the applicant must restore the area through vegetation replanting and/or hydrological modifications.
3. The applicant must submit monitoring reports with photographs from the area of the excavated corridor prior to the work commencing, immediately following the project completion, one year after project completion, and at yearly intervals for a total of three years.
4. Excavated material from the dike corridor must not be stockpiled, but placed on barges or on high ground, when possible. If the excavated material is temporarily placed in wetlands, it must be placed at intervals to allow for adequate circulation of water in the marsh. If the material is temporarily placed on high ground, the applicant must contain the material in order to minimize sedimentation and erosion.
5. The excess material not proposed for backfill in the dike corridor must be placed in the Clouter Creek disposal site along with the material dredged from the turning basin.
6. The stone and riprap used to stabilize the contraction dike must consist of clean stone or masonry material free of all potential sources of pollution.
7. The application must access the existing dikes from open water, as proposed, rather than from adjacent marsh.

The above permits authorize the use of upland disposal facilities for the disposal of materials resulting from the deepening/widening that has occurred and the maintenance dredging that continues to occur in the Charleston Harbor. The *Site Management and Monitoring Plan* dated November 2005 for the Charleston ODMDS site outlines the history, site characteristics, uses, and proper management of the ocean disposal site. The document was prepared by a team of agency professionals and was signed by both the Charleston District Commander and the Director of EPA's Region 4 Water Management Division. In order to stay in compliance and continue to utilize the Charleston ODMDS, suitability of dredged material for ocean disposal must be verified and coordinated/approved by EPA prior to disposal every three years. This verification must be in the form of a MPRSA Section 103 Evaluation.

CONCLUSIONS

Charleston Harbor is a vibrant modern intermodal harbor receiving and exporting goods throughout the world. The vessel fleet calling on Charleston Harbor and Shipyard River include containerships, bulk carriers, tankers, and to a lesser degree rollon-rolloffs and cruise ships. The port has greatly exceeded projected tonnage from the 1996 feasibility report (see table 3 on page 11). Continued maintenance to the authorized depth is warranted. The South Carolina States Ports Authority recently received approval to construct a new containerized terminal at the former Naval Base. The approved SCSPA Naval Base Terminal will greatly increase the harbor's capacity to handle containerized cargo.

The inner harbor channels and turning basins are dredged by means of hydraulic pipeline dredges with the material being placed in the existing Clouter Creek Upland Disposal Area. With proper funding and effective management, Clouter Creek Dispoal Area will have a useful life well beyond the 20 year projection of this report. The entrance channel is maintained by means of hopper dredges operating within the turtle dredging window and disposing of the material in the EPA approved ODMDS located southwest of the entrance channel. The easement on the Daniel Island Disposal Site expired in January 1998 necessitating placement of Lower Harbor material in the ODMDS by means of clamshell dredge and dump scows. With the Lower Harbor maintenance material going to the ODMDS, it is estimated that the ODMDS has a remaining capacity life of more than20 years (Table 14) at a clearance elevation of -25 feet MLLW. The SCSPA has cancelled its plans to develop the former Daniel Island Disposal Area into a container terminal. It may be possible for the District to pursue negotiations to once again acquire a disposal easement at the Daniel Island site, which would further prolong the useful capacity of the ODMDS. There is also a plan in the works for SCSPA to use 4-6 MCY of material from the ODMDS for use as fill material for the new Port at the former North Charleston Navy Base.

TABLE 17

The ability to maintain this project for the next 20 years is limited by:	
Disposal Site Capacity	NO
Economic Viability	NO
Environmental Compliance	NO

RECOMMENDATIONS

Based on the above analysis, continued maintenance of Charleston Harbor to the authorized depth is warranted on the basis of project usage, indicators of economic productivity, and maintenance activities in compliance with applicable environmental laws and regulations for the next 20 years. With the expiration of the Daniel Island Disposal Area easement in January 1998, a larger portion of new work and maintenance dredged material has been placed in the ODMDS at an increased project cost and thereby decreasing its remaining useful life. In spite of this fact, we still have more than 20 years capacity in our disposal areas. As the former Daniel Island Disposal Area is once again potentially available, efforts will be initiated in the future to obtain a new easement at this site. The Project Sponsor, South Carolina State Ports Authority, will remove 4-6 MCY of material from the ODMDS over the next five years to be utilized as fill for their new Navy Base Terminal. This will increase the life of the ODMDS to more than 20 years. Any future deepening of the Charleston Federal Channel would reduce the life of the ODMDS.

Date 19 MAR 10

Jason A. Kirk, P.E.
Lieutenant Colonel, EN
Commanding

Savannah River American Shad Habitat Plan
submitted by
Georgia and South Carolina

Habitat Assessment

Tributaries of the Savannah River begin in the Appalachian Mountains in Georgia, North Carolina, and South Carolina. The Savannah River begins at the confluence of the Tugaloo River and the Chattooga River and flows 506 kilometers (km) across the piedmont and coastal plain before emptying into the Atlantic Ocean. The river serves as the border between Georgia and South Carolina throughout its entire length and has a watershed of approximately 27,255 km^2. Tidal influence typically extends to km 56 and the fresh/saltwater interface occurs approximately 22 km upstream from the mouth of the river.

