National Parks Conservation Association Natural Resource Assessment for Fort Pulaski National Monument

by

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ABSTRACT

As a national monument, much of the focus at this park is on cultural heritage rather than natural resources. However, this park is home to 5,000 acres of near pristine wetland as well several hundred more acres of upland and aquatic habitat. Using the methodology laid out by the National Parks Conservation Association Center for the State of the Parks, a qualitative assessment of the natural resources at this park was performed. This was accomplished by performing an extensive literature review at the park, with state and federal data providers, and with National Park Service Regional Inventory and Monitoring offices. Interviews with park staff and, to a limited extent, on-site inspections occurred. These data were used to assign scores of 0-3 (0 being irreparably damaged, 3 being pristine) to various natural resource categories. The sum of these categories was then used as an overall indicator of park health. The park was found to be in vulnerable condition overall.

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I. Executive Summary

This report was completed as part of the State of the Parks Initiative being undertaken by the National Parks Conservation Association Center for the State of the Parks. It is a technical report representing one half of the assessment which will eventually be performed for every national park, seashore, monument and reserve. This report deals with an assessment of the natural resources at Fort Pulaski National Monument and is complemented by an assessment of the cultural resources at the park.

The mission and principal objectives of the Center for the State of the Parks are as follows.
Mission: To provide an accurate, comprehensive understanding of resource conditions in America's national parks.
Objectives:

- To identify and understand those park-specific and system-wide issues and threats that challenge both the immediate and long-term integrity of park resources.
- To foster and promote awareness of national park resource conditions within NPCA and among policy makers, the public, and the National Park Service.
- To provide a credible and defensible basis upon which NPCA can organize constituencies and strategies to effectively address identified concerns and promote the National Park Service's capacity to contain or mitigate them.
- To help achieve positive, measurable change in the condition of resources in our national parks.[1]

This report strives to support these objectives and follows the methodology laid forth by the National Parks Conservation Association.[2] This methodology relies on qualitatively assessing numerous natural resource indicators or "elements", and by looking at them as a whole, gaining an overall picture of the state of the natural resources at the park. Natural resource elements are given a score of 0-3 (0 being irreplaceably damaged and 3 being in pristine condition). These elements are scored based on peer reviewed literature, gray literature including state and federal reports, park staff interviews, and in some cases, on site inspections. Examples of these elements

[1] Center for the State of the Parks website. March 2007.
[2] National Parks Conservation Association State of the Parks Natural Resource Assessment Methodology. 2006.

include habitat loss or degradation, age class distribution, grazer effects, plant and animal disease, ozone, organic waste and erosion.

Natural resource elements are grouped together to form categories such as community structure and function, native species or waters. These are then further grouped together to form broad ecosystem, biotic and environmental measures, which when taken together give the overall assessment score for the park. Each grouped category is given a score (based on natural resource elements) from 0-100 and an informational basis score from 0-100. The purpose of the information basis score is to see how many elements in given group were able to be assessed versus those with insufficient data to assess. There was little correlation between how well a group scored versus its information basis score (R = 0.0107), which implies that scores were not biased by how much information was present for a given category. Rating scores and informational scores for the various categories can be seen in the table below. The complete ratings assessment worksheets can be seen in Appendix G of this report.

Ratings Category	Rating Score	Informational Basis
ECOSYSTEM MEASURES (ESM)	**79.279**	**72.549**

I. Ecosystem Extent and Function (EEF)	76	83.33333333
IA. Cover and Habitat Characterization	80	83.33333333
IB. Fragmentation	83.33333333	100
IC. Community Structure and Function	66.66666667	70
ID. Disturbance Regimes	77.77777778	90
II. Species Composition and Condition (SCC)	86.11111111	57.14285714
IIA. Total Species	77.77777778	75
IIB. Native Species	94.44444444	75
IIC. Trophic and Biotic Interactions	77.77777778	33.33333333
ENVIRONMENTAL & BIOTIC MEASURES (EBM)	**80.769**	**70.2703**
III. Biotic Impacts and Stressors (BIS)	76.66666667	80
IIIA. Animals	75.75757576	84.61538462
IIIB. Plants	77.77777778	75
IV. Environmental Quality Factors (EQF)	83.33333333	65.30612245
IVA. Air	93.33333333	50
IVB. Waters	81.66666667	80
IVC. Soils	80.95238095	50
OVERALL	**80.1**	**71.2**

Table 1. Rating and informational basis scores for Fort Pulaski National Monument based on the National Parks Conservation Association State of the Parks Natural Resource Assessment Methodology.

The overall score for the park is 80.1 which according to the methodology puts the park into the high end of the "vulnerable" category. The methodology defines this as the park's resources being generally in a good state but vulnerable to further degradation. Overall categories from worst state of resources to the best are critical (0-34), endangered (35-64), vulnerable (65-84), stable (85-94) and intact (95-100). The overall information basis score is a 71.2 which means that 71.2 of the applicable natural resource rating elements were able to be scored. This very good compared to some previous assessments performed on other parks.

The qualitative nature of this assessment makes it easy to score individual natural resources elements, even when there is little information available. The two major pitfalls of this methodology are to put too much credence on a categories score when the information basis score is low and its heavy reliance on grey literature. When the information basis is low, no true assessment (even a qualitative one) can be made on a *group* of natural resource elements. This assessment process uses peer reviewed literature when possible, but extensively relies on grey literature and interviews as a primary source when peer reviewed sources are unavailable. Interviews with park staff are a sometimes questionable source of data, especially when few of the park staff have any biological or ecological training as was the case here, where the resources of the park are primarily cultural in nature. Once gaps in the peer review literature on a park are identified it may be worthwhile to fund efforts to fill them.

Despite its flaws, this methodology and this report represent a powerful synthesis of many data sources which when taken together do give a good qualitative view of the resources at Fort Pulaski National Monument. The fact that it is qualitative assessment that relies on numerous individual rating elements is a strength and makes a project of this scope possible. Eventually this report with be reformatted and combined with the cultural resource assessment into a form more palatable to the public and to policy makers. It will be used to bring to light issues within the park and possibly to highlight regional or national issues within the park system. Eventually this assessment process will be repeated so that a comparison over some span of time can be made and it can be seen how the park's resources are evolving as well as what progress has been made in preserving those resources.

II. Introduction

Fort Pulaski National Monument (FOPU) represents a unique challenge when pursuing an assessment of the natural resources therein. As its name implies, the main reason that FOPU was added to the National Park System is the fort located at the park. Unlike a national seashore or a national park, the center of attention is Fort Pulaski and not a natural resource such as a protected habitat or unique geologic feature. Park staff are enthusiastic about protecting the land that has come under the park's jurisdiction, but the focus of much of the staff is on the fort, and the park

only recently hired a natural resource manager.[3] The Resource Management Plan for the park clearly states that if historical or cultural needs and natural resources conflict, the cultural or historical needs will take precedence.[4]

Fort Pulaski consists of 5,623 acres in Chatham County, GA. Most of this acreage is located on McQueens and Cockspur Islands. McQueens is the larger island; the fort is located on Cockspur. The vast majority of this land consists of saltwater marsh (~5000 acres), with a mix of upland habitat that comprises several hundreds of acres.[5] The park was created in 1933 when President Roosevelt signed the fort over to the National Park Service (NPS). A congressional act in 1936 further expanded the boundaries of the park to encompass lands formerly held by the Secretary of War. In 1939, the State of Georgia deeded over the 5000 acres of McQueens Island to the park, bringing FOPU up to its current acreage.[6]

Human alterations and influences are factors that cannot be separated from any natural resource assessment at Fort Pulaski. Until recently, the park has been a site for dredge spoil from the Savannah River.[7] This dredge spoil is the source of much of the upland habitat in the park. The amount of naturally occurring upland habitat in the park is an order of magnitude less than the amount which has grown upon the dredge spoil or that is maintained as grassland by the National Park Service. Some upland habitat also occurs as a result of Highway 80, which runs through McQueens Island. This habitat is ruderal in nature and occurs on the shoulders of the highway before the land progresses back to marsh.[8]

The salt marshes located within the jurisdiction of FOPU are some of the few nearly pristine saltwater wetlands left in the area. Anthropological threats to FOPU wetlands occur upstream of the park in the Savannah River in the form of industrial concerns, the city of Savannah, Georgia (~127,000 estimated 2003 population; http://quickfacts.census.gov/qfd/states/13/1369000.html),

[3] NPCA Meeting with Park Staff. June 2006.
[4] Breen, 1990.
[5] McFarlin and Alber, 2005.
[6] Meader, 2003.
[7] Breen, 1990.
[8] Govus, 1998.

and the Port of Savannah. These factors constitute a constant and increasing threat to the natural resources at the park.[9]

Given the smaller size of the park and the focus on cultural resources and interpretation, few studies have been done on the ecosystems present at the park. Much baseline monitoring of environmental quality has been performed in and around the park by researchers, contractors for the harbor expansion project, and staff at the Southeast Coastal Network (SECN) Inventory and Monitoring Office of the National Park Service. A considerable portion of the monitoring is in the context of the Savannah Harbor Expansion Project (SHEP). However, the SECN Inventory and Monitoring Office has initiated many of its own monitoring programs within FOPU and the surrounding parks. Numerous animal and plant inventories have been completed for the park as well as a comprehensive coastal watershed assessment. These studies form the majority of the basis for this assessment. There is little information on the higher order ecological functions and conditions thereof within the park. This assessment follows the methodology provided in the NPCA Natural Resource Assessment and Ratings.[10]

III. Park Resources and Context

A. Biogeography and Physical Setting

i. Park Location, Size and Area

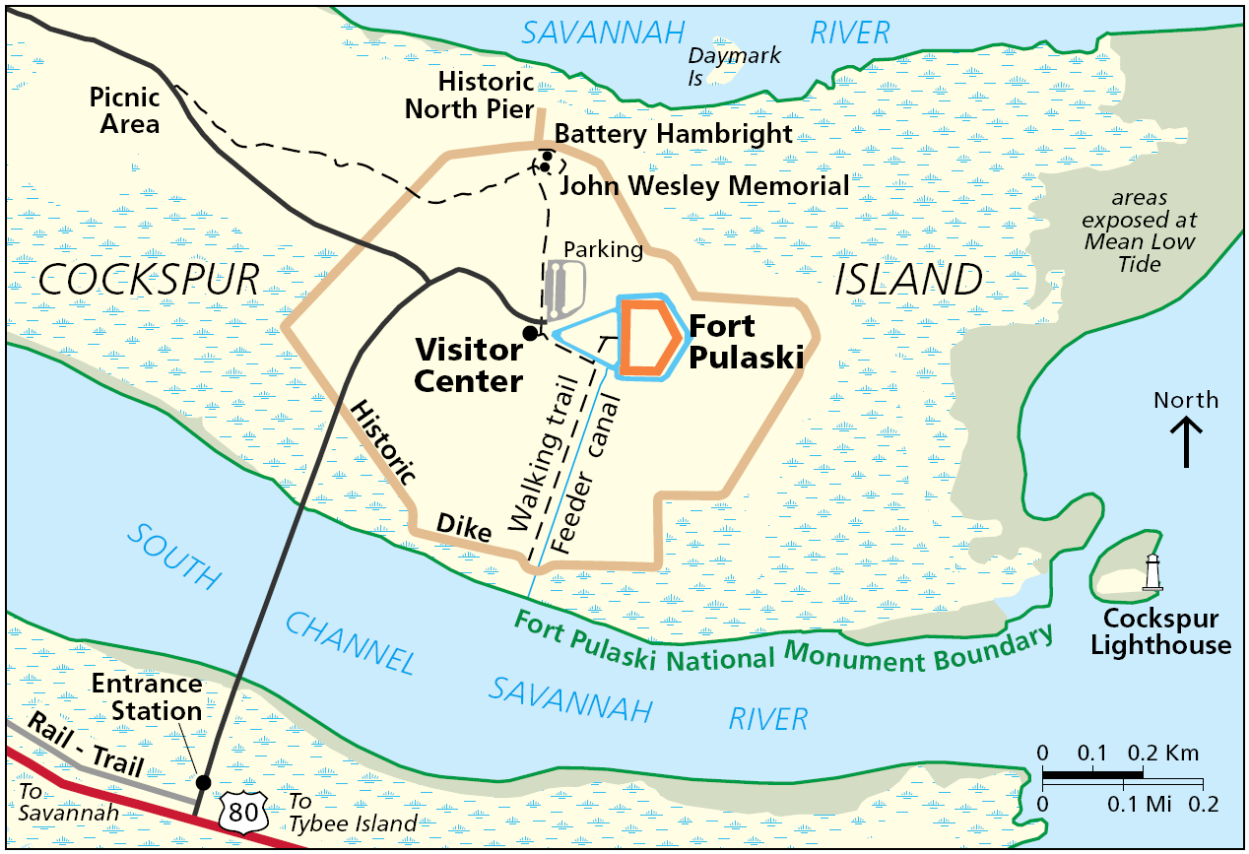
Fort Pulaski National Monument (FOPU) is located on the Savannah River from river miles 0-7 in Chatham County, Georgia. Located approximately 15 miles downstream (east) of the city of Savannah, the park consists of 5623 acres including some or all of Cockspur, McQueens, and Daymark Islands. The NPS owns all land on the islands with the exception of US Highway 80 that runs through McQueens Island and connects Tybee Island to Savannah. 608 acres of the park are contained on Cockspur Island and are comprised mostly of uplands. These uplands represent almost all the upland habitat in the park, over 500 acres. McQueens Island is approximately 5000 acres and is almost entirely salt marsh. The Park also includes the Cockspur

[9] McFarlin and Alber, 2005. Joe DeVivo, Personal Communication, 2006.
[10] National Parks Conservation Association, State of the Parks Natural Resources Assessment and Ratings Methodology. Accessed 2006.

Island Lighthouse Reservation.[11] Daymark Island and the Cockspur Island Lighthouse Reservation account for minimal acreage in the park, less than 15 acres combined.

There are no inholdings within park boundaries. The Savannah Bar Pilots lease land from the NPS and operate from Cockspur Island. The Savannah Bar Pilots exist, like other bar pilot organizations, to guide ships through the dangerous areas near the mouths of rivers and bays. Dangerous conditions are generally due to shifting sand bars. The US Coast Guard, under the aegis of a long term special use permit, maintains a search and rescue station on Cockspur Island. A special use permit allowed Chatham County to construct a public boat access in Lazaretto Creek (on McQueens Island) in 1962. FOPU jurisdiction does not extend into the water column, and intertidal and sub tidal areas are held in trust by the state of Georgia. These resources are managed by the Georgia DNR Coastal Resources Division[12]

Fig 1. A map of FOPU. Includes Cockspur Island, Daymark Island, The Cockspur Island Lighthouse Reservation and a portion of McQueens Island.[13]



[11] McFarlin and Alber, 2005.
[12] McFarlin and Alber, 2005.
[13] NPS, http://home.nps.gov/applications/hafe/hfc/carto-detail.cfm?Alpha=FOPU#, Accessed Oct. 18, 2006.

ii. Climatic Regime

The NPS website for Fort Pulaski[14] describes the climate at FOPU as "Hot and humid in summer, mild to chilly and breezy in winter. Rainy periods throughout the year." Snow is rare and the area is only occasionally threatened by hurricanes. The annual temperature range can be from 20-100 degrees Fahrenheit and seasonal temperatures average 51°F in winter, 64°F in spring, 80°F in summer and 66°F in fall. Annual average precipitation is just over 49 inches.[15] Climatic regime has numerous implications for FOPU natural resources in terms of climate change. Climate change, i.e. global warming, is generally considered to have negative implications for wetlands of which the park is largely comprised.[16] It is important to view the habitats in the park in light of potential global shifts in climate.

iii. Geology and Landforms

Geologically the area is on a coastal plain formed by slow sedimentation. Landforms in the park consist of marshes, tidal creeks, ponds, and uplands. The biggest influences in the park geologically are sedimentation and erosion. Altered sedimentation regimes are a concern with the Savannah Harbor Expansion Project (SHEP) and industrial activity upstream. Erosion leading to habitat loss is a concern due to ship wakes on the northern edge of Cockspur Island.[17] The park does have a shoreline change study currently being completed which should allow park managers to make effective decisions in regards to erosion and accretion shoreline issues. The shoreline in question is not sandy and consists of an oyster berm. Nourishment is unlikely to be an option, since the berm is a potential threat to cultural resources it is far more likely that some of the mass around such features would be removed. The current study focuses on rates of accretion, historical change, and anthropogenic effects such as structures being built and wave action from shipping. Effects on habitat were not mentioned in the study.

