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Natural Resource Stewardship and Science

Natural Resource Conditions at Fort Pulaski National Monument

Findings and Management Considerations for Selected Resources

Natural Resource Report NPS/FOPU/NRR—2023/2555

ON THIS PAGE
Cocksure Island vegetation with wading shorebirds.
NPS / CANDICE SMITH

ON THE COVER
Photos are listed clockwise from upper left. The Savannah River along the north shore of Cockspur Island during high tide. Container ship in the Savannah River. McQueens Island salt marsh and oyster bed. King tide flooding on November 23, 2018, at Fort Pulaski National Monument's entrance station. Monarch butterfly on yellow coneflower. Cockspur Island landscape as viewed from the fort.
Image Credits: NPS / CANDICE SMITH except for the monarch butterfly, which was taken by © PATRICIA VALENTINE-DARBY and the McQueens Island salt marsh and oyster bed was taken by NPS.

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Natural Resource Report NPS/FOPU/NRR—2023/2555

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Executive Summary

The National Park Service (NPS) Water Resources Division's Natural Resource Condition Assessment (NRCA) Program initiated an NRCA project with Fort Pulaski National Monument (FOPU) in 2022. The purpose of an NRCA is to synthesize information related to the primary drivers and stressors affecting natural resource conditions at a park and to report conditions for natural resource topics selected by park managers. Resource conditions are evaluated as either a condition assessment or a gap analysis, depending on data availability. For FOPU's NRCA, managers selected salt marsh, shorebirds, Eastern oyster (*Crassostrea virginica*), and butterflies as the focal resources.

FOPU is comprised of two islands in coastal Georgia, McQueens and Cockspur, which are separated by the Savannah River near its confluence with the Atlantic Ocean. Cockspur Island contains the 19th century masonry fort, Fort Pulaski, and the monument's visitor services and facilities and is primarily constructed with dredge material from the Savannah River. McQueens Island is almost entirely salt marsh habitat and most of its area is eligible federal wilderness, containing one of Georgia's oyster recreational harvest areas (RHAs), Oyster Creek RHA. Both McQueens and Cockspur islands are designated as a National Oceanic and Atmospheric Administration Marine Protected Area (MPA), underscoring FOPU's natural resource significance.

Riverine, freshwater, and estuarine wetlands cover 83.81% of FOPU, with the latter accounting for almost 99% of all monument wetlands. Persistently emergent vegetation of smooth cordgrasses (*Spartina* spp.) and unconsolidated shore represent the dominant wetland types. McQueens Island estuarine wetlands were evaluated for 11 functions and were rated primarily as high functioning, except for the wetland north of Highway 80, where the causeway has altered its ability to function properly. The wetland west of the Highway 80 bend is composed of unconsolidated material so was rated as moderately functioning in carbon sequestration, retention of sediments, and shore stabilization. In contrast, the unconsolidated shore wetland in the Oyster Creek RHA, where the highest concentration of FOPU's oysters occurs, were rated high for all expected wetland functions.

In 2013, over 75% of the total oyster area from within four of Georgia's RHAs was in the Oyster Creek RHA. A spectral analysis of oyster density in Oyster Creek RHA, comparing 2013 and 2018 images, reported an increase in the high-density class, a decrease in the moderate-low class, and an increase in the no oyster class, with the latter likely a function of how oyster areas were drawn between the images. A successful 2013 enhanced reef project in Oyster Creek RHA reported a pre-enhancement oyster area of 2.68 m^2 (28.8 ft^2) that increased to 894.2 m^2 (0.22 ac) of oysters by 2018.

FOPU's extensive salt marsh habitat and beaches provide critical food sources and habitat for shorebirds in the Atlantic Flyway, especially during the pre-breeding season. The American Oystercatcher (*Haematopus palliates*), Whimbrel (*Numenius phaeopus*), and the federally threatened *rufa* subspecies of Red Knot (*Calidris canutus rufa*) are identified as high priority species in the flyway and have been observed on Cockspur Island during the Manomet International Shorebird Surveys (2019–2022) at FOPU. The USFWS (2023) is seeking additional critical habitat designation, which will include Cockspur Island, for the *rufa* subspecies of Red Knot, whose estimated population abundance trend is declining throughout its entire range.