There are no physical obstructions to the amount of historical estuarine habitat available to migrating adults or young-of-the-year fish in the Savannah River. However, major river channel modifications for shipping and commerce have occurred since colonial times and the impacts from these actions have altered salinity, decreased dissolved oxygen at depth, increased flushing rates in the lower estuary, and reduced freshwater tidal wetlands (Reinert 2004). For example, the installation and operation of a tide gate on the Back River channel and harbor deepening projects altered salinity and dissolved oxygen in a section of the lower river. Due to these impacts, the tide gate was removed in 1991, thus restoring a more natural flow regime. Currently, there are plans to further deepen the harbor in Savannah, GA to accommodate larger ships in the future.

The first barrier to upstream migration on the Savannah River is the New Savannah Bluff Lock and Dam (NSBLD) located at km 301 near Augusta, Georgia. The lock at NSBLD was designed for navigation and initially provided very limited fish passage. In the late 1980s, identification and documentation of more efficient passage methodologies were completed at the NSBLD and have since been implemented annually. The first true barrier with no dedicated fish passage is the Augusta Diversion Dam located at km 333, which results in migrating adults having access to approximately 66% of the historical riverine habitat.

Historic Habitat

American shad had access to the entire Savannah River and its tributaries throughout the 27,255 km^2 watershed (South Carolina's portion of the watershed occupies 11,864 km^2). According to Welch (2000), the only record that could be found describing the inland distribution of American shad was from Stevenson's 1899 report where he firmly places the historical inland migration of American shad at "Tallulah Falls, 617 km by the river course from the sea".

Current Useable Habitat

Spawning - American shad begin spawning in tidal freshwater near km 64 (McCord 2003), and have about 237 km of suitable riverine channel habitat for spawning in the Savannah

River below the New Savannah Bluff Lock and Dam. Since the late 1980's, efficient passage methodologies have been implemented allowing American shad access to an additional 32 km of the Savannah River to the base of the Augusta Diversion Dam (km 333), the first barrier with no dedicated fish passage.

Rearing - Suitable rearing habitats are similar to the listed waterways for suitable spawning habitat with the addition of 10,031 ha of estuary in the Savannah River basin (DHEC).

Threats Assessment

a. Barriers to migration inventory and assessment

There are currently 6 dams on the main stem of the Savannah River with only the first barrier currently passing American shad. The US Fish and Wildlife Service developed a diadromous fish restoration plan (Hill 2005) for the middle Savannah River that includes establishing fish passage at the next two main stem Savannah River barriers and barriers within the Stevens Creek tributary system. Additionally, plans to improve fish passage at NSBLD have been developed as a part of the mitigation plan for deepening the Savannah shipping harbor and would enhance passage to approximately 33 km of the Savannah River below the Augusta diversion dam. If fully implemented, approximately 77 km miles of main-stem river, and 72 km of tributary reaches would be made available through provision of fish passage at the Augusta Diversion Dam and Stevens Creek Dam. This includes approximately 2,917 acres of potential new habitat. The lowermost dam in the Savannah River is the New Savannah Bluff Lock and Dam (NSBL&D at km 301).

Name	Pupose	Owner	Height (ft.)	Width (ft.)	Length (ft.)	Impoundment size	Water storage capacity	Location	River Kilometer	Fish Passage	Method
NSBL&D	Hydro	USACE	~25	~45	4109	2,866 acre	30,893 acre/ft.	34.982947°N/79.877540°W	301	Yes	Lock

Action 1: Improve fish passage at the New Savannah Bluff Lock and Dam

Regulatory Agencies/Contacts: The United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), Georgia Department of Natural Resources (GA DNR), South Carolina Department of Natural Resources (SC DNR), City of Augusta, and federal and state legislators.

Goal/Target: Construct a fishway that will effectively pass diadromous fish species.

Progress: Mitigation plans for expansion of the Savannah River harbor included construction of a new fish passage system at NSBLD. USACE is close to completing design work for the new fish passage, which under current plans must be completed before dredging is initiated in the harbor. These plans call for the construction of a series of terraced rock ramps on the South Carolina side of the river. During periods of low flow, the gates could be closed to divert the total flow of the river to the off-channel rock ramp.

Cost: $30,000,000

Timeline: Dependent upon funding

Action 2: Fish passage at the Augusta Diversion Dam and Stevens Creek Dam

Regulatory Agencies/Contacts: The United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), Georgia Department of Natural Resources (GA DNR, South Carolina Department of Natural Resources (SC DNR), City of Augusta, and federal and state legislators.

Goal/Target: The National Marine Fisheries Service (NMFS) goal is to concurrently initiate construction and operation of fishways at both the Augusta Diversion Dam and the Stevens Creek Dam to ensure fish passage above both projects, allowing access to the main-stem Savannah River, and major tributaries.

Progress: The relicensing of the Augusta Diversion Canal and Stevens Creek projects provided an opportunity to consider diadromous fish needs and resulted in a fishway prescription from the Secretaries of Interior and Commerce. Upstream passage at Stevens Creek Dam is required following the construction of a fishway at the Augusta Diversion Dam.

Augusta Diversion Dam

In August 2004 the USFWS and NMFS submitted a preliminary fishway prescription for the Augusta Canal Hydropower Project that included a vertical slot fishway on the Georgia side of the river. Based on comments received from the City of Augusta, and additional evaluation and review by the USFWS and NMFS, the fishway prescription was modified to include a vertical slot fishway on the South Carolina side of the Savannah River. Negotiations between the USFWS and NMFS and project operator are still ongoing and construction of the fishway has not been initiated.