The surrounding land is very flat. The last soil inventory of the park was performed by the Soil Conservation Service in the 1970s and is probably in need of update. Soil types described in that survey are Caper soils, coastal beach, Chipley-Urban land complex, Kershaw-Osier complex,

[14] http://www.nps.gov/fopu Accessed August, 2006.
[15] McFarlin and Alber, 2005.
[16] Nicholls et al, 1999. Mitsch and Gosselink, 2000.
[17] McFarlin and Alber, 2005. Howell and Alexander, 2005.

man-made (i.e. dredge spoil), Osier fine sand and tidal marsh, salty. The vast majority of the park consists of soils in the "tidal marsh, salty" descriptor due to the vast salt marsh that is McQueens Island.[18] Cockspur Island falls largely into the "man made" soil category as this is where dredge spoil from the Savannah River was deposited. In fact, Cockspur Island used to consist of two islands, Cockspur and Long Island, until they were combined by the addition of dredge spoil.

iv. Hydrologic Overview

FOPU is entirely in the Savannah River estuary. The natural resources at FOPU are heavily influenced by tides. Tides are semidiurnal with a mean range of 2.1 meters. The salinity wedge formed by the confluence of the Atlantic Ocean and the Savannah River does not occur within the boundaries of FOPU; however, upstream areas of the monument's waters have slightly reduced salinity levels between 20 - 33 psu (practical salinity units).[19]Essentially, most of the water in the park is undiluted sea water. There are three major upstream dams from FOPU on the Savannah River. The dams are the Hartwell, the Richard B. Russell and the Clark Hill. Uses include reservoir formation and hydroelectric power. Flow regime in the area has been affected; maximum and minimum flow levels have been made less extreme and flow rate fluctuations have decreased in intensity and frequency. It is also believed that there may have been an overall 10% decrease in flow rates over historical levels due to reservoir evaporation.[20]

Fresh water in the area is primarily supplied by the Upper Floridian Aquifer. The park gets its water from this aquifer. Recharge may be an issue due to large industrial concerns upstream of the fort and use by the City of Savannah. Saltwater intrusion and a general lowering of the level of this aquifer have been noted.[21] The moat that surrounds the fort is an artificial freshwater body that is replenished by a spring. On occasion, the moat is flushed with salt water from a tidal gate in the case of algal and bacterial blooms. There are two unnamed freshwater ponds on Cockspur Island that are used for mosquito control. Oyster Creek and Lazaretto Creek are two tidally influenced salt water creeks located on McQueens Island. Lazaretto Creek forms the boundary

[18] Soil Conservation Service, 1974.
[19] McFarlin and Alber, 2005. Howell and Alexander, 2005.
[20] McFarlin and Alber, 2005.
[21] DeVivo et al., 2006. McFarlin and Alber, 2005. Breen, 1990.

between McQueens Island and Tybee Island. Oyster Creek is the only place in Chatham County where recreational shell fishing is allowed.[22]

v. Ecological and Habitat Classifications

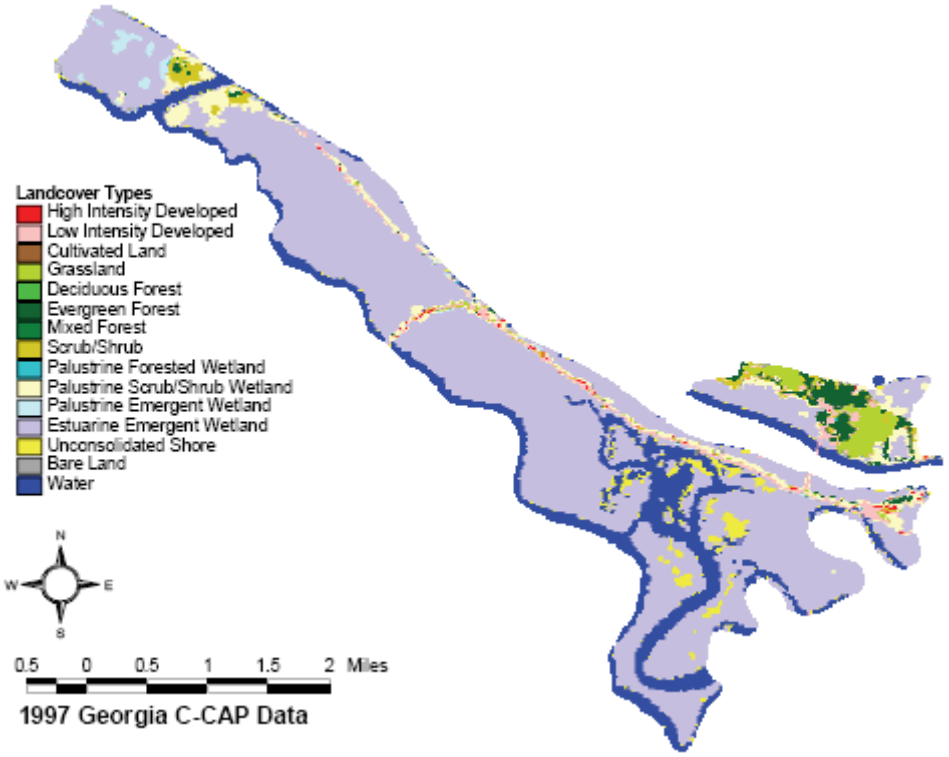
FOPU falls into the South Atlantic Coastal Plain ecoregion.[23] The region spans the Carolinas to a portion of Florida and is bounded by Piedmont to the west and the Atlantic Ocean to the east. Characteristic habitats include barrier islands, dunes, marshlands, maritime forest, sandy soils and fire-controlled upland pine. A 6312 acre coastal watershed assessment, which included FOPU as well as tidal creeks that are held in trust for the state of Georgia and administered by the GA Coastal Resources Division (CRD) characterized the habitats in the area as 66.3 percent of estuarine emergent wetland, 16 percent water and 5.3 percent Palustrine Scrub or Shrub Wetland habitats[24]. The remaining habitats include unconsolidated shore and low or high intensity developed, as well as other upland habitats (Table 2).

Land Cover Classification	Acres	% of Total
Estuarine Emergent Wetland	4185.0	66.3
Water	1023.7	16.2
Palustrine Scrub/Shrub Wetland	332.0	5.3
Unconsolidated Shore	165.9	2.6
Low Intensity Developed	147.7	2.3
Evergreen Forest	139.9	2.2
Grassland	134.8	2.1
Scrub/Shrub	93.2	1.5
Palustrine Emergent Wetland	55.6	0.9
High Intensity Developed	17.6	<0.5
Bare Land	14.7	<0.5
Palustrine Forested Wetland	1.3	<0.5
Deciduous Forest	0.4	<0.5
Mixed Forest	0.2	<0.5

Table 2. Land Cover Classification for FOPU and some surrounding area by the Georgia CRD. Based upon 1997 Georgia C-CAP data.[25]

[22] McFarlin and Alber, 2005.
[23] Slaats. 1999.
[24] Georgia DNR CRD, 1997.
[25] Georgia DNR CRD, 1997.

Fig 2. Land Cover Classification for FOPU and some surrounding area by the Georgia CRD. Based upon 1997 Georgia C-CAP data.



The emergent wetland consists largely of salt marsh *Spartina sp.* communities. The open water is largely tidally influenced creeks and rivers, with two freshwater ponds and a moat around the fort that is fresh to brackish. The two freshwater ponds provide habitat to mosquito fish which serve as mosquito control.[26]

The majority of the upland area of the park is the result of deposition of dredge spoil from the Savannah River or construction of Highway 80. Historically, before construction of the various forts on the island, the area that now comprises FOPU contained only tens of acres (1-2% of the park) of upland habitat. Currently, twenty-three percent of the park is classified as upland which includes the fort, roads, and support buildings for the NPS, Coast Guard and Bar Pilots.[27]

A vegetation survey performed in 1998 described the various upland habitats that could be found in the park. These included lowland seasonal temperate forest, planted/cultivated temperate or sub polar needle-leaved evergreen forest, temperate broad-leaved evergreen woodland, saturated

[26] Meader, 2003.
[27] McFarlin and Alber, 2005. Govus, 1998.

temperate broad-leaved evergreen shrub land, tidal cold-deciduous shrub lands, tidal needle-leaved or microphyllous evergreen dwarf-shrub land, tidal temperate of sub polar grassland, maintained grass, ruderal, and recent sandy dredge spoil. [28] The maintained grassland, i.e. lawn, is located around and within the fort and near the visitor center and picnic areas. The ruderal habitat is adjacent to Highway 80 and represents the area of highest plant diversity on the island.[29]

It is worthwhile to note that the maritime forest, which is predominately located on Cockspur Island, is not considered true Georgia maritime forest due to the lack of live oak (*Quercus virginiana)*, potentially caused by a policy of keeping the island vegetation free until the 1920s.[30] Maintenance staff at the park have recently reported live oak (age class unknown) on Cockspur Island, so the forest may be on its way to succeeding into true Georgia maritime forest.[31]

B. Regional and Historical Context

Fort Pulaski has a long history of human use in and around it. The Monument exists in a human use dominated landscape, and was itself developed for military use. To assess the status of its natural resources its historical human activities must first but understood.

i. Land Use History[32]

Prior to the construction of any forts of the island, it is known that several Native American tribes inhabited nearby islands, including Tybee Island. Several shell middens on McQueens Island have been found which indicate usage by Yamacraw Creek inhabitants. The extensive development on Cockspur Island has hindered prehistoric archeological research. James Edward Oglethorpe first anchored at Cockspur Island in 1733, and in 1759, King George II deeded over 150 acres of the island and reserved 20 acres for construction of Fort George. In 1761 Fort George was constructed to defend against the Spanish. This fort was small, and was essentially a wooden palisade. It was allowed to fall into disrepair in the 1770s.[33] A second fort, Fort Greene, was built in 1794 and destroyed by a hurricane in 1804. Fort Greene was located southeast of the

[28] Govus, 1998.
[29] Govus, 1998.
[30] McFarlin and Alber, 2005. Joe DeVivo, Personal Communication, 2006.
[31] Mike Hosti, Personal Communication, 2006.
[32] Meader, 2003.
[33] Meader, 2003.

future site of Fort Pulaski. Historically Cockspur Island was marsh land and marshy hammocks with minimal upland habitat. Construction of forts required filling and draining marsh area. Any upland vegetation, such as brush and trees, occurring on the land was clear cut to improve visibility.[34]

The construction of the fort that is preserved on FOPU's grounds began in 1829 as part of the "third system" of coastal defense. The main structure was completed in 1847. The total cost of the fort was over one million dollars, a substantial amount for the time. The construction of Fort Pulaski included a dike and drainage system to keep the area the fort was sited on from inundation at high tide. This significantly altered the hydrology of the area. There is also a migrating oyster shell ridge on the north side of Cockspur Island that may be altering tidal hydrology in the marshes on that side of the island. The shell ridge, or berm, is an artifact of wave action on the island. Shells are thought to come from the oyster population on Daymark Island. Evidence for this comes from the recent development of another oyster berm there. The size of boats coming through this channel and storms affect the build up and transport of such ridges.[35] In 1861 the fort was captured by Confederate troops during the outset of the American Civil War, under the order of Georgia's Governor. On April 10, 1862, Union troops attacked the fort using the new technology of rifled cannons. This new weapon allowed union troops to breach the wall and forced the surrender of the fort into Union hands. The first use of this new weapon and its impact on the use and construction of coastal forts or batteries highlights the historical significance of Fort Pulaski. Other important historical aspects of the fort include its use by the Underground Railroad to smuggle escaping slaves from 1862 until the end of the Civil War.[36] It also served as a prison for the "Immortal 600", a group of Confederate prisoners of war that were mistreated and held at Fort Pulaski during the bitter cold winter of 1865. In 1873 the fort was closed and in 1884 it was turned over to the Army Corp of Engineers. The Army Corp used the island as a depot for dredge spoils until 1996 when Congress canceled the Army Corp of Engineers reservation to deposit the spoil on Cockspur Island. The spoil came from dredging activities on the Savannah River that kept the navigation channel to the Port of Savannah open.

[34] Meader, 2003.
[35] Howell and Alexander, 2005
[36] Brent Rothschild, Personal Communication, 2006.

To allow for improved visibility and security, land surrounding the fort was clear cut and maintained as cleared land since the beginning of the location's use as a fortification. An end to the clear cutting of vegetation on Cockspur Island occurred in the 1920s. Once the island was of less military significance, the practice was no longer necessary and much of the newly established upland habitat was able to begin to regenerate naturally.

Fort Pulaski was established as a national monument by presidential proclamation in 1924, and in 1933 President Roosevelt transferred the park to the National Park Service. Much work was done on the fort by the Civilian Conservation Corp around this time. The biggest expansion of the park's land came in 1939 when the State of Georgia deeded over 5000 acres of marshland on McQueens Island to the park. This brought the park to its current acreage.

The Savannah Bar pilots established operations on the west end of Cockspur Island in 1940, where they still operate today. At the outset of the US involvement in WWII in 1942 the monument was closed to the public and the transferred from the Department of the Interior to the Navy Department where it remained until the end of World War II. The intent was for the fort to be used for prisoners of war; however it was never used for that purpose. The park returned to the NPS in 1948.

The park has a long standing history of cooperation with the Chatham County Mosquito Control Commission (CCMCC). This relationship was developed from 1960-1963 when the CCMCC excavated canals, filled low areas and sprayed for mosquitoes in the park. This relationship remains today. In 1965, the Coast Guard established a Search and Rescue station on Cockspur Island which is still operational. Perhaps the most important event in the park's history from the standpoint of natural resource conservation occurred in 1996, when Congress revoked the Army Corp's reservation on dredge spoil deposition on Cockspur Island.

McQueens Island seems to have been sparsely used in prehistoric times and was largely untouched by development until the construction of a single track railroad in 1886. The railroad was in use until the 1930's. Then in 1992, the railroad was converted to a multiuse trail maintained by the park.[37] Road construction on McQueens Island occurred in 1923 with

[37] Meader, 2003.

Highway 80 being built to connect Savannah to Tybee Island. The Georgia DOT is looking to expand the 2-lane highway to a 4-lane highway.

In 1848 the Cockspur Island lighthouse was constructed. It was destroyed by a hurricane in 1854 and then rebuilt in 1856. In 1959 the lighthouse was transferred from the Coast Guard to the NPS.[38] Daymark Island is only 1.5 acres at high tide, and is not mentioned in a historical land use context in any of the documents referenced for this report. It was given to the NPS in 1958 by presidential decree.

ii. Adjacent Land Use

Adjacent land use is of great concern to FOPU. It lies directly downstream of a major metropolitan area and the 8th largest port in the nation[39] which leaves little doubt that upstream human activities can have great impact. Two recently proposed projects are of greatest concern: the expansion of the Port of Savannah and the proposed widening of Highway 80 which runs through McQueens Island.[40] Neither of these projects has yet to be approved or initiated. However, they are important and may cause significant impact if approved.

The expansion plans for the Port of Savannah include deepening the river channel from 42 feet to 48 feet over a 36-mile section of the river beginning at FOPU, as well as widening several bends in the river to accommodate the turnaround of larger cargo vessels[41]. Such deepening will affect sediment transport and may accelerate coastal erosion.[42] Dredging events during the deepening could also affect water clarity. A worst-case scenario is predicted to place > 1000mg/L of sediments into the water column which could have adverse effects on aquatic life. The Army Corp has not reported sediment concentrations that high during previous dredging events. Altered salinity regimes from deepening the river could also cause the loss of freshwater marsh habitat and altered locations, due to altered salinity regimes, of habitat for various aquatic species. Potentially affected species include shortnose sturgeon (*Acipenser brevirostrum)* and striped bass (*Morone saxatilis*), both of which are commercially important. [43]

[38] Meader, 2003.
[39] McFarlin and Alber, 2005.
[40] NPCA Meeting with Park Staff. June, 2006.
[41] McFarlin and Alber, 2005.
[42] Brad Murray, Personal Communication, 2005.
[43] Georgia Ports Authority, 1998. McFarlin and Alber, 2005.

The current draft of the Georgia Ports Authority Environmental Impact Statement for this project addresses these potential impacts and others under three different predictive models of flow after the deepening occurs.[44] Under highest flow and middle flow scenarios, impacts do not appear to be too severe and much of the habitat change would occur upstream from FOPU, since FOPU is already saltwater marsh rather than freshwater. There are some concerns over the lowest flow scenario in respect to dissolved oxygen. DO in the area is already low in some cases, and this could exacerbate the problem.