FOPU's non-wetland, upland habitat is primarily located on Cockspur Island and supports vegetation that can serve as host, roost and/or nectar plants for pollinators, especially butterflies. Cedar–Live Oak–Cabbage Palmetto (*Juniperus virginiana var. silicicola–Q. virginiana–Sabal* palmetto) Marsh Hammock and Cabbage Palmetto Woodland contain the most diversity of beneficial butterfly plants. While a comprehensive butterfly inventory is needed, fall migration surveys have recorded three target species of the Butterflies of the Atlantic Flyway (BAFA): monarch (*Danaus plexippus*), gulf fritillary (*Agraulis vanillae*), and cloudless sulphur (*Phoebis sennae*).

Collectively, FOPU's natural resources are affected by the sea level, which has risen by 0.35 m (1.15 ft) from 1935 to 2022. Hardened shorelines, such as causeways or armored structures, are identified as the greatest threat to the salt marsh habitat's ability to migrate upland with continued sea level rise. Erosion along Cockspur Island's north shore is an ongoing issue and FOPU managers have been working with the U.S. Army Corps of Engineers to develop solutions to address the erosion, while also creating habitat for shorebirds. Several agencies routinely monitor for water and sediment pollution in and around FOPU, which, if managed collectively, can inform landscape-level management actions to address drivers that are influencing resource conditions at the ecosystem level.

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Glossary

Condition Assessment: A condition assessment reports on the current condition of one or more *indicators of condition* for a focal natural resource when enough data are available. What constitutes "enough" data is a professional judgement based on a review of all available data and conceptual models and discussions with park staff, subject matter experts, and researchers involved in collecting the applicable data. Indicators of condition are rated using a three- or five-level rating system, ranging between good-fair-poor; if trend can be reported for a measure, it is reported as improving, stable, deteriorating, or unknown/indeterminate.

Condition Evaluation: A condition evaluation is either a condition assessment or a gap analysis. Which one depends on the amount of data with which to evaluate conditions and assign a condition rating(s). If enough data are available for key indicators of condition, then a condition assessment is developed. If data are lacking, a gap analysis is developed.

Condition Rating Statements: These correspond to the three- or five-level rating system developed to evaluate the indicators of condition. The five-level rating scheme includes good, good/fair, fair, fair/poor, and poor, and the three-level rating scheme includes good, fair, and poor, with corresponding "stop light" colors. Condition ratings statements are developed at the indicator level for the combination of measures evaluated for each indicator of condition. The condition rating statements reference criteria must be logical and defensible based on the best available science.

Confidence Level: These correspond to a three-level rating system of low–medium–high described for the indicators of condition ratings. The levels are based on the repeatability of evaluation findings and how confident the author is in the information used to rate condition.

Current Condition: This defines the status of condition for an indicator based on the evaluation of one or more measures. "Current" applies to the condition as it exists today based on what has previously occurred, not on what is likely to occur. For example, something such as hazard level or risk, which identifies the proposed or likelihood of what may occur because of the intrinsic characteristics of the resource, will not be used to report on current condition. In general, data collected within the last ten years can be used to determine current condition, although this will depend on the rate of change for a particular indicator of condition and its corresponding measures.

Data Gap: A data gap is when information is lacking, whether in the form of unavailable literature or subject matter expertise to adequately evaluate conditions.

Driver: Ecosystem drivers are major (and most often) external influencers of change to natural systems, functioning across extensive areas or scales. Drivers are defined as "any relatively discrete events in space and time that disrupt ecosystem, community, or population structure and change resources, substrate, or the physical environment (White and Pickett 1985)." Drivers are most often beyond a manager's ability to influence or change.

Gap Analysis: A gap analysis summarizes what is known about a focal natural resource, in addition to highlighting critical information that is lacking. A gap analysis does not rate indicators of

condition. Instead, a table of *proposed* indicators, measures, and reference criteria are reported, with the goal of providing a framework for a future study.

Indicator of Condition: An indicator of condition (or simply indicator) is a descriptor of something useful to measure, but it is not the measure itself. Indicators consist of one or more measures. Condition ratings are assigned at the indicator level. This is because natural resources are often more complex and nuanced than what is reflected in just a few measures and associated indicators.