Stevens Creek Dam

The Section 18 prescription in the current license for the Stevens Creek project includes a requirement to refurbish the navigation lock, which will be operated using attraction flows or other fish attraction mechanisms to provide a minimum of 30 lockages during the shad migration season. The prescription requires construction and operation of the USFWS and NMFS approved final fishway design following construction of fish passage facilities at the Augusta Diversion Dam. The USFWS and NMFS also reserve the authority to further evaluate alternative fishway designs.

Cost: Unknown

Timeline: Unknown

Action 3: Fish passage at the Stevens Creek Mill Dams

Regulatory Agencies/Contacts: The United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), South Carolina Department of Natural Resources (SC DNR), dam owners, and federal and state legislators.

Goal/Target: Establish fish passage on the Stevens Creek tributary to the Savannah River following the establishment of fishways at the Augusta Diversion Dam and Stevens Creek Dam.

Progress: Two historical mill dams have been identified on the mainstem of Stevens Creek. Price's Mill Dam is located just downstream of SSR 138, and Parks Mill Dam is located just upstream of Hwy 23 both in Edgefield County, South Carolina. Although both dams are less than 15 feet in height and operate as run-of-river, each is a barrier to movements of anadromous and riverine fish. Future anadromous fish restoration efforts may include evaluating potential alternatives at the dams to provide fish passage to upstream habitats including access to Stevens Creek, Cuffytown Creek and Hard Labor Creek. Possible passage alternatives include full removal, notching, or construction of fish passage facilities.

Cost: Unknown

Timeline: Unknown

b. The following is a list of point source and nonpoint source activities that occur in the Savannah River:

Active NPDES Facilities	*Facility Type*	*Permit Number*	*Section Number*	*Section Name*
BJW&SA/HARDEEVILLE CHURCH ROAD	MAJOR DOMESTIC	SC0034584	03060109-03	(Savannah River)
RINKER MATERIALS/DEERFIELD PIT	MINOR INDUSTRIAL	SCG730624	03060109-03	(Savannah River)
REED-HTI/SAVANNAH LAKE MINE	MINOR INDUSTRIAL	SCG731042	03060109-03	(Savannah River)
TOWN OF ALLENDALE WWTP	MAJOR DOMESTIC	SC0039918	03060106-09	(Savannah River)
CLAIRIANT CORP./MARTIN PLT	MAJOR INDUSTRIAL	SC0042803	03060106-09	(Savannah River)
USDOE WESTINGHOUSE SRS	MAJOR INDUSTRIAL	SC0000175	03060106-08	(Savannah River)
USDOE WESTINGHOUSE SRS	MAJOR INDUSTRIAL	SC0000175	03060106-08	(Savannah River)
USDOE WESTINGHOUSE SRS	MAJOR INDUSTRIAL	SC0000175	03060106-08	(Savannah River)
USDOE WESTINGHOUSE SRS	MAJOR INDUSTRIAL	SC0000175	03060106-08	(Savannah River)
USDOE WESTINGHOUSE SRS	MAJOR INDUSTRIAL	SC0000175	03060106-08	(Savannah River)
ECW&SA/WTP	MINOR INDUSTRIAL	SCG645036	03060106-06	(Savannah River)
KIMBERLY-CLARK CORP./BEECH ISLAND	MAJOR INDUSTRIAL	SC0000582	03060106-06	(Savannah River)
SCE&G/URQUHART STEAM STATION	MAJOR INDUSTRIAL	SC0000574	03060106-06	(Savannah River)
AIKEN PSA/HORSE CREEK WWTP	MAJOR INDUSTRIAL	SC0024457	03060106-06	(Savannah River)
US ARMY CORPS./LAKE THURMOND	MINOR INDUSTRIAL	SC0047317	03060106-01	(Savannah River/Stevens Creek Reservoir)

Nonpoint Source Management Program				
Landfill Facilities	***Status***	***Permit #***	***Section Number***	***Section Name***
SRS 632-G C&D LANDFILL	Solid Waste	065800-1901	03060106-08	(Savannah River)
USDOE WESTINGHOUSE SRS	Solid Waste	025800-1901	03060106-08	(Savannah River)

All point source and nonpoint sources that occur in the Savannah River are closely monitored by the South Carolina's Department of Health Environmental Control (DHEC) and Georgia Environmental Protection Division (GAEPD). All discharges are held to water quality standards for the states. Therefore, it is highly unlikely these programs impact American shad migration and utilization of historic habitat. In addition, all programs are currently undergoing 316a to assess the likelihood of impingement or entrainment.

c. Toxic and thermal discharge inventory and assessment-none

d. Channelization and dredging inventory and assessment

The following is a list of historic dredging programs that occurred in the Savannah River System:

Start_Date	River	DA_Number	Action_Typ	Project_Na	County	Latitude	Longitude
11/4/1993	Savannah	SAC-1993-10125	SP	RAW WATER CANAL MODIFICATION	Jasper	32.342970	-81.130920

The Savannah River Harbor Expansion Plan (SHEP) includes dredging the Inner Harbor from a depth of 42-foot to a depth of 48-foot and could exacerbate low seasonal dissolved oxygen levels in this portion of the river.

Dissolved Oxygen-Low dissolved oxygen levels have been documented in a portion of the lower Savannah River, particularly during low flow periods in summer months.

Action 1: Mitigate potential impacts on dissolved oxygen levels due to SHEP.