A recent 8000-gallon oil spill in the Savannah River closed down a 12 mile stretch of the river.[45] Such incidents highlight the risks that the park can face from increased levels of boat traffic and the port expansion project upstream of its location. While any oil spill is a concern, this was not a spill of great magnitude. The Coast Guard responded to the spill quickly and long term impacts are highly unlikely. The only other recorded spill in the vicinity of the park occurred in 1995 when 60 gallons of phosphate was leaked into the Savannah River from a ruptured tank.[46]

The proposed highway expansion project for Highway 80 is currently a topic of discussion between Park Staff and the Georgia Dept. of Transportation (GADOT). Currently, Highway 80 is a 2-lane road which the GADOT proposes to widen to a 4-lane highway. The rationale for this project rests largely on the increasing population of nearby Tybee Island and concerns over evacuation efficacy from Tybee Island in the case of natural disasters such as hurricanes.[47] FOPU is concerned over additional loss of land to GADOT as well as the location of their fee collection booth and turning lane design leading into the park. GADOT will need 22-30 acres of park land for the project which would have to be deeded over by an act of Congress. The park land in question is largely salt marsh, and is located on McQueens Island. GADOT is proposing to give the park 200 acres of wetland adjacent to the park which it acquired from the federal government with the stipulation that it be used for wetland mitigation, in exchange for the land it needs for the expansion project.[48] NPS staff consider the exchange proposed by GADOT to be of benefit to the park as the land requested by GADOT is of poor quality, and the 200-acre parcel

[44] Georgia Ports Authority, 1998.
[45] Associated Press, 2006.
[46] Brent Rothschild, Personal Communication, 2006.
[47] NPCA Meeting with Park Staff. June, 2006.
[48] NPS Briefing Statement, 2006.

that would be granted in the exchange would add significantly to their natural resource holdings.[49]

Several other adjacent use issues are worth noting. Boat traffic has increased in the Savannah Harbor and could cause shoreline damage from the wakes of larger boats.[50] One of the main reasons for the Harbor Expansion Project is so that the largest class of container ship can come into the port. The majority of the ships coming into the port are container cargo ships. Figure 3 shows the increase in overall tonnage the port handles over ten year.

Fig. 3. Georgia Ports Authority Ten Year Total Tonnage History.[51]

A study of marine debris in Chatham County used four sites, two of which were located at FOPU. The site with the most debris found was in FOPU.[52] Marine debris is aesthetically unappealing and park staff should be aware of its presence.

There are no federally regulated industrial facilities and no non-point pollution sources within the FOPU. However, upstream point and non-point sources of pollution are of concern to water quality within the park. The largest releasers of organic matter and nutrients in the Savannah River are President St. wastewater treatment plant for municipal facilities; and the Savannah Electric Co., International Paper and Weyerhauser for industrial facilities. While these are the major contributors, numerous other facilities are permitted for discharges and all told the facilities discharge several hundreds of millions of gallons a day into the Savannah River. [53]

[49] Joe DeVivo, Personal Communication, 2006.
[50] McFarlin and Alber, 2005.
[51] Georgia Ports Authority website, 2006. http://www.gaports.com/index2.html
[52] Gilligan et al, 1992.
[53] McFarlin and Alber, 2005.

Chemical industries account for 91% of all surface water contaminants in the area. The International Paper Company releases the greatest variety of contaminants and Kerr-McGee Pigments releases the largest amount. Contaminants include PAHs, nickel, chromium and zinc. The International Paper Company is also responsible for the greatest point source atmospheric release of chemicals in the area. When combined with the output of Savannah Electric and McIntosh Plant they account for almost 60% of the atmospheric chemical point sources in the area. There are 20 Superfund sites in Chatham County, including the Savannah International Airport.

There are two nuclear facilities located upstream on the Savannah River, The Savannah River Site and the Vogtle Electric Plant. Both are approximately 160 km upstream in Burke County, SC. The Savannah River Site is no longer in operation and was used for enriching weapons grade fissionables. The Vogtle Electric Plant has been in operation since 1985. Elevated levels of tritium and radioactive isotopes of strontium and cesium were found around the sites and at lower levels downstream. Downstream radionuclide levels do not exceed EPA standards, but are elevated.[54]

Industry regulations regarding runoff in the area have improved, as has wastewater treatment. While these contribute to water quality issues at FOPU, urban runoff is actually the greatest threat to water quality in the area, and will most likely only become more of a problem as the city of Savannah grows.[55]

Park staff is also trying to protect land outside its boundaries. There was a recent discovery of the location of a Civil War battery outside the park's boundary, so Park Staff are working with the local community to protect this cultural resource. While this is not an example of natural resource preservation, it does illustrate the staff's dedication to their job and a willingness to cooperate with outside organizations/people for issues they feel are of importance to the park. Both the Coast Guard and the Savannah Bar Pilots have long term special use permits on Cockspur Island. The Coast Guard maintains a search and rescue station, and the Savannah Bar Pilots also have a boat launch from which they ply their trade.

[54] McFarlin and Alber, 2005.
[55] Joe DeVivo Personal Communication, 2006.

C. Unique Park Resources and Designations

i. Aesthetic Resources

Aesthetic natural resources at the park are numerous and include views of pristine marsh, walks through upland and maritime forest habitat, and opportunities to sight numerous bird, animal, and plant species.

The park facilitates the enjoyment of those resources through a number of access points including a bridge leading from McQueens Island to Cockspur Island, a public boat access on McQueens Island, and the fort itself which provides a wonderful vantage point to look over the park. Dolphins and other marine life can observed, and a host of marsh species of flora and fauna seen.[56] Adjacent land development could pose some threat to the natural resource viewshed.[57]

Several types of trails are available throughout the park that allows visitors to get closer to the habitats. One trail, progeny of a Rails-to-Trails project, is excellent for biking and running and offers scenic views of the surrounding marsh. Other trails take guests through some of the upland habitats of the park and lead to historical features. One trail that is still being developed through the east end of Cockspur Island (it has been cleared but not marked) leads visitors through upland habitat and to a spectacular view of the Cockspur Island lighthouse.

ii. Unique Features

There are no "name brand" natural resource features at FOPU as at some larger parks where natural resources are the primary focus. However, this does not diminish the importance of the natural resources at the park, which should be viewed in the larger context of the surrounding area. The park provides important protection of wetland resources. While wetlands are not unique in the area, they are becoming scarcer as coastal development in the area, and indeed along the entire eastern seaboard, proceeds. Sea level rise and global warming are also likely contributors to the loss of wetlands globally.[58] As wetland loss in the area continues, whether through development, natural succession, or sea level rise, the wetlands present at FOPU become a more important resource. They are some of the best protected wetlands in the area and overall are in very good condition.

[56] Andrew DiMatteo, Personal Observation, 2006.
[57] NPCA Meeting with Park Staff. June, 2006.
[58] Nicholls et al., 1999.

iii. Special Designations

No special designations exist for the natural resources at FOPU. There are several state and federally listed threatened and endangered species that occasionally use the park, but there has been no designation of critical habitat at the park itself. No world heritage sites or other similarly designated sites exist at FOPU.

D. Park Science and Resource Management

i. Management Plans

Numerous FOPU management plans deal with natural resources. The Resource Management Plan for the park[59] includes current baseline information on the park, agreements and cooperation with non-NPS organizations, and current research needs. The following are some of the items included in this plan, as well as the park's Land Protection Plan[60] and Integrated Pest Management Plan[61]:

- Photo monitoring points have been established around Cockspur Island in order to detect changes in composition and extent of upland habitats.
- A deer monitoring program has been emplaced to monitor the population established in the park.
- The park seeks to create a geographic information system for the park including UTM coordinates of various resources.
- A clarification of dredge spoil rights on Cockspur Island and legislation that would limit the Army Corp of engineers from any future deposition of spoil.
- Mosquito control is done in partnership with the Chatham County Mosquito Control Commission through a Memorandum of Understanding. Pesticides are used only when set threshold are reached and are followed up with post-treatment monitoring.
- The park has a comprehensive Integrated Pest Management Plan giving the park definitive strategies on how to deal with the identified invasive species at the park. The park would like a database of exotic species locations in the park and treatment strategies to make better management decisions.

[59] Breen, 1990.
[60] Breen, 1995.
[61] NPS, 1993.

- Vegetation maps are needed to better control invasive and exotic plants.
- Illegal hunting and fishing in the park are not large problems but they do occur. Replacement of a full time law enforcement ranger and a study to assess the extent of these issues are needed to better manage this issue.
- Developments outside of park boundaries are identified as a potential issue. The park has been helping in the implementation of the Coastal Zone Management Plan for the state of Georgia and addresses most adjacent land use through its Land Management Plan.

The IPM from 1993 focuses on pest invertebrates, such as fire ants, mosquitoes and cockroaches which have traditionally been managed at the park, and also addresses the issue of invasive plants on the island and methods of control. Plant species that are being controlled are Chinese tallow (*Triadica sebifera),* Chinese privet (*Ligustrum sinense)*, China berry (*Melia azedarach*), and oleander (*Nerium oleander)*. Black rats are also controlled. The IPM states that chemical controls will be used only when other options have been exhausted.[62] The FOPU Land Protection Plan[63] and the FOPU Resource Management Plan[64] date from 1995 and 1990 respectively. Both are still in use, and represent a reasonable mix of attention paid both to cultural and natural resources. Given the nature of the park, they do give more credence to and attention to the protection of cultural resources, but natural resources are by no means ignored. Both plans adequately address protection of natural resources at the park, and the new General Management Plan (GMP) seeks to take this further. There was a Master Plan in effect at the park, but no GMP. The park is currently developing a new GMP; the initial phase has been completed. The draft of this report contains several insights into the future management of natural resources at the park. The GMP seeks to split the natural resources at FOPU into either natural resource preservation zones or natural resource recreation zones. At this phase of the plan, there is no formal draft for public comment but different alternatives within the plan are in the process of being evaluated and the public is welcome to send in their ideas and comments. The GMP still needs to have a formal draft made and an EIS completed, a period of public meetings, publish a

[62] NPS, 1993.
[63] Breen, 1995.
[64] Breen, 1990.

final document and then implement the plan. In the original timeline for the GMP, completion from this point in the process was given as two years.[65]

Natural resource preservation zones would be set aside as near pristine natural environments. The desired visitor effect would be to see the area as an undisturbed natural coastal area. No structures would be allowed in the area and interpretive signs and trails would be limited to "less ecologically sensitive areas".[66] Management would be kept to a minimum, doing only what would be required to maintain a natural appearance and remove invasive or exotic species. Cooperation with other organizations with natural resource jurisdiction, such as the Georgia DNR, would be encouraged. Visitor usage would be relatively low and would be limited to low impact activities, with bird watching and photography given as examples. It is unclear how much of the park would be set aside in this manner, as the new GMP is still in the planning stages and various options are being discussed.[67]

The natural resource recreation zones would in general have a higher use than the preservation zones and have the potential to be adapted for visitor use. The preliminary plan states that interaction with natural resources would be an important part of these areas and that dedicated structures could be emplaced. Impact from visitors would be minimized but the focus would be on enhancing the visitor experience**.** As above, it is unclear what percentage of the park would be used in this manner or where such zones would be located.

The preliminary draft of the GMP lists several management options. In terms of natural resources the only real differences listed between the options would be the removal of some vegetation in order to improve the historic viewshed to and from some of the cultural resources present at the fort. Of five alternative presented, three would allow for some level of vegetation removal. The GMP also shows a commitment to involvement in both the Highway 80 expansion project and the Savannah Harbor Expansion Project (SHEP) in all management options.

[65] Breen, 2003.
[66] FOPU GMP Preliminary Management Zone Descriptions, 2006.
[67] Brent Rothschild, Personal Communication 2006.

The park currently lacks a formal fire management plan. The current practice is one of suppression.[68]

ii. Research and Monitoring

Numerous studies have been performed at the park in order to provide baseline information on the biota present at the park and on air, water and sediment quality. Much of the upland habitat of the park has been surveyed and detailed lists of the plants present have been compiled. Animal surveys have been done on vertebrates, herpetofauna, bats, mammals, and, to a limited extent, fish. No work has been done on invertebrates or aquatic plants. Water quality has been extensively monitored within and outside of the park. This monitoring is planned to continue especially in light of the SHEP. Air quality is not closely monitored in the park and is not identified as being of great concern.[69] There is an ongoing photo point study in place at the park to track succession changes and location changes of upland habitat.

The park wishes to continue its strong effort to inventory and analyze its natural resources. It has proposed numerous avenues of research to accomplish this task. Projects waiting to be funded include:

- Acquisition of baseline GPS shoreline data and a boundary survey
- Continuation of a coastal shoreline erosion study
- Baseline monitoring and analysis of the health of the salt marsh ecosystem
- Initiation of air quality monitoring
- Mitigation of exotic animal species
- A study and inventory of finfish in the park

There is also impetus to continue periodic, general surveys of plant and animal life in the park. Several of these studies were completed recently. Govus did a vegetation survey in 1998[70] (see Appendix E), with a companion survey done on animals by Rabolli and Ellington in 1999[71] (see Appendices A, B, and D). These surveys sought to inventory the types of fauna and flora found at FOPU. Two recent studies sponsored by the Southeast Coastal Network Inventory and Monitoring Office looked at bat and herpetofaunal (see Appendices A and C) diversity of the

[68] NPCA Meeting with Park Staff. June, 2006.
[69] Breen, 1990.
[70] Govus, 1998.
[71] Rabolli and Ellington, 1999.

southeast network of coastal parks. The northern yellow bat, which is considered imperiled in GA, was found in FOPU.[72] No further broad studies are planned in the near future.

iii. Education and Outreach

Education and outreach at FOPU manifests itself in numerous ways. The overriding focus in terms of interpretation is definitely on the fort itself but attention is paid to the natural resources at the park. Trails with interpretive signs give insight to some of the natural resources and some of the trails are constructed specifically with the intent of the user enjoying the natural environment. One such trail is the Rail-to-Trails path on McQueens Island and another takes the visitor out from the fort, through a portion of the park's upland habitat, to a view of the Cockspur Lighthouse.

The new GMP will be a boon to natural resource interpretation at the park as well and several initiatives to increase public awareness about water quality and other natural resource concerns are also underway. The park hopes to be a part of a "seamless network of parks" initiative that would educate visitors on water quality from the lower Savannah River all the way to Gray's Reef National Marine Sanctuary. The park also looks for money in order to fund participants in the Youth Conservation Corp. Another project that the park wishes to fund is the resurfacing of a nature trail to meet ADA safety standards.

Volunteers at the park have done work on natural resource projects in the past. Deer counts are one such activity that volunteers participate in.[73]

IV. Assessment Criteria

A. Ecosystem Measures.

i. Ecosystem Extent and Function

a. Cover and Habitat Characterization

The historical loss of marsh on Cockspur Island due to the construction of the forts (1761 – 1847) and clear-cutting associated with the presence of the forts (ending in the 1920s), as well as the repeated deposition of dredge spoil (1867-1996) are the major concerns at FOPU in terms of

[72] Loeb, 2005. Tuberville et al, 2005.
[73] Brent Rothschild, Personal Communication, 2006.

historical changes. These events have allowed the development of upland habitats and an overall increase in biodiversity; however they represent a historical loss of habitat.[74]

Two vegetation studies done at the park lend insight into the state of the canopy and structure of the upland habitats and the substrate on which they occur. Cover density and homogeneity appear to be appropriate given the communities present at the park, barring the lack of live oak in the maritime forests that was discussed earlier.[75] While the upland areas may be rapidly progressing through succession, this is of mild concern and reflects the fact that vegetation clearing was practiced until the 1920s. Chinese tallow, an invasive species, has come to dominate in several patches and is being monitored closely.[76] It occurs mostly in disturbed patches made by dredge spoil deposition. Substrate quality is somewhat poor given that the initial substrate was dredge spoil which, in more recent deposits, is sandy in nature.[77] These deposits are sterile and will have to go through a long succession process to become fully mature.

The park is predominately comprised of salt marsh and is dominated by *Spartina sp.* Salt marshes function as critical habitat for numerous bird (see Appendix B) species and act as nurseries to many commercially important fish species, such as bass, croaker and mullet (See Appendix D). Marshes also act as a natural filtering system and can impact water quality in an area.[78]

Approximately 135 acres of the park is maintained as grassland, most around the fort, but also around the picnic area, visitor's center, and fee collection booth. This practice has established excellent habitat for deer to reside in, and the park now has a burgeoning population. Park staff report no cultural or natural resource impact from the deer population[79], but there is a visible browse line and potential impacts in upland habitats on Cockspur have not been studied.