Measure: A measure is qualitative, quantitative, or a combination of both and provides specific information about the indicator of condition. There can be one or more measure(s) for each indicator. Selected indicators and measures are often those that are commonly used by NPS staff in monitoring the status of a resource, as well as those that are well represented in the literature and can provide context when park-specific data are lacking.

Pressure: A pressure results from a driver, potentially affecting a resource. An NRCA presents drivers and pressures as the fundamental forces that play important roles in regulating or altering ecological resource conditions in the park. NRCAs do not differentiate between drivers and pressures because the focus of the report content is on the manifestation of those influences on natural resource conditions, not on the differentiation of drivers and pressures.

Reference Criteria: Reference criteria are pivot points, thresholds, or ranges based on peer-reviewed literature, state standards, known criteria, or some other justifiable source of information that forms the basis of the condition rating statements. Quantitative reference criteria are generally better than qualitative reference criteria, but when specific data are lacking, qualitative reference criteria are useful. Regardless of the type of reference criteria used, they must be justifiable and cited appropriately for the repeatability of future condition evaluations.

Response: Useful near-term actions/activities park managers can consider for protecting, maintaining, and/or restoring important ecological resource conditions in parks.

State (Condition): The current "health" or condition of the focal natural resource reported at the indicator of condition level. State is synonymous with condition.

Stressor: "Stressors can manifest as physical, chemical, or biological perturbations [disturbances] to a system that are either foreign to that system, or natural to the system, but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. They act together with drivers on ecosystem attributes (Barrett et al. 1976)." When possible, stressors are selected as measures with which to evaluate the current condition of an indicator.

Trend: A trend is a statistical analysis intended to find patterns in data. If a trend can be reported for a measure, it is reported as improving, stable, deteriorating, or unknown/indeterminate. Only quantitative trends are reported in the NRCA technical report.

Natural Resource Condition Assessment – Introduction

The National Park Service (NPS) Natural Resource Stewardship and Science Directorate provides scientific, technical, and administrative support to national parks for the management of natural resources. The directorate includes nine Service-wide divisions that assist NPS managers across the United States with protecting park resources and values sustainably over time. The NPS Natural Resource Condition Assessment (NRCA) Program is within the Service-wide's Water Resources Division, and its mission is to assess and report the conditions and trends of natural resources.

NRCA Goals

The primary goal of an NRCA is to deliver scientifically credible natural resource condition and trend information for park manager-selected topics of interest. NRCAs distill existing information into concise, easily understood assessments that inform management decisions. NRCAs also highlight data gaps to help managers prioritize information that is needed to inform future management decisions.

Each NRCA project is completed within approximately one year from the scoping workshop to the development of the technical report, using a standard workflow. The NRCA findings are published in a technical report (Chapters 1–4 are ~50 pages or fewer), which is posted to the NPS Data Store along with supporting materials (e.g., GIS datasets, study plan, assessment methods summaries) (https://irma.nps.gov/DataStore/).

Technical Report

The content of every NRCA report is organized using an ecological drivers, pressures, stressors, states, and responses (DPSSR) logic framework (Figure 1; adapted from the Office of National Marine Sanctuaries 2020; Harwell et al. 2019). The DPSSR framework emphasizes the connection between the natural and human (or anthropogenic) drivers-pressures (hereafter referred to as drivers) that influence ecosystem or natural resource change. A change may affect the condition (or state) of a resource as a positive or negative stressor. In turn, park managers may respond to a stressor(s) that negatively impacts a resource to restore its condition to a desired state, such as controlling non-native invasive plants in a high priority habitat or submitting a study proposal for funding to further a park manager's understanding of the resource.