Regulatory Agencies/Contacts: The United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), Georgia Department of Natural Resources (GA DNR), South Carolina Department of Natural Resources (SC DNR), Georgia Ports Authority, South Carolina Coastal Conservation League, Savannah Riverkeeper, and South Carolina Wildlife Federation, Savannah River Maritime Commission (SRMC) and the South Carolina Department of Health & Environmental Control (DHEC).

Goal/Target: Install oxygenation system to mitigate dissolved oxygen impacts of the SHEP.

Progress: The USACE has agreed to install and evaluate a “Speece Cone” oxygen injection system (Tetra Tech 2010) prior to commencement of dredging activities on the inner harbor. The final settlement agreement (USACE 2013) states the oxygen injection system must be operated and instream dissolved oxygen must be monitored continuously for a period of 59 days (2 lunar cycles). Continuous daily water quality monitoring must be conducted during this period at specified locations. If the Corps determines that the oxygen injection system test meets “success criteria”, it will commence inner harbor channel dredging. Following the installation of the entire oxygen injection system, a second analysis will be completed for a “start-up run”. The second round of testing will follow very similar protocols to the initial evaluation, but stipulates that at least one 29.5 day testing period (one lunar cycle) must occur in July, August, or September immediately following the installation of the oxygen injection system.

Following both the test run and “start-up run” the USACE, conservation groups, SRMC and DHEC each will independently evaluate the results report and other relevant information to assess achievement of “success criteria”. DHEC, SRMC, and the conservation groups each reserves the right to take any appropriate action if its independent determination is that the “success criteria” has not been met, including but not limited to suspension, rescission, and revocation of the state approvals, initiation of an enforcement or other legal action, and/or termination of this agreement. The USACE does not waive any objection or defense to such actions, including any objection or defense based on federal preemption, sovereign immunity, or immunity from state regulation.

Cost: $16,000,000

Timeline: Dependent upon funding

Action 2: Develop a TMDL implementation plan.

Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GADNR)-Georgia Environmental Protection Division (GAEPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), Federal Energy Regulatory Commission (FERC), US EPD, federal and state legislators, and local municipalities

Goal/Target: Reduce organic loads to sustain acceptable DO levels.

Progress: The Savannah River and Harbor have been extensively studied over the last ten years and a TMDL has been proposed for DO. The Savannah River and Harbor TMDL indicates a need for substantial reductions in organic loads for all dischargers from Augusta to the harbor (GAEPD 2011). Groups from South Carolina and Georgia representing the Central Savannah River Area (CSRA) as well as harbor dischargers have been tasked to develop a TMDL implementation plan.

Cost: Unknown

Timeline: Unknown

Salinity-Dredging/deepening the Savannah Harbor has altered salinity levels in the lower Savannah River and the current SHEP could exacerbate saltwater intrusion.

Action 1: Mitigate potential impacts of SHEP on salinity levels.

Regulatory Agencies/Contacts: The United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), United States Army Corps of Engineers (USACE), Federal Energy Regulatory Commission (FERC),, Georgia Department of Natural Resources (GADNR), South Carolina Department of Natural Resources (SC DNR), Georgia Ports Authority, South Carolina Coastal Conservation League, Savannah Riverkeeper, and South Carolina Wildlife Federation, Savannah River Maritime Commission (SRMC) and the South Carolina Department of Health & Environmental Control (DHEC).

Goal/Target: Develop and implement plans that would mitigate the effects of the SHEP on the salinity levels in the lower Savannah River.

Progress: USACE utilized models to determine appropriate measure to mitigate for salinity and tidal wetland impacts. Mitigation plans call for series of actions that include a diversion structure, closure of cuts, filling a sediment basin, and removal of tide gate abutments and piers (Tetra Tech 2010). While these plans do not fully mitigate for all impacts, they are expected to provide substantial benefits to the fresh water marsh ecosystems by providing additional fresh water flows to the Back River System and will limit saltwater intrusion to the Back River area.

Cost: Unknown

Timeline: Unknown

Detailed information concerning the SHEP project can be found at the following website: http://www.sas.usace.army.mil/Missions/CivilWorks/SavannahHarborExpansion.aspx

e. Land use inventory and assessment-none

f. Atmospheric deposition assessment

Atmospheric deposition is measured as a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies as part of the National Atmospheric Deposition Program (NADP). This organization uses many networks (NTN, AIRMoN, MDN, AMNet, and AMNoN) to monitor methyl mercury, ammonia, etc. Detailed information concerning

atmospheric deposition in SC can be found at the following website:
http://nadp.sws.uiuc.edu/data/annualmaps.aspx

It does not appear that current levels of atmospheric deposition are impacting American shad migrations or utilization of historic habitat.

g. Climate change assessment

A changing climate will present water-related challenges for American shad in several areas including: water quality, water quantity and changes in sea level. Current climate models predict continued warming across the southeast, with the greatest temperature increases projected in summer. Average annual temperatures are projected to rise 4.5°F by the 2080s under a lower emissions scenario and 9°F under a higher emissions scenario with a 10.5°F increase in summer. The frequency, duration and intensity of droughts are likely to continue to increase with higher average temperatures and a higher rate of evapotranspiration. Drought conditions could potentially impact American shad recruitment and long duration drought could negatively impact multiple year classes. Sea level rise is of concern because of the expected change in location of the saltwater/freshwater interface. As sea level rises, saltwater will move further up the river systems of the state thus reducing the amount freshwater spawning habitat available. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. A changing climate will impact the water resources of South Carolina and will present challenges for American shad management.