Insufficient data was available to assess intra-patch integrity.

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[74] Tucker, 1986. Breen, 1990 . McFarlin and Alber, 2005.
[75] Govus, 1998
[76] Tucker, 1986. Govus, 1998.
[77] Govus, 1998
[78] Mitsch and Gosselink, 2000.
[79] NPCA Meeting with Park Staff. June, 2006.

b. Fragmentation

Roads, paths, mowing, park structures and the dike system in place at the park fragment portions of the upland habitat. Historical loss of marsh on Cockspur, and the construction of Highway 80 and the railroad on McQueens Island have also served to partially fragment some of the marsh habitat previously present on the two islands. On Cockspur Island, dredge spoil deposition has destroyed and disconnected historic marsh habitat. On McQueens Island, the fragmentation of the marsh is pronounced. Highway 80 and the railroad trail bisect the island with a thin strip of marsh between them, and marsh on either side. The marsh in between the two features is connected to the marsh on the side of McQueens Island facing Cockspur Island by feeder channels that run under bridges in the trail. However these channels do not seem to be accomplishing much, as the marsh habitat in the middle is of poor quality. Some areas appear to be drowned due to poor drainage while other areas appear to be filled in and are becoming almost ruderal in nature.[80] Despite that the majority of marsh habitat remains intact and un-fragmented. [81] No patch connectivity problems were noted in reference to the wetland habitats at FOPU, but this issue may not have been assessed. There may be overall fragmentation problems concerning marsh land in the area due to development. If this is indeed the case, keeping the marsh at FOPU intact becomes even more important. There is predicted to be loss of freshwater marsh upstream of FOPU from the deepening of the Savannah River navigation channel.[82]

None of the various species level inventories (see appendices) done at the park mention instances of species isolation or dispersal barriers.[83] While omission of mention does not mean a problem does not exist, there does not appear to be an issue with either of these two factors. Dispersal is mentioned in a positive way with respect to the dike system. The dike system allows for fish dispersal including mosquito fish used for mosquito control.[84] While islands may be viewed as a dispersal barrier due to their insular nature, within the park they are very close together spatially and are only separated by relatively small tidal creeks which do not pose a challenge to most terrestrial animals. None of the islands at the park are directly adjacent to the mainland of GA. There are several other small islands in between the two. There is a road off of Highway 80 that

[80] Andrew DiMatteo and Joe DeVivo, Personal Observation. June, 2006.
[81] Southeastern Wildlife Services, 1981. Govus, 1998. Meader, 2003.
[82] McFarlin and Alber, 2005.
[83] Govus, 1998. Rabolli and Ellington, 1999.
[84] Rabolli and Ellington, 1999.

connects McQueens and Cockspur Islands, but there is no connection between Cockspur and Daymark Islands.

There are no reported instances of actual extirpation for either plants or animals at FOPU. Oysters were "reintroduced" into Oyster Creek (1988), but it was not because they were actually extirpated, but rather they existed in numbers too low to support recreational fishing for them.

c. Community Structure and Function

Data on degradation of community structure, intra-patch microclimate alteration, inter-patch isolation and microclimate, primary production and decomposition were lacking at FOPU. It is unlikely that primary production is a problem in the park, given the healthy state of marsh predators, such as fish and shorebirds. Primary production in salt marshes is regulated by a top down trophic cascade[85], i.e. it is regulated and kept healthy by top predators in the system. One aspect of the history of human alteration in the park is the various different upland communities that have developed as a result of the dredge spoil being placed on the island. While this represents a loss of marsh habitat, uplands otherwise would have comprised an exceedingly small percentage of the park. Admittedly, these uplands do not represent the state of the park historically, but it is unlikely that these uplands will ever be returned to their historical state. Uplands now contribute heavily to the diversity in the park and diversity would be a fraction of what it currently is without their presence.[86] As they mature they could become an important park resource and afford the park the opportunity to protect a more diverse array of habitat while the majority of the park remains historical salt marsh habitat. Basically while the majority of the uplands habitat in the park represents a deviation from a historical state, it is not going to be changed back and as such should be utilized as best as it can be from a natural resource context.

Patch size and shape change is a concern on two fronts. One is the historical deposition of spoil in the Cockspur Island, which was extensive and probably will never return to its pristine state. The other more pressing issue is ongoing shoreline change on Cockspur. There is a migrating oyster shell ridge that is of concern to park managers, both in terms of potential habitat loss and

[85] Silliman and Bertness, 2002.
[86] Govus, 1998.

in destruction of cultural features.[87] The shell ridge is buffering marsh habitat on the north side of Cockspur islands and may be altering tidal influence. The shell ridge is also migrating and may be endangering historical piers that are part of the cultural legacy of the park.[88] A shoreline change assessment for the park is nearing completion, highlighting historical changes to the shoreline and the effects of dredging and boat wakes for Savannah Harbor.[89]

Too little is known about generalist domination of patches or age class distributions for plants or animals in order to determine if the problems are widespread, but several examples exist that indicate that there are at least isolated concerns. Two sources cite concern over the domination of a few patches by invasive Chinese tallow and park staff has mentioned the difficulty in eradicating it.[90] In a 1999 animal survey, Rabolli and Ellington suggest that the deer population on Cockspur is not at the ideal age and sex class distribution.[91]

Hydrologic change is ongoing. The Upper Floridian Aquifer has been lowered from industrial and civic use. There is also concern over saltwater intrusion into the system. No studies have mentioned how this may affect the ecosystems at FOPU. Deepening of the Savannah River may alter salinity regimes in the river but would not likely affect FOPU as FOPU as already almost entirely saltwater.[92] It is not thought that the increased boat activity from the deepening would affect hydrology at the park.[93] The dike/drainage system on Cockspur Island significantly altered the hydrology on that island and along with the addition of dredge spoil has allowed for the growth of extensive upland habitat.

[87] NPCA Meeting with Park Staff. June, 2006.
[88] Howell and Alexander, 2005.
[89] Howell and Alexander, 2005.
[90] Govus, 1998. Breen, 1990.
[91] Rabolli and Ellington, 1999.
[92] McFarlin and Alber, 2005.
[93] Joe DeVivo, Personal Communication, 2006.

d. Disturbance Regimes

Because FOPU is composed primary of salt marsh and tidal creek habitats, the natural systems at FOPU depend on regular tidal cycles for their health. Regular inundation and exposure are the normal disturbance regime for this ecosystem. It has been noted that the fish populations in the park are well adapted to tidal cycles and drought cycles**.** Occasional drought may lead to increased transmission of communicable diseases amongst the mammalian population on the island.[94]Two possible reasons for this are decreased water resources that have to be shared by more animals, and resource conflicts that can cause transmission through injury (bites). No pronounced effects of the current drought have been noted by park staff. Flooding has occurred at the park in the past. A hurricane in 1881 flooded the parade ground of the fort with five feet of water and another in 1981 flooded Tybee Rd.[95] No studies mention lasting effects of flooding on either fauna or flora at the park.

Climate change research has shown that rising sea levels may imperil wetlands.[96] Another predicted impact of global warming is increased storm frequency and strength.[97] Increased storm frequency may challenge the ability of both wetland and upland habitat to recover. While adapted to tidal cycles and able to rebound from occasional severe storms, salt marshes can still drown and marsh banks can be eroded by large or persistent storms.[98]

Neither grazing effects of deer nor visitor impacts appear to be important parts of the disturbance regimes at the park. While there is a visible browse line from deer, this occurs most in the managed grassland portions of the park.[99] Park staff does not view the current deer population as a threat to either the cultural or natural resources of the park, but are continuing to monitor the situation. Visitor impact from a natural resource standpoint is said to be limited to small paths to fishing spots around the bridge leading to Cockspur Island from McQueens Island. [100]

Historically the land of Cockspur was disturbed regularly through the deposition of dredge spoil and clearing of vegetation in order to maintain a view all around the island. Dredge spoil

[94] Southeast Wildlife Services, 1981.
[95] Brent Rothschild, Personal Communication, 2006.
[96] Nicholls et al, 1999.
[97] Lubick, 2005.
[98] Mitsch and Gosselink, 2000.
[99] Rabolli and Ellington, 1999.
[100] NPCA Meeting with Park Staff. June, 2006.

deposition has ended and for the most part so has vegetation clearing.[101] There is talk amongst park staff of potentially clearing a portion of the park's upland area to restore the historical viewshed from the fort to the island of Tybee. Most of the park's upland habitat would not be affected by this since most of the upland habitat on Cockspur Island occurs away from that side of the island. The new GMP, still in its planning stages, does not state specific acreage for clearing and several options are under discussion, as to how much, or if any at all should be cleared.[102]

The largest potential disturbances to the park come from upstream.[103] As mentioned earlier, it is impossible to assess the natural resources of this park without taking into account upstream industrial concerns, the expansion of Savannah Harbor and the growth of the city of Savannah. In general alteration and adjacent development affects have had and will have the most effect on the resources of FOPU.

ii. Species Composition and Condition

This section is another example of the need for higher level ecosystem studies to be performed at FOPU.

a. Total Species

It would be difficult to understate the importance of the development of upland habitats in the park as reason for the park's increased diversity compared to if it had remained almost entirely salt marsh, though this comes at the cost of historical salt marsh habitat.. This was mentioned earlier but is worth restating in this context. The upland habitat at the park may not have been there historically, but it is native to the area and was historically present in the park covering fewer acres.

FOPU supports a wide array of avian species and plants. Some mammals, such as deer, possums, raccoons, rabbits, black rats, house mice, bats and squirrels are present as well.[104] Herpetofaunal diversity is low compared to some other parks in the Southeast[105] and little is

[101] Govus, 1998. Meader, 2003. McFarlin and Alber, 2005.
[102] Brent Rothschild, Personal Communication, 2006.
[103] Breen, 1995. McFarlin and Alber, 2005. DeVivo et al., 2006.
[104] Govus, 1998. Rabolli and Ellington, 1999.
[105] Tuberville et al., 2005.

know about the invertebrates of the park. Numerous fish species have also been identified in various inventories of the park or area surrounding the park[106]. (See Appendices for species lists)

As with many ecosystems, non-native species are becoming established at Fort Pulaski. Sixty-eight (68) non-native plants species have been identified in the park accounting for 23 percent of the total plant species identified.[107] The black rat (*Rattus rattus*), house mouse (*Mus musculus*) and the European starling (*Sturnus vulgaris*) are also non-native. There has not been an invertebrate survey done at the park, but it would not be surprising to find non-native species in such a survey given the appearance of non-native species in other types of fauna and flora surveys at the park. The European starling is of concern because it competes with native birds for habitat.[108] Armadillos (*Dasypus novemcintus*) have also been seen in the park, although there is debate as to whether this is an invasive incident or a natural range expansion. It is not anticipated that they will become a threat to the park ecosystems.[109]

The invasive species of most concern at the park are plants. Eighteen plant species at FOPU are invasive or disruptive to native habitat.[110] Three are of special concern; Chinese privet, China berry, and Chinese tallow. Chinese tallow and China-berry have come to dominate several isolated patches of spoil deposit in the park. Eradication attempts have been unable to completely dislodge the Chinese tallow. It has yet to invade mature forest on in the park[111] The main threat of these species is their ability to dominate patches. This makes succession of native plants difficult if not impossible in non-native dominated patches.

No studies of the genetics of either plants or animals have been done at the park. Nothing is known about genetic variability.

b. Native Species

There have been changes in plant species composition between the two most recent vegetation surveys (1) Govus, 1998 and 2) Southeastern Wildlife Services, 1981. Govus[112] remarked that

[106] Rabolli and Ellington, 1999. McFarlin and Alber, 2005.
[107] Govus, 1998. McFarlin and Alber, 2005.
[108] Rabolli and Ellington, 1999.
[109] Joe DeVivo, Personal Communication, 2006.
[110] Govus, 1998.
[111] Park Staff, Personal Communication, 2006.
[112] Govus, 1998.

this may be a simple case of not seeing a given species on the new survey. It is also possible that the changes are due to the somewhat rapid succession occurring in some of the upland habitats in the park. Now that clearing of vegetation in a widespread manner is no longer practiced, some of the habitats may be reaching maturity, reflecting the noted composition changes. The extensive wetland areas of the park provide critical habitat to numerous bird and fish species native to the area (see Appendices B and D). Without wetlands and the abundant resources they supply, numerous native species would be seriously imperiled or threatened with extinction.[113]

No plant pathogens or parasites have been reported but several diseases affect the animal populations at the park and are of concern to park officials. Cases of raccoons with rabies have occurred and hantavirus has been found in mice and rats in the park. Rabies is not reported as being widespread or as significantly impacting the population. Hantavirus can be passed to humans and requires caution when handling the animals, their urine or feces.[114] Hantavirus is not dangerous to the animal populations which carry it, but it is a threat to human populations that come in contact with it.[115] There is also concern over chytrid fungus, a disease that can severely harm numerous amphibian species. The SECN Inventory and Monitoring program plans to initiate a study of the disease in the area.[116]

Numerous invertebrate species of animals are known to be present at the park and include both terrestrial and aquatic species. However, a formal invertebrate survey has not been conducted at the park and could yield significant insight into the species present at the park. Most of what is known about invertebrates at the park is in the context of pest species and is addressed in the IPM.[117]

Several state or federally listed threatened and endangered animals have been seen in the park. They are as follows.[118] (See Appendix F for a complete list of federally protected species in the surrounding area.)

[113] Mitsch and Gosselink, 2000.
[114] Rabolli and Ellington, 1999.
[115] Langlois et al., 2001.
[116] Joe DeVivo, Personal Communication, 2006.
[117] NPS, 1993.
[118] Rabolli and Ellington, 1999. McFarlin and Alber, 2005.

Birds:

-American Oystercatcher *Haematopus palliates*

-Bachman's warbler *Vermivora bachmanii*

-Gull-billed tern *Sterna nilotica*

-Least tern *Sterna antillarum*

-Peregrine falcon *Falco perigrinus*

-Piping plover *Charadrius melodus*

-Swallow-tailed kite *Elanoides forficatus*

-Wilson's plover *Charadrius wilsonia*

Mammals:

-West Indian manatee *Trichechus manatus*

Reptiles:

-Loggerhead sea turtle *Caretta caretta*

FOPU staff follows the guidelines set forth by the National Park Service when dealing with these animals or their habitats. None are permanent residents of the park, but it is important that the park notes that they use the habitat present and takes steps to protect them while they are there. The park provides an important refuge for these animals.

Painted bunting (*Passerina crisis)* can also be found at the park. While not listed by the state or the federal government, they are thought to be in decline. Two plant species are also present in the park that are listed as species of concern by the Georgia Natural Heritage Program.[119] They are:

-Florida privet *Forestiera segregate*

-Swamp dock *Rumex verticillatus*

Diamondback terrapins (*Malaclemmys terrapin)* and alligators (*Alligator mississippiensis*) are present in the park. Diamondback terrapins are not federally listed or state listed in Georgia, but they are listed as threatened in several states on the eastern seaboard. Alligators can sometimes be seen in the moat of the fort, on the lawn surrounding the fort and in other places throughout

[119] Govus 1998. McFarlin and Alber, 2005.

the park. Park staff has avoided putting up too much signage about the alligators for fear of encouraging visitors to look for them.[120]

Extirpation has not been a problem at the park, although the oyster level in Oyster Creek was so low at one point that they were "reintroduced" in order to provide viable recreational harvest. This attempt was successful.[121] Also, there were several plants species found in the 1981 vegetation survey that were not seen in the most recent one. This however is not necessarily an indication of extirpation. Because of the loss of marsh habitat on Cockspur Island, there has been a concurrent decrease in the number of marsh birds on that island. Those birds can still be found in other parts of the park.[122]

No studies have identified what if any keystone species are present in the park ecosystems or if there are any issues concerning dominant species density dependence. It is believed that the deer population on the island is reaching its carrying capacity[123] but other than this other species have not been assessed in terms of population status. They have simply been identified as being present in the park, native, non-native or invasive, and in the case of protected species, whether they are residents of the park or not.

c. Trophic and Biotic Interaction

The known problems stem from non-native species and yield changes wrought on native species and ecosystems. Grazer effects are not thought to be a problem in this context. Competitor change has occurred due to habitat competition from the non-native European starling.[124] Starlings compete with other cavity nesting birds at the park for nesting space. Species include many of those listed in Appendix B, excluding wading birds, shorebirds, gulls, rails, and waterfowls. Chinese tallow affects dominance alteration in some patches, namely, the native species (Coastal red-cedar, sugarberry, cabbage palmetto, wax-myrtle, lantana, and numerous native herbaceous species) which otherwise would have colonized recent dredge spoil.[125]

[120] NPCA Meeting with Park Staff. June, 2006.
[121] Baker, 1988. Govus, 1998.
[122] Tucker, 1986.
[123] Rabolli and Ellington, 1999.
[124] Rabolli and Ellington, 1999. NPCA Meeting with Park Staff. June, 2006.
[125] Govus, 1998.

B. Environmental Quality and Biotic Measures

i. Water Resources

A recent NPS report from the Water Resources Division did a comprehensive study of water quality and watershed conditions in and around FOPU.[126] This report has proved to be an excellent resource not only for water quality information but also the biotic and ecosystem issues present at the park.

Alkalinity and general pH are within normal parameters for a Georgia salt marsh as were temperature, salinity and turbidity.[127] Chlorophyll a concentrations were not noted as a problem in any report that mentioned them. Dissolved oxygen (DO) was seen as a potential problem at the park. Numerous measurements outside the park were below standards as were several within the park. This is thought to be caused by industry upstream outputting wastes and urban runoff that increase oxygen demand in the river. There are eight municipal waste water treatment plants, and numerous pulp, paper, and chemical treatment plants that hold major permits (greater than one million output gallons per day) that increase organic matter and biological oxygen demand in the Savannah River. Despite this, regulations in the area have improved and it is thought that urban runoff form the city of Savannah is of more concern as the city continues to grow. In addition to DO, numerous measurements of nutrient levels that were rated fair to poor were found in and around the park; with more outside than in.[128] More monitoring has occurred outside the park than inside, so further investigation is certainly merited.

Algal blooms have occurred through out the history of the park in the moat; at one point in 1957 there was a massive bacterial infection that led to fish kills and an unattractive appearance of the moat. Measures to combat this issue have included replacing the water in the moat with fresh river water, and in the case of the bacterial infestation, a massive dose of copper sulfate. The current method of preventing and caring for algal blooms is to use the tidal gates present in the park to flush the system as needed, managing it as a "semi-closed system".[129]

[126] McFarlin and Alber, 2005.
[127] Richardson and Sajwan, 2002.
[128] McFarlin and Alber, 2005. DeVivo et al., 2006.
[129] FOPU Resource Management Plan, 1990. Meader, 2003.

No problems with flow were noted within the park though several problems were highlighted as occurring upstream in the Savannah River.[130] The Upper Floridian Aquifer, which was mentioned above, is the main source of fresh water in the area both for industrial concerns and for the population in the area, including providing the fresh water at FOPU. The two concerns in reference to the aquifer are recharge and salt water intrusion. This matter bears careful monitoring as the population in the area increases, because there will almost certainly be a corresponding increase in demand on an already lowered aquifer.[131] Sedimentation presents an interesting conundrum. The Savannah River naturally has a high sediment load. This means that in order to maintain the port of Savannah constant dredging must occur. This is why dredge spoils were historically deposited on Cockspur Island. Most of the spoil is now shipped to inland sites, but as long as the port exists dredging will be a problem that must be dealt with, especially with the proposed expansion of the harbor.[132]

Elevated levels of heavy metals over background levels have been detected in the river from upstream industry and from recently disturbed sediments. In addition to heavy metals there are elevated levels of radionuclides in the water column. This most likely stems from the two nuclear power plants that are located upstream; both are regulated by the US government. They are the Vogtle Electric Plant and the Savannah River Site both approximately 160km upstream from the mouth of the river. Organic matter from industry and occasional sewage spills or septic tank leaks are chronic and occasional problems respectively.[133] Metals which were found to be elevated in either sediment or oyster and shrimp tissue[134] samples:

- Lead – sediment
- Chromium – sediment
- Vanadium – sediment
- Mercury – sediment, tissue
- Chromium – sediment
- Copper – sediment
- Arsenic – sediment, tissue

[130] McFarlin and Alber, 2005.
[131] FOPU Resource Management Plan, 1990. DeVivo et al., 2006. McFarlin and Alber, 2005.
[132] McFarlin and Alber, 2005.
[133] McFarlin and Alber, 2005. DeVivo et al., 2006.
[134] Loganathan et al, 2001. Richardson and Sajwan, 2001.

- Cadmium – sediment
- Nickel –sediment
- Zinc – sediment
- Molybdenum – sediment
- Manganese - sediment

Only one invasive species, the green mussel, has been reported in the Savannah River near FOPU. . The port has large container vessels coming in and out constantly and this provides ample opportunity for introduction of species that have traveled in a ship's ballast water. Given this, constant vigilance for introduced aquatic species needs to be maintained. The list of fish species found in the Savannah River estuary and near Fort Pulaski make no designation as to whether they are native or non-native species. The comprehensive watershed assessment done for the park mentions that non-native game and bait fish are present in the Savannah River watershed. This is the entire watershed stretching from its headwaters in Tennessee to the mouth of the river in GA. The report does not give specific species, but states that they have been intentionally stocked and have, in general, been benign.[135]

Assessment categories for which there was insufficient data include benthic index, diatoms, drawdown, plankton and submerged macrophytes.

ii. Air Quality

Data could be found for only five out of ten rating categories in this subcategory. Missing were Cl-oxides/Cl-nitrates, HFCs/FHCs/HCs, nitrogen oxides, mercury and visibility. There was not an IMPROVE site close enough that could provide long-term visibility data.[136] The two closest IMPROVE sites are located in Okefenokee National Wildlife Refuge in Georgia and on Cape Romain in South Carolina.[137]

From surface water quality samples it was determined that aerial deposition of acids was unlikely. Long-term data from the closest IMPROVE site does note some suspended particulate matter in the air. Ozone measurements do sometimes exceed standards, however managers do

[135] McFarlin and Alber, 2005.
[136] DeVivo et al., 2006.
[137] IMPROVE Metadata Browser. Accessed Oct. 2006.

not this consider this a problem for the park for two reasons: the problem is not acute and there is no record of ozone sensitive plants at the park.[138] The nearest NPS ozone monitoring station to FOPU is located in Congragee National Park in SC.[139] The watershed assessment for FOPU, did state that VOCs were definitely put into the atmosphere near the park, but did not mention whether they exceeded standards or were a problem.[140]

iii. Soils and Sediments

Very little soil work has been done at FOPU. There was an older study that listed and mapped several basic soil types at the park, but for the purposes of this assessment it has little value, and mostly focused on the historical difficulties of building a fort on what was essentially a tide marsh.[141] More recent work has been done on sediments in a study to assess baseline marsh health in the park.[142] Sediment samples have also been analyzed in reference to the proposed expansion of the port.[143]

Acidity, alkalinity, pH and metals, were assessed in sediment samples around the park in a 2002 study.[144] Locations included Oyster Creek and other tidally influenced channels around the park. No problems were reported with acidity, alkalinity or pH. Levels of heavy metals were low compared to industrialized areas. Other contaminants were detected at elevated levels, including arsenic, PAHs, and DDT.[145] Elevated levels of radionuclides were found in sediments further upstream from the park, most likely for the same reason they were found elevated in the water column, the two nuclear power plants.[146]

While organic matter is being put into the water column from industry upstream it was not mentioned as a problem in any sediment analyses; whether or not a problem exists is questionable. Dredging could put settled organic matter back into the water column and increase

[138] DeVivo et al., 2006.
[139] NPS Nature and Science website. Accessed Oct. 2006.
[140] McFarlin and Alber, 2005.
[141] Soil Conservation Service, 1974.
[142] Richardson and Sajwan, 2002.
[143] McFarlin and Alber, 2002.
[144] Richardson and Sajwan, 2002.
[145] Loganathan et al, 2001. Richardson and Sajwan, 2002.
[146] McFarlin and Alber, 2005.

BOD along with other contaminants. As with water resources, organic waste could find its way into park sediments from several outside sources.[147]

Erosion is the current main concern when it comes to soils and sediments in the park. Due to the high level of cargo ship traffic and the constant dredging, as well as natural factors, shoreline change has been an ongoing process at the North Channel of Cockspur Island.[148] A current study aims to give managers options and techniques to deal with erosion and accretion issues at the park. An opinion that has garnered support is that the deepening of the river and the increase in draft of the cargo containers coming through will not affect erosion issues more so than they already do.[149]

Data was insufficient to assess compaction, infiltration/permeability, nutrients, salinity and sodicity, soil fauna and macroflora, soil microbiota, and xenobiotics.

iv. Climate

Climate change is a heavily researched topic, in part because of its controversy in the popular press and in part because of its far-reaching impacts. As with almost any ecosystem, climate change has the potential to impact FOPU and its managers should be aware of the potential threats.

Sea level rise is one impact of global warming. Salt marsh wetlands have a natural mechanism to deal with rising sea levels, but it is questionable as to whether that mechanism can keep up with some of the predicted rates of sea level rise.[150] The grasses present in salt marshes trap sediment as it flows through with the tide. The higher the water level is around the grasses, the faster it traps sediment and raises itself up, given that sufficient sediment is present in the water. There is an upper limit to how fast sediment can be trapped and accreted, and salt marshes are capable of drowning. Global sea level rise is predicted to be around 38 cm by the year 2080.[151] The natural resources at FOPU are comprised largely of salt marshes which provide valuable habitat to wading birds and other animals as well as providing important ecological functions such as being

[147] McFarlin and Alber, 2005.
[148] Breen, 1990. Howell and Alexander, 2005. Georgia Ports Authority, 1998.
[149] Joe DeVivo, Personal Communication, 2006.
[150] Nicholls et al., 1999. Brad Murray, Personal Communication, 2005.
[151] Nicholls et al., 1999.

a nursery for many species of fish. [152] Wetlands are already imperiled in other places around the world; it would be tragic to lose more, especially ones that are already protected.

Another potential impact of global climate change is increased power and frequency of storms, including hurricanes. More frequent and stronger storms could lead to swifter erosion of shorelines and more loss of habitat for animals and loss of substrate for plants.[153]

While it would be extremely difficult for park staff to mitigate the potential effects of climate change on park resources, let alone mitigate the causes of climate change itself, it is important that they be aware of current research and impacts. This is especially true given the sensitive nature of the salt marsh resources.

v. Biotic Health

Inventories done at FOPU allowed for some insight to potential problems at the park.

a. Animals

Oyster Creek, which is located in the park, is the only area in Chatham County that is open for recreational harvesting based on water quality monitoring done by the Georgia DNR.[154] This is an excellent example of a resource that is likely only to thrive with continued protection by the park. Despite protection within the park, the resource is threatened by upstream influences. The same groups that performed and assessed water quality samples in the park also looked at oyster tissue samples and found evidence of elevated levels of harmful contaminants.[155] Evidence of bioaccumulation of contaminants, both metals and organic, have also been found for shrimp and several species of fish in the Savannah River.[156]

Park staff has seen no evidence of any negative impact on wildlife from guests at the park aside from occasionally incidents of road kill. Since September 2006, park staff have logged the strike and kill of both a fawn and a raccoon. Recreational fishing is allowed within the park creeks, and a boat launch is maintained within park boundaries on McQueens Island by Chatham County.

[152] Mitchener et al, 1997. Mitsch and Gosselink, 2000.
[153] Howell and Alexander, 2005.
[154] Baker, 1988.
[155] Richardson and Sajwan, 2001, McFarlin and Alber, 2005.
[156] Rabolli and Ellington, 1999. Loganathan et al, 2001. McFarlin and Alber, 2005.

Commercial fishing is not allowed within the park although there have been instances of poaching by commercial fishers in park waters; species taken are generally either crabs or oysters.[157] The park has just hired a law enforcement ranger who is doubling as the natural resource manager for the park.

Land use history in the park as well as natural disasters have altered habitats for the various animal communities in the park.[158] Aside from marsh birds and aquatic animals, the dredge spoil on Cockspur forms the basis of almost the entire habitat for animals in the park. This however did represent the loss of a large chunk of habitat for marsh species. While hurricanes rarely make landfall in the area, nor'easters are common and can contribute to erosion just as much as a hurricane albeit over a longer time period. This erosion has resulted in some habitat loss.[159] Additional habitat loss for animals comes from competition with non-native species, such as European starling.

The managed lawn area around the fort provides excellent habitat for deer. It is unlikely that either the deer or the food source is going to go away in the near future. Though this is an unnatural situation, it appears the deer population is reaching its carrying capacity[160]. Park officials have seen no problems and it currently seems that the situation is tenable.

Categories with insufficient data were acoustics and isolation/insulation.

b. Plants

What follows is a brief synopsis of issues associated with plants at FOPU.

- Exotic competition from invasive species, with Chinese tallow being the main concern.
- Clear cutting of vegetation on Cockspur Island until relatively recently kept the upland habitats in early successional stages.
- Park staff may clear some upland to restore the historic viewshed from the fort.
- Shoreline change and erosion is a concern on the North Channel of Cockspur Island.

[157] NPCA Meeting with Park Staff. June 2006.
[158] Tucker, 1986
[159] Howell and Alexander, 2005.
[160] Rabolli and Ellington, 1999.

- Substrate increases on Cockspur occurred due to continual deposition of dredge spoil until 1996, when the Army Corp lost their right to do so.
- Visitor impact on plant life is negligible.
- No reports of disease have been made.

Data were insufficient to rate the following categories: environmental quality, nutrient supply and population dynamics.

V. Conclusions and Recommendations

A. Overall Results and Conclusions

The natural resources at the park are in good condition and well managed, but, due to historical perturbations and the growing upstream population, will never return to a pristine state. The park represents important ecological resources in the region and, as more development occurs in the area, they will only become more important as refuges. The park is, however, vulnerable largely as a result of anthropogenic influences outside the park, past land use history and, to some extent, invasive species within the park. Many of those influences are difficult if not impossible for park managers to change or affect. It will be important for park staff to continue to be active in discussion of future development in the area so that the best level of protection for the park from outside influences can be afforded.

Given the principal mission of the park, i.e. cultural and historical resources, park staff do a good job of protecting and interpreting their natural resources. More interpretation of natural resources would certainly be helpful, but current levels appear to be adequate, especially in light of the new general management plan being developed.

There is a need for more extensive ecological research at the park. Research needs to be undertaken at the park to understand higher order ecosystem functions as well as continued monitoring of baseline indicators of ecosystem health. As with any system, the more that is understood, the better and more informed the decisions to protect it will be. Management will be able to provide targeted, effective solutions to problems that may arise. In addition to providing

for enhanced solutions to problems, more information may identify problems that previously were unknown. In the course of this assessment, various issues were addressed. There was a strong trend that the more information that was present in a given category, the more problems were identified. Below are recommendations for the park in general and research objectives that would provide some of the information that was lacking in portions of this assessment.

B. Recommendations

i. Park Management

Interpretive staff at the park should become more versed in the natural resources at the park. Work on tie-ins between the historical significance of the fort and the current natural resources that the park protects.

Continue to build relationships with regional offices that affect land development in the area and that can provide baseline air and water quality data to the park. The park should focus on environmental protection in the area, given the potential for outside influences to have deleterious effects on sensitive habitat present in the park.

ii. Future Research at Fort Pulaski

Baseline data for the park is continually being collected. This provides an excellent resource for assessments such as this, but more is needed. Several baseline data needs identified in the park are regular monitoring of water quality within FOPU, better access to federal and state water quality data, additional plant and animal surveys, identification of sentinel organisms, and air quality monitoring.[161]

- Much of the water quality data used in this assessment came from monitoring that occurred outside of the park. While this is certainly useful, internal data is crucial.
- The numerous plant and animal surveys already completed, and the ones that are planned, are superb resources. Such surveys should be periodically repeated to identify population structure changes over time.

[161] McFarlin and Alber, 2005.

- One significant lack in terms of animal surveys at the park is that of an invertebrate survey. One should be commissioned for the park, in addition to the finfish survey the park is trying to fund.
- Little is known about the air or soil quality at the park. Regular air quality monitoring should be initiated, especially with the amount of upstream industry present in the area.
- A soil survey should be conducted to determine the quality of substrate in the upland habitats of the island. The origin of the substrate is not natural and this could have ramifications for the upland habitat present on the island. Sediment quality in the marshes and creeks of the park should continue to be monitored as well.