Action: Develop a climate change plan.

Regulatory Agencies/Contacts: SC Department of Natural Resources (SCDNR)

Goal/Target: Establish recommendations to address climate change.

Progress: A "draft" plan has been developed and is still under review. It can be accessed at the following weblink:

http://www.dnr.sc.gov/pubs/CCINatResReport.pdf

Cost: Unknown at this time.

Timeline: Unknown

h. Competition and predation by invasive and managed species assessment

Aquatic invasive species occur throughout South Carolina's coastal rivers, and non-native ictalurids are some of the most ubiquitous invasive species. Flathead catfish (*Pylodictis olivaris*) and blue catfish (*Ictalurus furcatus*) were introduced into South Carolina in 1964 and are now found in all of South Carolina's coastal rivers. A significant portion of blue catfish and especially flathead catfish diet is comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad. Ictalurid population information is currently unavailable for South Carolina's coastal rivers; however current studies are occurring in South Carolina and other neighboring states to assess the potential impacts of non-native catfish on American shad.

Action: Develop an invasive species plan.

Regulatory Agencies/Contacts: SC Department of Natural Resources (SCDNR) and GA Department of Natural Resources (GADNR)

Goal/Target: Establish recommendations to address invasive species.

Progress: SCDNR programs are currently monitoring catch rates of invasive catfish as part of non-targeting sampling and any flat head catfish captured during these activities are being removed from the system. In addition, current eradication programs, such as those that occurred on the Satilla River, GA, are being reviewed by SCDNR staff to determine if such programs are feasible for SC Rivers.

GA DNR completed experimental electro-fishing removals of flathead catfish from the Altamaha River system during the 1990s in an effort to restore native fish redbreast sunfish and bullhead spp populations that had been adversely impacted. These efforts were discontinued due to the large nature of the river, budget reductions, and shifts in angler attitudes. Current practices in the Satilla River will be reviewed to assess the feasibility of such programs for GA Rivers.

Cost: Unknown at this time.

Timeline: Unknown

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Shad Habitat Plan-Georgia

Altamaha River

Habitat Assessment

The Altamaha River is formed by the confluence of the Ocmulgee and Oconee rivers and flows approximately 220 km before emptying into the Atlantic Ocean near Darien, GA. Including its longest tributary (the Ocmulgee River) the Altamaha River runs for approximately 756 km making it the seventh longest river in the U.S. that is entirely within one state. The Altamaha River drainage basin covers an area of approximately 36,000 km^2 with its headwaters arising near Atlanta, GA for the Ocmulgee River and near Athens, GA for the Oconee River. There are no dams directly on the Altamaha, though there are dams on both the Oconee and the Ocmulgee rivers.

With no barriers directly on the Altamaha all historical estuarine habitat remains available to juvenile and migrating adult shad.

Historical evidence suggests that American shad once occurred in the Altamaha Basin at least as far upstream as the vicinity of Covington, GA in the Ocmulgee River Basin and near the city of Athens, GA in the Oconee River Basin [Bryson 1826; Baird 1884; Bill Frazier, U. S. Fish and Wildlife Service (retired), 2001, personal communication; Elizabeth Reitz, University of Georgia, 2007, personal communication]. However, the construction of dams has limited the migrations. Most of these structures are still in place and continue to serve as barriers to nearly 6,000 acres of potential riverine shad habitat.

American shad currently occur from the mouth of the Altamaha River to the East Juliette Hydroelectric Dam on the Ocmulgee River (approximately river km 570) and Sinclair Dam on the Oconee River (approximately river km 446). Approximately 70% of the historical riverine habitat currently remains available to migrating adult American shad.

Threats Assessment

1. **Migration Barriers**- Full utilization of all potential spawning habitat in the Altamaha River Basin could entail modification of at least nine dams in the Oconee Basin, seven dams in the Ocmulgee Basin, and one dam in the Ohoopee Basin to facilitate fish passage.

   Action 1: Develop a plan for establishing fish passage at barriers in the Altamaha River system.

   Regulatory Agencies/Contacts: USFWS, NMFS, FERC, USACE, Georgia Department of Natural Resources (GA DNR), dam owners and operators, and federal and state legislators.

Goal/Target: Establish fish passage at all dams in the Altamaha basin, where passage is determined to be feasible.

Progress: GA DNR has developed an American shad restoration plan for the Altamaha River Basin which includes the implementation of fishways as a restoration strategy. The plan calls for utilizing Section 18 of the Federal Power Act, which provides the U.S. Departments of Commerce and Interior mandatory conditioning authority to prescribe fish passage during the Federal Energy Regulation Commission (FERC) licensing process for hydroelectric facilities. The FERC-licensed hydroelectric facilities in the Altamaha Basin that are within the historic range of the American shad should have fish passage provisions included in their upcoming licenses, when passage is determined to be feasible.

For FERC-licensed facilities that already have a spawning population directly below them (e.g., currently East Juliette Hydroelectric Dam, Sinclair Dam), fish passage should be evaluated and implemented as soon as feasible (or upon FERC relicensing). For all other FERC-licensed facilities, fish passage should be provided in a stepwise fashion upon the establishment of spawning runs directly below these structures (upon fish passage at all downstream structures).