The above recommendations would provide needed baseline data for the park. There is another concern for data in the park as well. Many of the ratings elements in this assessment that were unable to be scored were based on information about higher-order ecosystem functions. In order to truly determine how well the ecosystem at FOPU is functioning, studies looking at multiple system components should be undertaken. This should be a research priority for the park. Studies could be broken down to tackle the various communities present at the park, and eventually a study could be done to see how these communities interact. Questions that these studies could explore include:

- How would global climate change affect the ecosystems present at the park?
- Are the any problems associated with intra-patch integrity, edge effects, or microclimate alteration?
- What is the state of primary production and nutrient/decomposition cycling at the park? This could especially be important in the context of how communities at the park interact.
- What are the important populations of plants and animals within the park? Are there any keystone species or predators?
- What levels of genetic variability are present in important populations at the park? Does it appear as if any have gone through a recent bottleneck?
- What web dynamics exist in the park and is the web stable? Look at predation rates, primary production rates, and food chain lengths.
- Are there instances of species isolation? What kind of population dynamics exist within and between various populations?

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VII. Appendices

A. Mammals seen at FOPU[162]

Armadillo *Dasypus novemcintus*
Atlantic Bottle-nosed dolphin *Tursiops truncates*
Black rat *Rattus rattus*
Eastern gray squirrel *Sciuris carolinensis*
Hispid cotton rat *Sigmodon hispidus*
House Mouse *Mus musculus*
Humpback whale *Megaptera novaeangiae*
Marsh rabbit *Sylvilagus palustris*
Marsh rice rat *Oryzomys palustris*
Raccoon *Procyon lotor*
Virginia opossum *Didelphis virginiana*
White-tailed deer *Odocoileus viriginianus*

Bats
Big brown bat *Eptesicus fuscus*
Red bat *Lasiurus borealis*
Northern yellow bat *Lasiurus intermedius*
Seminole bat *Lasiurus seminolus*
Evening bat *Nycticeius humeralis*
Eastern pipistrelle *Pipistrellus subflavus**
Mexican free-tailed bat *Tadarida brasilensis**

*not captured, but detected acoustically.

B. Common bird species found at FOPU[163]

Wading Birds
Brown Pelican *Pelecanus occidentalis*
Double-creasted Cormorant *Phalacrocorax auritus*
Great Blue Heron *Ardea herodias*
Great Egret *Casmerodius albus*
Snowy Egret *Egretta thula*
Little Blue Heron *Egretta caerulea*
Cattle Egret *Bubulcus ibis*

[162] Rabolli and Ellington, 1999
[163] NPS (2004). Fort Pulaski National Monument. NPS website. Retrieved 2004. http://www.nps.gov/fopu/naturescience/birds.htm

Great-backed Heron *Butorides striatus*
White Ibis *Eudocimus albus*

Waterfowl
Lesser Scaup *Aythya affinis*
Hooded Merganser *Lophodytes cucullatus*
Turkey Vulture *Cathartes aura*
Osprey *Pandion haliaetus*
American Kestrel *Falco sparverius*

Rails, Gulls, Shorebirds
Northern Bobwhite *Colinus virginianus*
Clapper Rail *Rallus longirostris*
Black-bellied Plover *Pluvialis squatarola*
Semipalmated Plover *Charadrius semipalmatus*
Killdeer *Charadrius vociferus*
Willet *Catoptrophorus semipalmatus*
Red Knot *Calidris canutus*
Dunlin *Calidris alpina*
Dowitcher (mostly shortbilled)
Limnodromus griseus
Common Snipe *Gallinago galllinago*
Laughing Gull *Larus atriculla*
Ring-billed Gull *Larus delawarensis*
Herring Gull *Larus argentatus*
Royal Tern *Sterna maximus*
Common Tern *Sterna hirundo*
Forster's Tern *Sterna forsteri*

Doves, Owls, Swifts, Hummingbirds,
Kingfishers, Woodpeckers
Chimmey Swift *Chaetura pelagica*
Belted Kingfisher *Ceryle alcyon*
Red-bellied Woodpecker *Melanerpes carolinus*
Nothern Flicker *Colaptes auratus*
Common Barn Owl *Tyto alba*
Ruby-throated Hummingbird *Archilochus colubris*

Buntings, Sparrows, Blackbirds,
Nothern Cardinal *Cardinalis cardinalis*

Orioles, Finches
Painted Bunting *Passerina ciris*
Savannah Sparrow *Passerculus sandwichensis*
Swamp Sparrow *Melospiza georgiana*
Song Sparrow *Melospiza melodia*
White-throated Sparrow *Zonotrichia albicollis*
Red-winged Blackbird *Agelaius phoeniceus*
Boat-tailed Grackle *Quiscalus major*
Brown-headed Cowbird *Molothrus ater*
Orchard Oriole *Icterus spurius*

American Goldfinch *Carduelis tristis*

Starlings, Vireos, Wood Warblers
American Robin *Turdus migratorius*
Gray Catbird *Dumetella carolinensis*
Northern Mockingbird *Mimus polyglottos*
Cedar Waxwing *Bombycilla cedrorum*
European Starling *Sturnus vulgaris*
White-eyed Vireo *Vireo griseus*
Yellow-rumped Warbler *Dendroica coronata*
Pine Warbler *Dendroica pinus*
Prairie Warbler *Dendroica discolor*
American Redstart Setophaga ruticilla

C. Reptiles found in Fort Pulaski [164]

Frogs
Acris gryllus Southern cricket frog
Bufo terrestris Southern toad
Gastrophryne carolinensis Eastern narrowmouth toad
Hyla cinerea Green treefrog
Hyla squirella Squirrel treefrog
Psuedacris ocularis Little grass frog
Rana utricularia Southern leopard frog

Salamanders
Eurycea cirrigera Southern two-lined salamander

Alligators
Alligator mississippiensis Alligator

Turtles
Malaclemys terrapin Diamondback terrapin
Terrapene carolina Eastern box turtle
Trachemys scripta Yellow-bellied slider
Caretta caretta Loggerhead sea turtle

Lizards
Anolis carolinensis Green anole
Eumeces inexpectatus Southeastern five-lined skink
Ophisaurus ventralis Eastern glass lizard
Scincella lateralis Ground skink

Snakes
Agkistrodon piscivorus Cottonmouth
Coluber constrictor Black racer

[164] Tuberville et al , 2005.

Crotalus adamanteus Eastern diamondback rattlesnake
Elaphe guttata Corn snake
Elaphe obsoleta Rat snake
Lampropeltis getula Eastern kingsnake
Nerodia fasciata Banded water snake
Opheodrys aestivus Rough green snake

D. Fish species located near FOPU[165]

Alosa sapidissima American shad
Chloroscombrus chrysurus Atlantic bumper
Micropogonias undulatus Atlantic croaker
Brevoortia tyrannus Atlantic menhaden
Selene setapinnis Atlantic moonfish
Rhizoprionodon terraenovae Atlantic sharpnose shark
Opisthonema oglinum Atlantic thread herring
Anchoa mitchilli Bay anchovy
Symphurus plagiusa Blackcheek tonguefish
Pomatomus saltatrix Bluefish
Myliobatis freminvillei Bullnose ray
Peprilus triacanthus Butterfish
Hypleurochilus geminatus Crested blenny
Hypsoblennius hentzi Feather blenny
Etropus crossotus Fringed flounder
Peprilus alepidotus Harvestfish
Trinectes maculatus Hogchoker
Synodus foetens Inshore lizardfish
Caranx hippos Jack crevalle
Scomberomorus cavalla King mackerel
Elops saurus Ladyfish
Lepisosteus osseus Longnose gar
Selene vomer Lookdown
Astroscopus guttatus Northern stargazer
Ancylopsetta quadrocellata Ocellated flounder
Monacanthus hispidus Planehead filefish
Archosargus probatocephalus Sheepshead
Bairdiella chrysoura Silver perch
Cynoscion nothus Silver seatrout

[165]McFarlin and Alber, 2005. Fish identified in the Savannah River estuary in a sample taken at river mile 9 in a 2002 study. Collins et al, 2002.

E. Plants found at FOPU[166]

Scientific Name	Common Name	Family
Acacia farnesiana (L.) Willd.	huisache	Mimosaceae
Acalypha gracilens Gray	acalypha	Euphorbiaceae
Acer rubrum L.	red maple	Aceraceae
Agalinis fasiculata (Ell.) Raf.	gerardia	Scrophulariaceae
Agrostis hiemalis (Walt.) BSP	bentgrass	Poaceae
Alternanthera philoxeroides (Mart.) Griseb.	alligator-weed	Amaranthaceae
Amaranthus hybridus L.	pigweed	Amaranthaceae
Ambrosia artemisifolia L.	ragweed	Asteraceae
Ampelopsis arborea (L.) Koehne	pepper-vine	Vitaceae
Anagallis arvensis L.	scarlet pimpernel	Primulaceae
Andropogon glomeratus (Walter)BSP	broom sedge	Poaceae
Andropogon virginicus L.	broom sedge	Poaceae
Apium leptophyllum (Persoon)	marsh parsley	Apiaceae
Arenaria serpyllifolia L.	thyme-leaved sandwort	Caryopyhllaceae
Arundinaria gigantea (Walt.) Muhl.	switch cane	Poaceae
Asplenium platyneuron (L.) Oakes	ebony spleenwort	Aspleniaceae
Aster subulatus Michx. var. *ligulatus* Shinners	aster	Asteraceae
Aster tenuifolius L.	salt marsh aster	Asteraceae
Atriplex arenaria Nuttall	seabeach orach	Chenopodiaceae
Atriplex prostrata Boucher ex DC	sea beach atriplex	Chenopodiaceae
Baccharis angustifolia Michaux	false willow	Asteraceae
Baccharis halimifolia L.	groundsel tree	Asteraceae
Batis maritima L.	saltwort	Bataceae
Bidens bipinnata L.	spanish-needles	Asteraceae
Bidens pilosa L.	sheperd's-needle	Asteraceae
Boerhavia coccinea P. Miller	wineflower	Nyctaginaceae
Borrichia frutescens (L.) DC	sea ox-eye	Asteraceae
Briza minor L.	quaking grass	Poaceae

[166] Govus, 1998.

Bromus catharticus Vahl.	rescue grass	Poaceae
Bulbostylis capillaris (L.) Clarke	bulbostylis	Cyperaceae
Callicarpa americana L.	French mulberry	Verbenaceae
Calystegia sepium (L.) R.Brown	hedge bindweed	Convolvulaceae
Campsis radicans (L.) Seem. ex Bureau	trumpet creeper	Bignoniaceae
Carex albolutescens Schweinitz	greenish-white sedge	Cyperaceae
Carya illenoensis (Wang.) K. Koch	pecan	Juglandaceae
Celtis laevigata Willd.	sugarberry	Ulmaceae
Cenchrus echinatus L.	southern sandspur	Poaceae
Cenchrus longispinus (Hackel) Fernald	northern sandspur	Poaceae
Cenchrus tribuloides L.	dune sandspur	Poaceae
Centella asiatica (L.) Urban	centella	Apiaceae
Centrosema virginianum (L.) Benth.	climbing butterfly pea	Fabaceae
Cephalanthus occidentalis L.	buttonbush	Rubiaceae
Chaerophyllum tainturieri Hooker	wild chervil	Apiaceae
Chamaecrista nictitans (L.) Moench var. *aspera* (Muhl. ex Ell.) Irwin & Barneby	southern sensitive-plant	Fabaceae
Chamaesyce bombensis (Jacquin) Dugand	chamaesyce	Euphorbiaceae
Chamaesyce cordifolia (Ell.) Small	spurge	Euphorbiaceae
Chamaesyce maculata (L.) Small	chamaesyce	Euphorbiaceae
Chamaesyce polygonifolia (L.) Small	seaside spurge	Euphorbiaceae
Chasmanthium laxum (L.) Yates	slender spikegrass	Poaceae
Chenopodium album L.	lamb's-quarters	Chenopodiaceae
Chenopodium ambrosiodes L.	mexican tea	Chenopodiaceae
Cinnamomum camphora (L.) Presl.	camphor-tree	Lauraceae
Cirsium arvense (L.) Scop.	Canada thistle	Asteraceae
Cladium jamaicense Crantz	saw-grass	Cyperaceae
Clitoria mariana L.	butterfly pea	Fabaceae
Cnidoscolus stimulosus (Michaux)	spurge nettle	Euphorbiaceae

Commelina communis L.	dayflower	Commelinaceae
Conyza bonariensis (L.) Cronq.	horseweed	Asteraceae
Conyza canadensis (L.) Cronq.	horseweed	Asteraceae
Coreopsis grandifolia Hogg.	tickseed	Asteraceae
Croton glandulosus L. var. *septentrionalis* Mueller	sand croton	Euphorbiaceae
Croton punctatus Jaquin	silverleaf croton	Euphorbiaceae
Cynanchum angustifolium Persoon	sand-vine	Apocynaceae
Cynodon dactylon (L.) Persoon	bermuda grass	Poaceae
Cyperus breifoloides Thieret & Delahoussaye	cyperus	Cyperaceae
Cyperus filicinnus Vahl.	cyperus	Cyperaceae
Cyperus lancastriensis Porter	cyperus	Cyperaceae
Cyperus ovularis (Michaux) Torrey	cyperus	Cyperaceae
Cyperus polystachys Rottb. var. *texensis* (Torrey) Fernald	cyperus	Cyperaceae
Cyperus retrorsus Chapman	cyperus	Cyperaceae
Cyperus rotundus L.	cyperus	Cyperaceae
Cyperus virens Michx.	cyperus	Cyperaceae
Digitaria sanguinalis (L.) Scopoli	crab grass	Poaceae
Diodia teres Walter	rough buttonweed	Rubiaceae
Diodia virginiana L.	button-weed	Rubiaceae
Diospyros virginiana L.	persimmon	Ebenaceae
Distichlis spicata (L.) Greene	salt grass	Poaceae
Echinocloa crusgali (L.) Beauvois	barnyard grass	Poaceae
Eclipta alba (L.) Hasskarl	eclipta	Asteraceae
Eleusine indica (L.) Gaertner	goose grass	Poaceae
Eragrostis elliottii Watson	love grass	Poaceae
Erechtites hieracifolia (L.) Raf.	fireweed	Asteraceae
Erigeron quercifolius Lam.	flea-bane	Asteraceae

Erigeron strigosus Muhl. Ex Willd.	daisy fleabane	Asteraceae
Eupatorium capillifolium (Lam.) Small	dog-fennel	Asteraceae
Eupatorium compositifolium Walt.	dog-fennel	Asteraceae
Eupatorium fistulosum Barratt.	joe-pye weed	Asteraceae
Eupatorium serotinum Michaux	thoroughwort	Asteraceae
Euphorbia curtisii? Engelm.	euphorbia	Euphorbiaceae
Eustachys petraea (Sw.) Desv.	finger grass	Poaceae
Euthamia tenuifolia (Pursh) Greene	goldenrod	Asteraceae
Ficus carica L.	fig	Moraceae
Fimbristylis castanea (Michaux.) Vahl.	fimbristylis	Cyperaceae
Fimbristylis puberula (Michx.) Vahl.	fimbristylis	Cyperaceae
Forestiera segregata	Florida privet	Oleaceae
Fumaria officinalis L.	fumatory	Fumariaceae
Gaillardia pulchella Foug.	Indian blanket	Asteraceae
Galactia elliotii Nuttall	galactia	Fabaceae
Galactia regularis (L.) BSP.	milk-pea	Fabaceae
Galactia volubilis (L.) Britton	milk pea	Fabaceae
Galium hispidulum Michaux	bedstraw	Rubiaceae
Galium parisiense L.	wall bedstraw	Rubiaceae
Gaura angustifolia Michaux	gaura	Onagraceae
Gleditsia triacanthos L.	honey locust	Caesalpiniaceae
Glottidium vesicarium (Jacquin) Mohr.	bladder-pod	Fabaceae
Gnaphalium obtusifolium L.	rabbit tobacco	Asteraceae
Gnaphalium purpureum L.	purple cudweed	Asteraceae
Helenium amarum (Raf.) H. Rock	bitterweed	Asteraceace
Heliotropium curassavicum L.	seaside heliotrope	Boraginaceae
Heterotheca subaxillaris (Lam.) Britton & Rusby	camphorweed	Asteraceae
Hordeum pusillum Nuttall	barley	Poaceae
Hydrocotyle bonariensis Lam.	pennywort	Apiaceae

Hydrocotyle umbellata L.	water pennywort	Apiaceae
Hypericum gentianoides (L.) BSP.	pineweed	Hypericaceae
Hypericum hypericoides (L). Crantz	St. Andrew's Cross	Clusiaceae
Hypochoeris brasiliensis (Less.) Hook. & Arn.	cat's ear	Asteraceae
Hypochoeris glabra L.	cat's ear	Asteraceae
Hypochoeris microcephala (Schultz-Bip.) Cabrera var. *albiflora* (Kuntze) Cabrera	cat's ear	Asteraceae
Ilex vomitoria Aiton	yaupon	Aquifoliaceae
Ipomea hederacea (L.) Jacquin	morning glory	Convolvulaceae
Ipomea pandurata (L.) Mey.	manroot	Convolvulaceae
Ipomea sagittata Cav.	morning glory	Convolvulaceae
Iva frutescens L.	marsh elder	Asteraceae
Juncus coriaceus Mackenzie	rush	Juncaceae
Juncus dichotomus Ell.	rush	Juncaceae
Juncus diffusissimus Buckley	diffuse rush	Juncaceae
Juncus effusus L.	common rush	Juncaceae
Juncus marginatus Rostk.	rush	Juncaeae
Juncus roemarianus Scheele	black needle-rush	Juncaceae
Juncus tenuis Willd.	path rush	Juncaceae
Juniperus virginiana L. var. *silicicola* (Small) J. Silba	coastal red-cedar	Cupressaceae
Krigia oppositifolia Raf.	dandelion	Asteraceae
Krigia virginica (L.)	dandelion	Asteraceae
Lactuca floridana? (L.) Gaertner	wild lettuce	Asteraceae
Lactuca graminifolia Michx.	wild lettuce	Asteraceae
Lagerstromia indica L.	crape myrtle	Lythraceaeae
Lantana camara L.	lantana	Verbenaceae
Lepidium virginicum L.	poor-man's pepper	Brassicaceae
Lespedeza cuneata (Dumont) G. Don	sericea	Fabaceae

Ligustrum japonicum Thunberg	Japanese privet	Oleaceae
Ligustrum sinense Lour	Chinese privet	Oleaceae
Limonium carolinianum (Walter)	sea lavender	Plumbaceae
Liquidambar styraciflua L.	sweet-gum	Hamamelidaceae
Lonicera japonica Thunberg	Japanese honeysuckle	Caprifoliaceae
Medicago polymorpha L.	bur clover	Fabaceae
Melia azedarach L.	China-berry	Meliaceae
Melilotus alba Desr.	white sweet clover	Fabaceae
Melilotus indica (L.) All.	sour clover	Fabaceae
Melilotus officinalis (L.) Lam.	yellow sweet clover	Fabaceae
Melothria pendula L.	creeping cucumber	Cucurbitaceae
Mikania scandens (L.) Willd.	climbing hempweed	Asteraceae
Mirabilis jalapa L.	four-o'clock	Nyctaginaceae
Modiola caroliniana (L.) G. Don	modiola	Malvaceae
Morus alba L.	white mulberry	Moraceae
Muhlenbergia filipes M.A. Curtis	muhlenbergia	Poaceae
Myrica cerifera L.	wax myrtle	Myricacea
Nerium oleander L.	oleander	Apocynaceae
Nuttallanthus canadensis (L.) D.A. Sutton	Canada toadflax	Scrophulariaceae
Oenothera humifusa Nuttall	dunes evening primrose	Onagraceae
Oenothera laciniata Hill.	evening primrose	Onagraceae
Oenothera speciosa Nuttall	primrose	Onagraceae
Oplismenus hirtellus (L.) Beauv.	woods-grass	Poaceae
Opuntia humifusa (Raf.) Raf.	prickly pear	Cataceae
Opuntia pusila (Haw.) Haw.	devil's joint	Cactaceae
Oxalis stricta L.	wood sorrel	Oxalidaceae
Panicum amarum Ell.	seaside panicum	Poaceae
Parthenocissus quinquefolia (L.) Planchorn	Virginia creeper	Vitaceae
Paspalum dilatatum Poiret	Dallis grass	Poaceae

Paspalum distichum L.	paspalum	Poaceae
Paspalum notatum Flugge	Bahia grass	Poaceae
Paspalum urvillei Steudle	paspalum	Poaceae
Paspalum vaginatum Swartz.	seashore paspalum	Poaceae
Passiflora incarnata L.	maypops	Passifloraceae
Persea borbonia (L.) Sprengle	red bay	Lauraceae
Phalaris caroliniana Walter	canary grass	Poaceae
Phyla nodiflora (L.) Greene	frog's- bit	Verbenaceae
Phyllanthus sp.	phyllanthus	Euphoriaceae
Physalis walteri Nuttall.	dune ground cherry	Solanaceae
Phytolacca americana L.	pokeweed	Phytolaccaceae
Phytolacca rigida Small	maritime pokeweed	Phytolaccaceae
Pinus elliottii Engelm.	slash pine	Pinaceae
Platanus occidentalis L.	sycamore	Platanaceae
Pluchea rosea Godfrey	marsh-fleabane	Asteraceae
Polycarpon tetraphyllum (L.) L.	four-leaved allseed	Caryophyllaceae
Polygonatum punctatum Ell.	smartweed	Polygonaceae
Polygonum setaceum Baldwin ex Ell.	smartweed	Polygonaceae
Polypogon maritimus Willdenow	Meditteranean beardgrass	Poaceae
Polypogon monspielensis (L.) Desf.	rabbitfoot grass	Poaceae
Polypremum procumbens L.	polypremum	Loganiaceae
Portulaca oleracea L.	purslane	Portulacaceae
Portulaca pilosa L.	portulaca	Portulacaeae
Prunus angustifolia Marsh.	chickasaw plum	Rosaceae
Prunus caroliniana Aiton	Carolina laurel cherry	Rosaceae
Prunus serotina Ehrhart	black cherry	Rosaceae
Pteridium aquilinum (L.) Kuhn.	bracken fern	Dennstaediaceae
Pteris vittata L.	Chinese brake fern	Pteridaceae
Pyracantha coccinea MJ Roemer	pyracantha	Rosaceae

Pyrrhopappus carolinianus (Walter) DC.	false-dandelion	Asteraceae
Quercus hemisphaerica Bartram	laurel oak	Fagaceae
Quercus virginiana Miller	live oak	Fagaceae
Ranunculus pusillus Poiret	buttercup	Ranunculaceae
Ranunculus sardous Crantz.	buttercup	Ranunculaceae
Raphanus raphanistrum L.	wild radish	Brassicaceae
Rhus copallina L.	winged sumac	Anacardaceae
Rhynchosia tomentosa (L.) H.&A.	rhynchosia	Fabaceae
Richardia brasiliensis (Moq.) Gomez	richardia	Rubiaceae
Rubus argutus L.	blackberry	Rosaceae
Rubus hispidus L.	dewberry	Rosaceae
Rubus trivialis Michaux	dewberry	Rosaceae
Rumex hastatulus Baldwin ex. Ell.	wild sorrel	Polygonaceae
Rumex verticillatus L.	swamp dock	Polygonaceae
Sabal palmetto Lodd. Ex Schultes	cabbage palm	Arecaceae
Sabatia brachiata Ell.	sabatia	Gentianaceae
Sabatia stellaris Pursh	sabatia	Gentianaceae
Salicornia bigelovii Torrey	glasswort	Chenopodiaceae
Salix caroliniana Michaux	swamp willow	Salicaceae
Salix nigra Marshall	black willow	Salicaceae
Salsola kali L.	Russian-thistle	Chenopodiaceae
Salv*ia lyrata* L.	lyre-leaved sage	Lamiaceae
Sambucus canadensis L.	elderberry	Caprifoliaceae
Sanicula canadensis L.	snakeroot	Apiaceae
Sapium sebiferum (L.) Roxb.	Chinese tallow-tree	Euphorbiaceae
Sarcocornia perennis (Mill.) A.J. Scott	perennial glasswort	Chenopodiaceae
Sassafras albidum (Nutt.) Nees	sassafras	Lauraceae
Scirpus robustus Pursh	saltmarsh bulrush	Cyperaceae
Scleranthus annuus L.	scleranthus	Caryophyllaceae

Scleria triglomerata Michaux	nut-sedge	Cyperaceae
Senna obtusifolia (L.) Irwin & Barneby	coffeeweed	Caesalpinaceae
Sesbania exaltata (Raf.) Rydberg ex A.W. Hill	sesbania	Fabaceae
Sesuvium maritimum (Walt.) B.S.P.	sea purslane	Aizoaceae
Sesuvium portulacastrum L.	sea purslane	Aizoaceae
Setaria geniculata (Lam.)Beauvois	bent foxtail grass	Poaceae
Setaria magna Griesbach	giant foxtail grass	Poaceae
Sida acuta Burman f.	broomweed	Malvaceae
Sida rhombifolia L.	sida	Malvaceae
Sida spinosa L.	prickly mallow	Malvaceae
Sideroxylon tenax L.	tough buckthorn	Sapotaceae
Sisyrinchium exile Bickn.	annual blue-eyed-grass	Iridaceae
Sisyrinchium rosulatum Bick.	blue-eyed grass	Iridaceae
Smilax auriculata Walter	greenbrier	Smilacaceae
Smilax bona-nox L.	greenbrier	Smilacaceae
Solanum carolinense L.	horse-nettle	Solanaceae
Solanum pseudogracile Heisse	black nightshade	Solanaceae
Solanum sisymbriifolium Lam.?	buffalo bur	Soalanceae
Solidago canadensis L.	goldenrod	Asteraceae
Solidago sempervirens L.	seaside goldenrod	Asteraceae
Sorghum halepense (L.) Persoon	Johnson grass	Poaceae
Spartina alterniflora Loisel	smooth cordgrass	Poaceae
Spartina cynosuroides (L.) Roth	big cordgrass	Poaceae
Spartina patens (Aiton) Muhl.	salt meadow cordgrass	Poaceae
Spenopholis obtusata (Michx.) Scribn.	prairie wedge-grass	Poaceae
Spergularia salina J.&K. Presl	sand spurrey	Caryophyllaceae
Spermolepis echinata (Nuttall ex DC)	hooked spermolepis	Apiaceae
Spiranthes praecox (Walt.) Watson	grass leaved ladies' tresses	Orchidaceae
Sporobolus indicus (L.) R. Br.	smut grass	Poaceae

Sporobolus virginicus (L.) Kunth	coastal dropseed	Poaceae
Stachys floridana Shuttlew.	Florida hedge nettle	Lamiaceae
Stellaria media (L.) Cyrillo	chickweed	Caryophyllaceae
Stenotaphrum secundatum (Walt.) Kuntze	Saint Augustine grass	Poaceae
Strophostyles helvola (L.) Ell.	wild bean	Fabaceae
Suaeda linearis (Ell.) Moq.	suaeda	Chenopodiaceae
Tamarix gallica L.	tamarisk	Tamaricaceae
Taraxacum officinale Wiggers	dandelion	Asteraceae
Teucrium canadense L.	wood-sage	Lamiaceae
Tillandsia usneoides L.	Spanish moss	Bromeliaceae
Tribulus terrestris L.	puncture-weed	Zygophyllaceae
Trichostema dichotomum L.	blue-curls	Lamiaceae
Trifolium arvense L.	rabbit foot clover	Fabaceae
Trifolium dubium Sibthorp	low hop clover	Fabaceae
Triodanis perfoliata(L.) Nieuw.	Venus' looking glass	Campanulaceae
Triplasis *purpurea* (Walter) Chapman	sand grass	Poaceae
Typha angustifolia L.	narrow-leaved cattail	Typhaceae
Ulmus americana L.	American elm	Ulmaceae
Uniola paniculata L.	sea oats	Poaceae
Verbena bonariensis L.	verbena	Verbenaceae
Verbena brasiliensis Vellozo	verbena	Verbenaceae
Verbena hastata L.	verbena	Verbenaceae
Verbena tenuisecta Briquet	verbena	Verbenaceae
Veronica arvensis L.	speedwell	Scrophulariaceae
Vicia grandiflora Scopoli	large-flowered vetch	Fabaceae
Vicia sativa L. ssp. nigra (L.) Ehrhart.	narrow-leaved vetch	Fabaceae
Vicia tetrasperma (L.) Moench	vetch	Fabaceae
Vicia villosa Roth	winter vetch	Fabaceae
Vinca minor L.	periwinkle	Apocynaceae
Vitis aestivalis Michaux	summer grape	Vitaceae
Vitis rotundifolia Michx.	muscadine	Vitaceae
Vulpia sciurea (Nutt.) Henr.	squirreltail fescue	Poaceae
Wahlenbergia marginata (Thunberg) DC.	wahlenbergia	Campanulaceae
Youngia japonica (L.) DC.	hawk's beard	Asteraceaee
Yucca aloifolia L.	Spanish bayonet	Agavaceae
Yucca filamentosa L.	bear-grass	Agavaceae
Zanthoxylum clava-herculis L.	toothache tree	Rutaceae
Zephyranthes candida (Lindley) Herbert	zephranthes	Liliaceae

F. Protected species found in or near FOPU[167]

Grey shading denoted those species seen in FOPU[168]

Terrestrial Animals

Birds:

American Oystercatcher *Haematopus palliatus*
Bachman's warbler *Vermivora bachmanii*
Bald eagle *Haliaeetus leucocephalus*
Gull-billed tern *Sterna nilotica*
Least Tern *Sterna antillarum*
Peregrine Falcon *Falco peregrinus*
Piping plover *Charadrius melodus*
Red-cockaded woodpecker *Picoides borealis*
Swallow-tailed Kite *Elanoides forficatus*
Wilson's Plover *Charadrius wilsonia*
Wood stork *Mycteria Americana*

Reptiles:

Eastern indigo snake *Drymarchon couperi*
Gopher tortoise *Gopherus polyphemus*
Spotted Turtle *Clemmys guttata*

Amphibians:

Flatwoods salamander *Ambystoma cingulatum*
Dwarf Siren *Pseudobranchus striatus*

Mammals:

Rafinesque's Big-Eared Bat *Corynorhinus rafinesquii*

Plants:

Chaffseed *Schwalbea Americana*
Dwarf witch-alder *Fothergilla gardenii*
Narrowleaf obedient plant *Physostegia leptophylla*
Pondberry *Lindera melissifolia*
Pondspice *Litsea aestivalis*
Tidal Marsh obedient plant *Physostegia leptophylla*

Aquatic Animals

Mammals:

Humpback whale *Megaptera novaeangliae*
Right (Northern) whale *Eubalaena glacialis*
West Indian manatee *Trichechus manatus*

Fish:

Shortnose sturgeon *Acipenser brevirostrum*

Reptiles:

Green sea turtle *Chelonia mydas*
Hawksbill sea turtle *Eretmochelys imbricata*
Kemp's ridley sea turtle *Lepidochelys kempi*
Leatherback sea turtle *Dermochelys coriacea*
Loggerhead sea turtle *Caretta caretta*

[167] McFarlin and Alber, 2005
[168] Rabolli and Ellington, 1999

G. Natural Resource Rating Worksheets*

***IND – Insufficient data. NA – Not Applicable**

Fort Pulaski National Monument - FOPU

Ratings Category I. ECOSYSTEM EXTENT and FUNCTION (EEF)
Park Unit and Ecoregion Characterization:
Community Descriptors:
Indicator or Representative Species:

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IA. Cover and Habitat Characterization			
IA1. Habitat loss or degradation	Loss of marsh on Cockspur. Highway 80 expansion project. Pristine marsh land some of the only in the area.	2	Tucker, 1986. FOPU Resource Management Plan, 1990. McFarlin and Alber, 2005.
IA2. Intra-patch integrity		IND	
IA3. Cover loss or bare soil increase	None reported.	3	Southeastern Wildlife Services, 1981. Govus, 1998
IA4. Cover density/homogeneity	Appropriate cover in the given types of communities present (lack of live oak in maritime forest?)	3	Govus, 1998
IA5.Canopy and understory architecture change	Quick succession on Cockspur, result of dredge spoil. Chinese tallow (invasive) now dominant in some patches.	2	Tucker, 1986. Govus, 1998.
IA6. Substrate quality/quantity	Dredge spoil provided substrate for uplands to grown on. Poor quality and not a natural source.	2	Govus, 1998.
IA7.			
IB. Fragmentation			
IB1. Patch connectivity	Mowing, roads and dike system fragment upland areas of park	2	Southeastern Wildlife Services, 1981.
IB2. Species Isolation	None reported.	3	Govus, 1998. Rabolli and Ellington, 1999.
IB3. Dispersal barriers	Channels in dike system allow fish dispersal	3	Rabolli and Ellington, 1999.