For non-FERC-licensed dams resource agencies should work with owners to explore passage opportunities such as fishways, breaching, or removal. Where feasible, obsolete or non-functioning barriers to migration should be removed or breached.

<u>East Juliette Hydroelectric Dam</u>

A fish passage prescription for East Juliette Hydroelectric dam has been completed. However, negotiations between the Services and project operator are still ongoing and construction of the fishway has not been initiated.

Cost: Unknown

Timeline: Unknown

Action 2: Potentially conduct experimental trap and transport operations.

Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR), ASMFC, USFWS, NMFS, FERC, USACE, dam owners and operators, and federal and state legislators.

Goal/Target: Assess of upstream migratory behavior and level of passage at partial barriers and to provide access to additional spawning habitat that may be more suitable than that available below downstream barriers.

Progress: Experimental trap and transport operations are listed as a potential method for assessing migratory behavior, partial barrier passage, and allow for potential spawning at previously unavailable habitat. GA DNR has no immediate plans to initiate trap and transport activities at this time.

Cost: Unkown

Timeline: Uknown

2. **Dissolved Oxygen-**While there have not been any dissolved oxygen issues identified within the Altamaha River itself, segments of tributary rivers and streams have been identified as not having sufficient assimilative capacity to maintain dissolved oxygen levels of 5mg/L or greater at maximum permitted discharge levels under low flow conditions.

   Action 1: Develop a regional water plan that recommends appropriate water management practices to ensure healthy aquatic ecosystems.

   Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), state legislators, and local municipalities

   Goal/Target: Ensure water quantity remains adequate to support all life stages of American shad and other aquatic organisms in the Altamaha River.

   Progress: In 2008, the Georgia General Assembly, as part of the Statewide Comprehensive Water Management Plan, established 10 regional water planning councils that encompassed the 14 major river systems within Georgia. With technical guidance from GA EPD, these councils were tasked with developing regional water plans that outlined management practices to meet future water needs for both water quantity and water quality through 2050. In November 2011, the ten regional water plans were officially adopted by GA EPD.

   The Altamaha Council recommended a suite of surface water quality management practices in a phased approach to address water quality issues, including stream segments with limited localized dissolved oxygen assimilative capacity and insufficient wastewater permit capacity (GA EPD 2011a. These recommendations include such practices as the additional sustainable development of groundwater and surface water in areas with sufficient water supply; best management practices for water quality issues such as non-point source runoff, nutrient loadings, and TMDLs in the region; and additional educational and ordinance practices.

   For the Altamaha Region, 75 impaired stream reaches (total impaired length of 915 miles) and 2 impaired lakes (total impaired area of 390 acres) have been identified. The majority of impairments are due to low dissolved oxygen and fecal coliform. Total maximum daily loads have been completed for 71 of the impaired stream reaches and for both of the impaired lakes.

   Cost: Unknown

   Timeline: Regional water plan extends through 2050

3. **Competition and Predation by Invasive Species-**Flathead catfish and blue catfish have been introduced into that Altamaha River system through unauthorized stockings. A significant portion of both flathead catfish and blue catfish diets are comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad. Flathead catfish were first documented in the Ocmulgee River in the early-1970's and have now colonized the entire Altamaha River system. Abundance of flathead catfish rapidly expanded from approximately 1980 through the late-1990's. Electrofishing catch rates by weight peaked at 274 kg/hr in 1993 and by number at 108 fish/hr in 2004. Since 2000, electrofishing catch rates have ranged from 43-108 fish/hr. The average size of the flathead catfish in the Altamaha River peaked at approximately 3.5 kg in the mid-1990's and has since decreased to approximately 1 kg. A diet analysis of flathead catfish was completed during the months of June-September of 1997 and found the dominant prey items to be centrarchid spp. and ictalurid spp (Weller and Robbins, 2001). No Alosa spp. were identified in the stomach of flathead catfish during this study, but consumed juvenile American and/or hickory shad could have been unidentifiable due to extensive digestion.

   Blue catfish were first detected in the Altamaha River in 2006 and their abundance has steadily increased. In 2011, blue catfish electrofishing CPUE was 29 fish/hr. It is expected that the abundance of this species will continue to increase for several more years. Stomach contents of 257 blue catfish were analyzed in the summer of 2010 and it was found that Alosa spp. comprised 0.4% by number of prey items consumed (Bonvechio et al. 2012). This majority of the blue catfish in this study were relatively small (59.5% < 300 mm) so as larger blue catfish become more abundant utilization of Alosa spp as a prey item may increase.

   Action 1: Management of invasive catfish species.

   Regulatory Agencies/Contacts: GA DNR

   Progress: GA DNR completed experimental electrofishing removals of flathead catfish from the Altamaha River system during the 1990s in an effort to restore native fish redbreast sunfish and bullhead spp populations that had been adversely impacted. These efforts were discontinued due to the large nature of the river, budget reductions, and shifts in angler attitudes.

   Cost: Unknown

   Timeline: Discontinued

Ogeechee River

Habitat Assessment

The Ogeechee River originates in the Georgia piedmont and flows for approximately 425 km while crossing the fall line, sandhill region, and the coast plain before emptying into the Atlantic Ocean in Ossabaw Sound. The Ogeechee River watershed encompasses approximately 14,300 km^2. Tidal influence typically extends to rkm 72 and the fresh/saltwater interface occurs approximately 56 km upstream from the mouth of the river. No manmade barriers are present the entire length of the Ogeechee River so all historical riverine and estuarine habitats remain available to juvenile and migrating adult American shad.