IB4. Habitat loss	Loss of marsh on Cockspur.	2	Govus, 1998. FOPU Resource Management Plan, 1990.
IB5. Recolonization barriers		NA	
IB6.			
IC. Community Structure & Function			
IC1. Complexity and niche diversity	Development of numerous types of upland community from deposited dredge spoil. Need more live oak for true upland. High marshbird diversity.	3	Govus, 1998.
IC2. Degradation of structure	Repeated deposition of dredge spoil until recently. Erosion concerns from shipping and port expansion project. Likely conversion of freshwater marsh to saltwater marsh as a result of dredging. Vegetation clearing until 1920s.	1	Govus, 1998. Meader, 2003. GPA EIS, 1998. McFarlin and Alber, 2005.
IC3. Patch size/shape changes	Addition of dredge spoil from Savannah River. Shifting shorelines on Cockspur. Coast Guard and Savannah Bar Pilots occupy and affect some of the upland habitat.	1	Govus, 1998. Howell, 2005.
IC4. Intra-patch microclimate alteration		IND	
IC5. Inter-patch isolation and edge microclimate		IND	
IC6. Generalist species domination of patches	Chinese tallow competes well on numerous soil types and is invasive. Problem not widespread.	2	Govus, 1998.
IC7. Age class distribution	Deer population age and sex distribution is not ideal.	2	Rabolli and Ellington, 1999.
IC8. Primary production	Should not be a problem for the salt marshes present in the park.	3	Silliman and Bertness, 2002. Rabolli and Ellington 1999.
IC9. Decomposition/Cycling		IND	
IC10. Substrate/hydrologic change	Local aquifer lowered by nearby industry. Upstream dams mute flow variation and may have caused decreased flow. Dike system on Cockspur effects tidal flow.	2	FOPU Resource Management Plan, 1990. SECN Phase III Vital Signs Monitoring DRAFT, 2006.
IC11.			
ID. Disturbance Regimes			
ID1. Natural disturbance recovery	Fish populations in canals react well to varying tidal and drought conditions.	3	Southeastern Wildlife Services, 1981.
ID2. Perturbation resistance	Wetlands may be imperiled by rising sea level.	2	Nicholls et al, 1999.
ID3. Adjacent lands development effects	Land development could affect viewshed. Expansion of City of Savannah is a major threat to increased pollution from runoff in addition to upstream agriculture and industry.	1	FOPU Land Protection Plan, 1995. SECN Phase III Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
ID4. Fire	Need to develop fire management plan. Suppression is current practice.	2	Pers. Comm., Park Staff.

ID5. Flood	Occasional flooding of canal system by tidal surges (spring and storm) is essential for pulse stabilized system. Very infrequent flooding from hurricanes.	3	Southeastern Wildlife Services, 1981. Rothschild, Brent Pers. Comm., 2006.
ID6. Drought	Occasional drought may increase chances of communicable disease spreading amongst the mammal population. Fish populations in canals react well to varying tidal and drought conditions.	2	Southeastern Wildlife Services, 1981.
ID7. Grazing/Fencing	Deer grazing does not seem to be a problem, but could become one in the future. Continued monitoring and yearly counts being performed.	3	Pers. Comm., Park Stall. Rabolli and Ellington, 1999.
ID8. Climate change	Wetlands may be imperiled by rising sea level.	2	Nicholls et al, 1999.
ID9. Visitor impact	Minimal, limited to a few small trails near the bridge.	3	Pers. Comm., Park Staff

Ratings Category II. SPECIES COMPOSITION & CONDITION (SCC)
Park Unit and Ecoregion Characterization:
Community Descriptors:
Indicator or Representative Species:

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IIA. Total Species			
IIA1. Diversity (age, size class, distribution)	Plant and animal Diversity increased by newer upland habitats, still relatively low due to early age of said habitats. Herpetofaunal diversity unremarked upon in recent study. High bird diversity in wetlands	3	Govus, 1998. Rabolli and Ellington, 1999. Tuberville et al, 2005.
IIA2. Invasive/exotic species	Several exotic plants present and being monitored/controlled.	2	Govus, 1998
IIA3. Non-native species	Numerous plant species noted. Trade in the port of Savannah gives ample opportunity for introduction. Birds: Starling.	2	Govus, 1998. Rabolli and Ellington, 1999.
IIA4. Genetic variability		IND	
IIA5.			
IIB. Native Species			
IIB1. Composition change	Some composition change due to succession and possible lack of sightings during surveys.	3	Govus, 1998.
IIB2. Disease and parasites	Potential for rabies, Hantavirus and chythrid (sp?) fungus.	2	Rabolli and Ellington, 1999. Joe DeVivo, Pers. Comm.
IIB3. Threatened and endangered species	No T&E plants, several species of concern. Several state listed birds. Federally listed Sea turtles sometimes seen, but do not nest. Several other federally listed species occasionally utilize parks.	3	Govus, 1998. Rabolli and Ellington, 1999. Park Staff, Pers. Comm. McFarlin and Alber, 2005.
IIB4. Extirpation	*Mercenaria mercenaria* in Oyster Creek was "reintroduced" because it was at low levels for recreational fishing. Some plant species seen before not identified in most recent survey.	3	Baker, 1988. Govus, 1998

IIB5. Population change	Increase in deer population, no impacts noticed.	3	Rabolli and Ellington, 1999.
IIB6. Dominant species density-dependence		IND	
IIB7. Reintroduction	*Mercenaria mercenaria* in successfully reintroduced Oyster Creek.	3	Baker, 1988
IIB8. Keystone species		IND	
IIB9.			
IIC. Trophic & Biotic Interactions			
IIC1. Web dynamics -species loss		IND	
IIC2. Predation rates		IND	
IIC3. Grazer effects	Deer do not seem to be a problem as of yet.	3	Pers. Comm. Park Staff. Rabolli and Ellington, 1999.
IIC4. Food chain length		IND	
IIC5. Competitor change	Non-native European Starlings competing for habitat with native birds.	2	Rabolli and Ellington, 1999.
IIC5. Predatory-prey disruption		IND	
IIC6. Dominance alteration	Concern Chinese tallow may take over some communities if left unchecked.	2	Govus, 1998
IIC7. Species hybridization		IND	
IIC8. Allelopathy		IND	

Ratings Category III. BIOTIC IMPACTS AND STRESSORS (BIS)
Park Unit and Ecoregion Characterization:
Community Descriptors:
Indicator or Representative Species:

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IIIA. Animals			
IIIA1. Acoustics	No acoustic effects on animals	3	Pers Comm., Park Staff
IIIA2. Climate	Wetland loss could eliminate habitat for birds and nursery grounds for fish.	2	Nicholls et al, 1999. Mitsch and Gosselink, 2000.
IIIA3. Disease	Known occurrence of Hantavirus at the park. Further studies on that and on chytrid fungus to be performed. Several species on park land known to be disease carriers.	2	Rabalais and Ellington, 1999. Joe DeVivo, Pers. Comm.
IIIA4. Environmental Quality	Oyster Creek only place in Chatham County open to recreational shellfishing. Some PAHs and alkylphenols found in oyster tissue. Other contaminants found in oyster, shrimp and fish tissues. Bioaccumulation.	2	Baker, 1998. Richardson and Sajwan, 2001. McFarlin and Alber, 2005. Rabalais and Ellington, 1999. Loganathan et al, 2001.
IIIA5. Exotics Competition	Starlings may compete for native bird habitat.	2	Rabalais and Ellington, 1999
IIIA6. Food Source	Mowed lawn around the fort provides habitat for deer.	2	Rabalais and Ellington, 1999.
IIIA7. Isolation/Insulation		IND	
IIIA8. Land Use History	Loss of some marsh birds on Cockspur.	2	Tucker, 1986
IIIA9. Natural Disaster	Shoreline erosion exacerbated by hurricanes and nor'easters have lead to habitat loss	2	Hassell, 2005.
IIIA10. Poaching	Some poaching of shellfish and fish in the creeks for commercial purposes. Park seeking to acquire Law Enforcement Ranger to assist monitoring.	2	Pers. Comm., Park Staff
IIIA11. Population Dynamics	Visible browse line and doe/fawn ratio indicate deer may be reaching carrying capacity.	3	Rabalais and Ellington, 1999.
IIIA12. Visitor Impact	Legal recreational fishing in the creeks. Does not seem to be a problem, but has potential.	3	Pers. Comm., Park Staff. McFarlin and Alber, 2005.
IIIA14.			
IIIA15. Other (Specify)			
IIIB. Plants			
IIIB1. Climate	Wetlands may be imperiled by rising sea level.	2	Nicholls et al, 1999.
IIIB2. Disease	None reported	3	Pers . Comm., Park Staff
IIIB3. Environmental Quality		IND	
IIIB4. Exotics Competition	Some potential competition, exotics difficult to eradicate. Chinese tallow, Chinaberry, Chinese Privet.	2	Gavur, 1998. Pers. Comm., Park Staff.
IIIB5. Land Use History	Historical clearing of vegetation kept much upland habitat in early successional stages. Loss of marsh on Cockspur.	1	Gavur, 1998. FOPU RMP, 1990. McFarlin and Alber, 2005.
IIIB6. Management	Prepared clearing of some vegetation on Cockspur to improve historic viewshed.	2	Pers. Comm.,., Park Staff
IIIB7. Natural Disaster	Shoreline erosion exacerbated by hurricanes and nor'easters have lead to habitat loss	2	Hassell, 2005.
IIIB8. Nutrient Supply		IND	
IIIB9. Poaching	None Noticed.	3	Pers. Comm., Park Staff
IIIB10. Population Dynamics		IND	
IIIB11. Substrate Loss	Substrate increased by dredge spoil on Cockspur	3	Gavur, 1998. Meader, 2003
IIIB12. Visitor Impact	Small paths near bridge to get to fishing piers.	3	Pers. Comm., Park Staff
IIIB14. Other (Specify)			

Ratings Category IV. ENVIRONMENTAL QUALITY FACTORS (EQF)
Park Unit and Ecoregion Characterization:
Community Descriptors:
Indicator or Representative Species:

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IVA. Air			
IVA1. Acid Deparition (Acid Rain)	Water quality does not indicate possible aerial deparition of acids.	3	SECN Phase III Monitoring Draft, 2005
IVA2. Cl-oxides, Cl-nitrate		IND	
IVA3. HFC's, FHC's, HC's		IND	
IVA4. Nitrogen Oxides		IND	
IVA6. Particulates	Long term data from IMPROVE sites note some particulate matter in s	3	SECN Phase III Draft, 2005
IVA7. Ozone	Not currently a problem for plants, but passes standards occasionally.	3	SECN Phase III Vital Signs Monitoring DRAFT, 2006.
IVA8. VOC's	Definite output of VOCs near FOPU, but not identified as a problem.	3	McFarlin and Alber, 2005.
IVA9. Visibility	No long term visibility data available from IMPROVE.	IND	SECN Phase III Draft, 2005
IVA10. Hg		IND	
IVA11. Arsenic	Elevated levels of arsenic detected.	2	McFarlin and Alber, 2005.

IWB. Waters			
IWB1. Acid Deparition	Water quality does not indicate possible aerial deparition of acids.	3	SECN Phase III Draft, 2005
IWB2. Algae	Occasional blooms in moat.	2	Meader, 2003. McFarlin and Alber, 2005.
IWB3. Alkalinity	Normal for Georgia salt marshes.	3	Richardson and Sajwan, 2002.
IWB4. Benthic Index		IND	
IWB5. Chlorophyll a	Not noted as a problem	3	McFarlin and Alber, 2005. SECN Phase III Vital Signs Monitoring DRAFT, 2006.
IWB6. Diatoms		IND	
IWB7. Discharge/Drainage	Moat flushed occasionally to combat algal blooms. Dike system has al	2	FOPU Resource Management Plan, 1990.
IWB8. Dissolved Gases	DO has a potential red flag. Likely due to industrial discharge.	2	SECN Phase III Vital Signs Monitoring DRAFT, 2006. GPA EIS, 1998. McFarlin and Alber, 2005.
IWB9. Diversion	Dike and canal system present on the island alters natural flow. Upstr	2	SECN Phase III Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
IWB10. Draudown		IND	
IWB11. Flow	No problems noted.	3	SECN Phase III Vital Signs Monitoring DRAFT, 2006.
IWB12. Metals	Elevated levels of heavy metals found.	2	SECN Phase III Vital Signs Monitoring DRAFT, 2006.
IWB13. Nutrients	Numerous ratings of fair to poor in and around the park.	3	SECN Phase II Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
IWB14. Organic Matter	Numerous sources of output from industrial concerns and storm water.	2	McFarlin and Alber, 2005.
IWB15. Organic Water	Occasional sewage spills in nearby communities. Occasional measurements of fecal coliform below standards.	2	SECN Phase III Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
IWB16. pH	Normal for Georgia salt marshes.	3	Richardson and Sajwan, 2002.
IWB17. Plankton		IND	
IWB18. Recharge	Some concern over recharge of Floridian Aquifer due to use by industrial concerns. Increase in population in area may exacerbate problem.	2	FOPU Resource Management Plan, 1990. SECN Phase III Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
IWB19. Salinity	Normal for Georgia salt marshes. Concern over saltwater intrusion and salinity shifts with harbor expansion project and from industrial concerns.	2	Richardson and Sajwan, 2002. SECN Phase III Vital Signs Monitoring DRAFT, 2006. McFarlin and Alber, 2005.
IWB20. Sedimentation	High sediment load in Savannah River requires constant dredging.	2	McFarlin and Alber, 2005.
IWB21. Submerged Macrophytes		IND	
IWB22. Temperature	Normal for Georgia salt marshes.	3	Richardson and Sajwan, 2002.
IWB23. Turbidity	Normal for Georgia salt marshes.	3	Richardson and Sajwan, 2002.
IWB24. Xenobiotics	Green mussels found in Savannah River, but there is doubt as to whether they can survive winter. Ballast provides numerous opportunities for xenobiots.	3	McFarlin and Alber, 2005.
IWB25. Climate	Sea level rise could disrupt ecological services	2	McFarlin and Alber, 2005.
IWB26.			

Ratings Element	Specific Concern (s)/Events/Notes	Level	Reference
IVC. Soils			
IVC1. Acidity, Alkalinity, pH	Not noted as a problem.	3	Richardson and Sajwan, 2002.
IVC2. Compaction		IND	
IVC3. Erosion	Concern for erosion of spoil on North Channel of Cockspur.	2	FOPU Resource Management Plan, 1990. Hassell, 2005. GPA EIS, 1998.
IVC4. Infiltration/Permeability		IND	
IVC5. Metals	Relatively low levels compared to industrialized areas.	3	Richardson and Sajwan, 2002.
IVC6. Nutrients		IND	
IVC7. Organic Matter	Not noted as a problem in areas surrounding park.	3	McFarlin and Alber, 2005.
IVC8. Organic Waste	Potential for organic waste from upstream and nearby islands.	2	McFarlin and Alber, 2005.
IVC9. Salinity & Sodicity		IND	
IVC10. Soil Fauna & Macroflora		IND	
IVC11. Climate	Increase in hurricanes could exacerbate shoreline erosion.	2	Hassell, 2005. Lubick, 2005.
IVC12. Soil Microbiota		IND	
IVC13. Xenobiotics		IND	
IVC14. Contaminants	Elevated levels of arsenic, PAHs and DDT. Increased levels of radionuclides upstream.	2	Richardson and Sajwan, 2002. Loganathan et al, 2001. McFarlin and Alber, 2005.

Ratings Category	RATING	BASIS
ECOSYSTEM MEASURES (ESM)	**79.2793**	**72.54902**
I. Ecosystem Extent and Function (EEF)	76	83.33333333
IA. Cover and Habitat Characterization	80	83.33333333
IB. Fragmentation	83.3333333	100
IC. Community Structure and Function	66.6666667	70
ID. Disturbance Regimes	77.7777778	90
II. Species Composition and Condition (SCC)	86.1111111	57.14285714
IIA. Total Species	77.7777778	75
IIB. Native Species	94.4444444	75
IIC. Trophic and Biotic Interactions	77.7777778	33.33333333
ENVIRONMENTAL & BIOTIC MEASURES (EBM)	**80.7692**	**70.27027**
III. Biotic Impacts and Stressors (BIS)	76.6666667	80
IIIA. Animals	75.7575758	84.61538462
IIIB. Plants	77.7777778	75
IV. Environmental Quality Factors (EQF)	83.3333333	65.30612245
IVA. Air	93.3333333	50
IVB. Waters	81.6666667	80
IVC. Soils	80.952381	50
OVERALL	**80.1**	**71.2**