Threats Assessment

1. **Instream Flow**- The Georgia Environmental Protection Division (EPD) conducted resource assessments to predict resource conditions based on projection population growth and resulting water demands through 2050. Based on these predictions peak season agricultural irrigation may result in potential in-stream flow shortages in the Ogeechee Basin (GA EPD 2011b). The stream flow may fall below the in-stream flow target during summer low flow periods after meeting upstream irrigation needs.

   Action 1: Develop a regional water plan that recommends appropriate water management practices to ensure healthy aquatic ecosystems.

   Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)- Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), USFWS, NMFS, FERC, US EPD, USACE, federal and state legislators, and local municipalities.

   Goal/Target: Ensure water quantity remains adequate to support all life stages of American shad and other aquatic organisms in the Ogeechee River.

   Progress: In 2008, the Georgia General Assembly, as part of the Statewide Comprehensive Water Management Plan, established 10 regional water planning councils that encompassed the 14 major river systems within Georgia. With technical guidance from GA EPD, these councils were tasked with developing regional water plans that outlined management practices to meet future water needs for both water quantity and water quality through 2050. In November 2011, the ten regional water plans were officially adopted by GA EPD.

   To prevent potential shortages in meeting in-stream flow needs, the plan encompassing the Ogeechee River calls for more aggressive water conservation practices and development of drought management practices for the agricultural users/permittees in the Upper Ogeechee River Basin (GA EPD 2011b). The Council also recommends in-stream flow studies (to determine what flow levels are appropriate for protecting aquatic life) and additional stream flow monitoring in the Ogeechee River Basin (to confirm the frequency and magnitude of predicted in-stream flow shortages).

Cost: Unknown

Timeline: Regional water plan extends through 2050

2. **Point Source Discharges-** In May 2011, the Ogeechee River experienced a large-scale fish kill that affected multiple species including American shad. The upper extent of the kill was below the only industrial discharge above the kill area.

   Action 1: Develop and implement permits and monitoring to avoid future fish kills.

   Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), US EPD, and appropriate private industrial operators.

   Goal/Target: Ensure water quality remains adequate to support all life stages of American shad and other aquatic organisms in the Ogeechee River.

   Progress: After the 2011 fish kill, GA EPD reviewed and revised the existing discharge permit for King America Finishing in attempt to prevent future fish kills related to their discharge. GA EPD has since closely monitored water quality in this area of the Ogeechee River.

   Cost: Unknown

   Timeline: Currently ongoing

Satilla River

Habitat Assessment

The Satilla River originates in Ben Hill County near the town of Fitzgerald, GA and flows for approximately 378 km before emptying into the Atlantic Ocean in St. Andrews Sound. The Satilla River watershed encompasses approximately 10,000 km^2 of Georgia's coastal plain. Tidal influence typically extends to rkm 93 and the fresh/saltwater interface occurs approximately 32 km upstream from the mouth of the river. No manmade barriers are present the entire length of the Satilla River so all historical riverine and estuarine habitats remain available to juvenile and migrating adult American shad.

Threats Assessment

1. **Competition and Predation by Invasive Species-**Flathead catfish were introduced into that Satilla River system through unauthorized stockings in the mid-1990s and blue catfish were collected by GA DNR in 2012. A significant portion of flathead catfish diets are comprised of fish, and due to their large adult size (>60 lbs) they have the potential to consume both adult and juvenile American shad.

   Action 1: Management of invasive catfish species.

   Regulatory Agencies/Contacts: GA DNR

   Progress: GA DNR initiated electrofishing removals of flathead catfish from the Satilla River in 1996 with existing manpower and funding in an effort to preserve native fish species, specifically redbreast sunfish and bullhead spp. Flathead abundance continued to increase despite these efforts, which were limited due to manpower and fiscal limitations. Native fish populations were also showing early signs of decline. In 2006, Georgia's legislature appropriated funding for dedicated positions and equipment to conduct extensive flathead catfish removal efforts on the Satilla River. Since 2007, approximately 28,000 flathead catfish weighing over 68,000 lbs have been removed from the Satilla River. Over time, these efforts have resulted in a significant reduction in the flathead catfish biomass and appear to be preserving the abundance of native species.

   Blue catfish abundance is extremely low, with only a few individual being collected in 2012 and none thus far in 2013. GA DNR suspects that these fish may have colonized the Satilla River from the Altamaha River via the intercostal water way during a high flow period, due to their relatively high tolerance to brackish water.

   Cost: Unknown

   Timeline: Ongoing

2. **Dissolved Oxygen-** Dissolved oxygen levels below 3 mg/L occur during low flow events in the months of July-September in an approximately a 30 km segment of the tidally influenced portion of the Satilla River. The Satilla River naturally has a low assimilative capacity and resulting low DO levels during summer low flow periods, therefore it may not be possible to maintain DO levels above 3 mg/L at all times. However, the actions listed below will still be beneficial.

   Action 1: Develop a TMDL implementation plan.

   Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), state legislators, and local municipalities

   Goal/Target: Reduce organic loads to sustain acceptable DO levels.

Progress: GA DNR worked with representatives of local municipalities and conservation groups and developed a TMDL implementation plan that included a suite of management measure to reduce organic carbon, Total Nitrogen, and Total Phosphorous inputs in order to improve dissolved oxygen levels in the Satilla River.

Cost: Unknown

Timeline: Unknown

Action 2: Develop a regional water plan that recommends appropriate water management practices to ensure healthy aquatic ecosystems.

Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), USFWS, NMFS, FERC, US EPD, USACE, federal and state legislators, and local municipalities.

Goal/Target: Ensure water quantity remains adequate to support all life stages of American shad and other aquatic organisms in the Satilla River.

Progress: In 2008, the Georgia General Assembly, as part of the Statewide Comprehensive Water Management Plan, established 10 regional water planning councils that encompassed the 14 major river systems within Georgia. With technical guidance from GA EPD, these councils were tasked with developing regional water plans that outlined management practices to meet future water needs for both water quantity and water quality through 2050. In November 2011, the ten regional water plans were officially adopted by GA EPD.

The Suwannee-Satilla-St Marys Council recommended a suite of surface water quality management practices in a phased approach to address water quality gaps, including stream segments with limited localized dissolved oxygen assimilative capacity and insufficient wastewater permit capacity (GA EPD 2011c). Specific actions to add/improve infrastructure and improve flow and water quality conditions were identified and recommended. These recommendations include such practices as the additional sustainable development of groundwater and surface water in areas with sufficient water supply; best management practices for water quality issues such as non-point source runoff, nutrient loadings, and TMDLs in the region; and additional educational and ordinance practices.

Cost: Unknown

Timeline: Regional water plan extends through 2050

3. **Instream Flow-** The Georgia Environmental Protection Division (EPD) conducted resource assessments on current and predicted resource conditions based on projected population growth and resulting water demands through 2050. These assessments concluded that instream flow shortages were present under current and future demands in portions of the Satilla Basin.

   Action 1: Develop a regional water plan that recommends appropriate water management practices to ensure healthy aquatic ecosystems.

   Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), USFWS, NMFS, FERC, US EPD, USACE, federal and state legislators, and local municipalities.

   Goal/Target: Ensure water quantity remains adequate to support all life stages of American shad and other aquatic organisms in the Satilla River.

   Progress: The Satilla River water management plan was officially adopted by GA EPD in November 2011 and recommended a suite of management practices, including those that reduce net consumption, replace surface water use with groundwater use, and improve data on frequency and magnitude of gaps (GA EPD 2011c).

   Cost: Unknown

   Timeline: Regional water plan extends through 2050

St. Marys River

Habitat Assessment

The St. Marys River originates in the Okenokee Swamp and flows for approximately 203 km before emptying into the Atlantic Ocean in Cumberland Sound while forming the eastern portion of the border between Florida and Georgia. The St. Marys watershed encompasses approximately 3,350 km^2 of which 59% is in Georgia and 41% in Florida. Tidal influence typically extends to rkm 88 and the fresh/saltwater interface occurs approximately 33 km upstream from the mouth of the river. No manmade barriers are present the entire length of the St. Marys River so all historical riverine and estuarine habitats remain available to juvenile and migrating adult American shad.

Threats Assessment

1. **Dissolved Oxygen-** Dissolved oxygen levels below 3 mg/L occur during low flow events in the months of July-September months of July-September in an approximately a

40 km segment of the tidally influenced portion of the St. Marys River. The St Marys River naturally has a low assimilative capacity and resulting low DO levels during summer low flow periods, therefore it may not be possible to maintain DO levels above 3 mg/L at all times. However, the actions listed below will still be beneficial.

Action 1: Develop a TMDL implementation plan.

Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), FL FWC, FL DEP, St. Johns Water Management District, state legislators, and local municipalities

Goal/Target: Reduce organic loads to sustain acceptable DO levels.

Progress: GA DNR worked with representatives of local municipalities and conservation groups and developed a TMDL implementation plan that included a suite of management measure to reduce organic inputs in order to improve dissolved oxygen levels in the St. Marys River.

Cost: Unknown

Timeline: Unknown

Action 2: Develop a regional water plan that recommends appropriate water management practices to ensure healthy aquatic ecosystems.

Regulatory Agencies/Contacts: Georgia Department of Natural Resources (GA DNR)-Environmental Protection Division (EPD), Wildlife Resources Division (WRD), and Coastal Resources Division (CRD), USFWS, NMFS, FERC, US EPD, USACE, federal and state legislators, and local municipalities.

Goal/Target: Ensure water quantity remains adequate to support all life stages of American shad and other aquatic organisms in the St. Marys River.

Progress: In 2008, the Georgia General Assembly, as part of the Statewide Comprehensive Water Management Plan, established 10 regional water planning councils that encompassed the 14 major river systems within Georgia. With technical guidance from GA EPD, these councils were tasked with developing regional water plans that outlined management practices to meet future water needs for both water quantity and water quality through 2050. In November 2011, the ten regional water plans were officially adopted by GA EPD.

The Suwannee-Satilla-St Marys Council recommended a suite of surface water quality management practices in a phased approach to address water quality gaps, including stream segments with limited localized dissolved oxygen assimilative capacity and insufficient wastewater permit capacity (GA EPD 2011c). Specific actions to add/improve infrastructure and improve flow and water quality conditions were identified and recommended. These recommendations include such practices as the additional sustainable development of groundwater and surface water in areas with sufficient water supply; best management practices for water quality issues such as non-point source runoff, nutrient loadings, and TMDLs in the region; and additional educational and ordinance practices.

Cost: Unknown

Timeline: Regional water plan extends through 2050

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