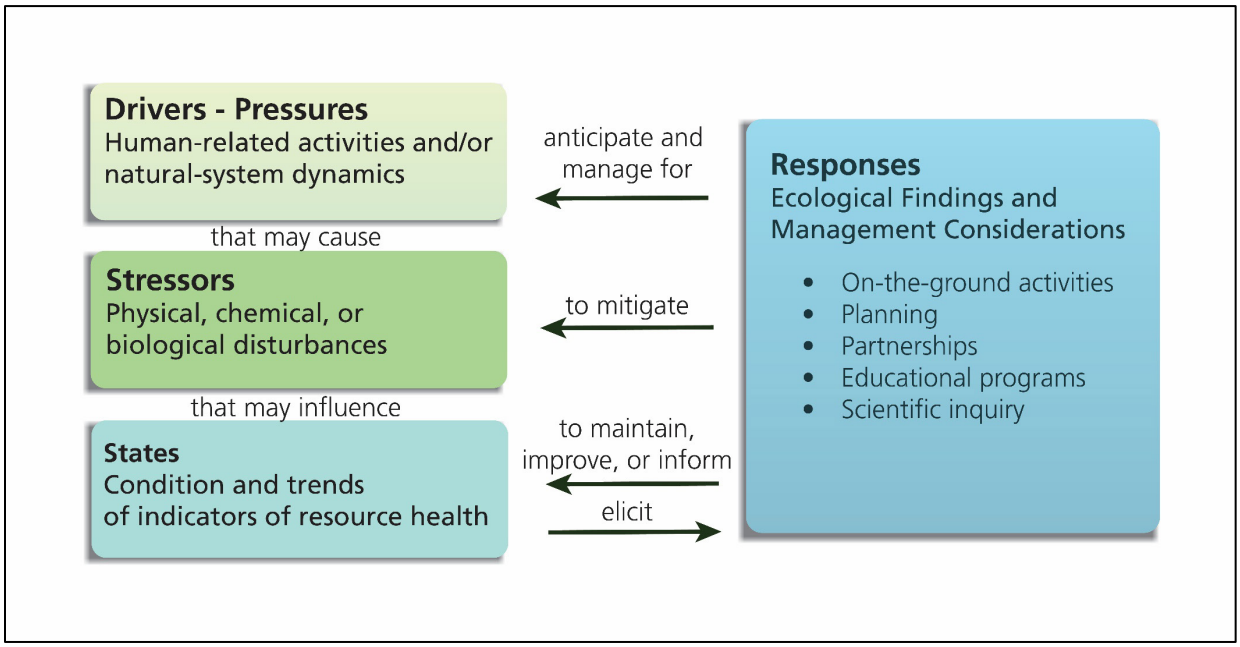


Figure 1. The drivers, pressures, stressors, states, responses (DPSSR) logic framework used to organize NRCA report content (adapted from Harwell et al. (2019) and the Office of National Marine Sanctuaries (2020)).

Even though there are stressors that managers can't directly influence, it's still helpful to understand the potential resource impacts, especially when setting realistic resource management goals. The DPSSR framework helps to illuminate these connections between drivers, stressors, resource conditions (states), and management responses, and guides the selection of the most relevant NRCA content to report.

It's important to note that while an NRCA project does not report on conditions for all the natural resources at a park, the DPSSR framework can guide the evaluation of additional natural resource conditions in the future. This is especially important as drivers and/or stressors change, or as new information becomes available with which to evaluate natural resource conditions.

Chapter 1. Introduction to Park Setting and Resources

Fort Pulaski National Monument (FOPU, monument) is one of 85 national monuments included in a system of 423 national park units. It was established in 1924, then transferred to the Department of Interior in 1933, to be administered by the National Park Service (NPS). FOPU was created to "*preserve and interpret the 19th century masonry fort and associated landscape that illustrate the evolution of civil engineering and military technology, a continuum of historic resources from colonial times to the present day, and approximately 5,000 acres [2,023 ha] of nearly pristine salt marsh on McQueens and Cockspur Islands in Savannah, Georgia*" (FOPU Presidential Proclamations: October 15, 1924, No. 1713 and August 14, 1958, No. 3254, as cited in NPS (2016)).

1.1. Location

FOPU is approximately 24 km (15 mi) east of Savannah, Georgia (GA) in Chatham County and west of Tybee Island, with U.S. Highway 80 providing access to both the monument and Tybee Island, GA (Figure 2). FOPU encompasses an area of 2,275 ha (5,623 ac), of which all but 104 ha (258 ac) are administered by the NPS. The monument is comprised of two islands: McQueens and Cockspur, which are separated by the south channel of the Savannah River. The confluence of the Savannah River and the Atlantic Ocean is east of Cockspur Island. Lazaretto Creek separates McQueens Island from Tybee Island, which fronts the Atlantic Ocean. The southern boundary of McQueens Island is along the Bull River, which separates it from Wilmington and Washington islands.

A view of the Cockspur Island landscape along its northern boundary that parallels the north channel of the Savannah River. Image Credit: NPS / JOEL CADOFF.

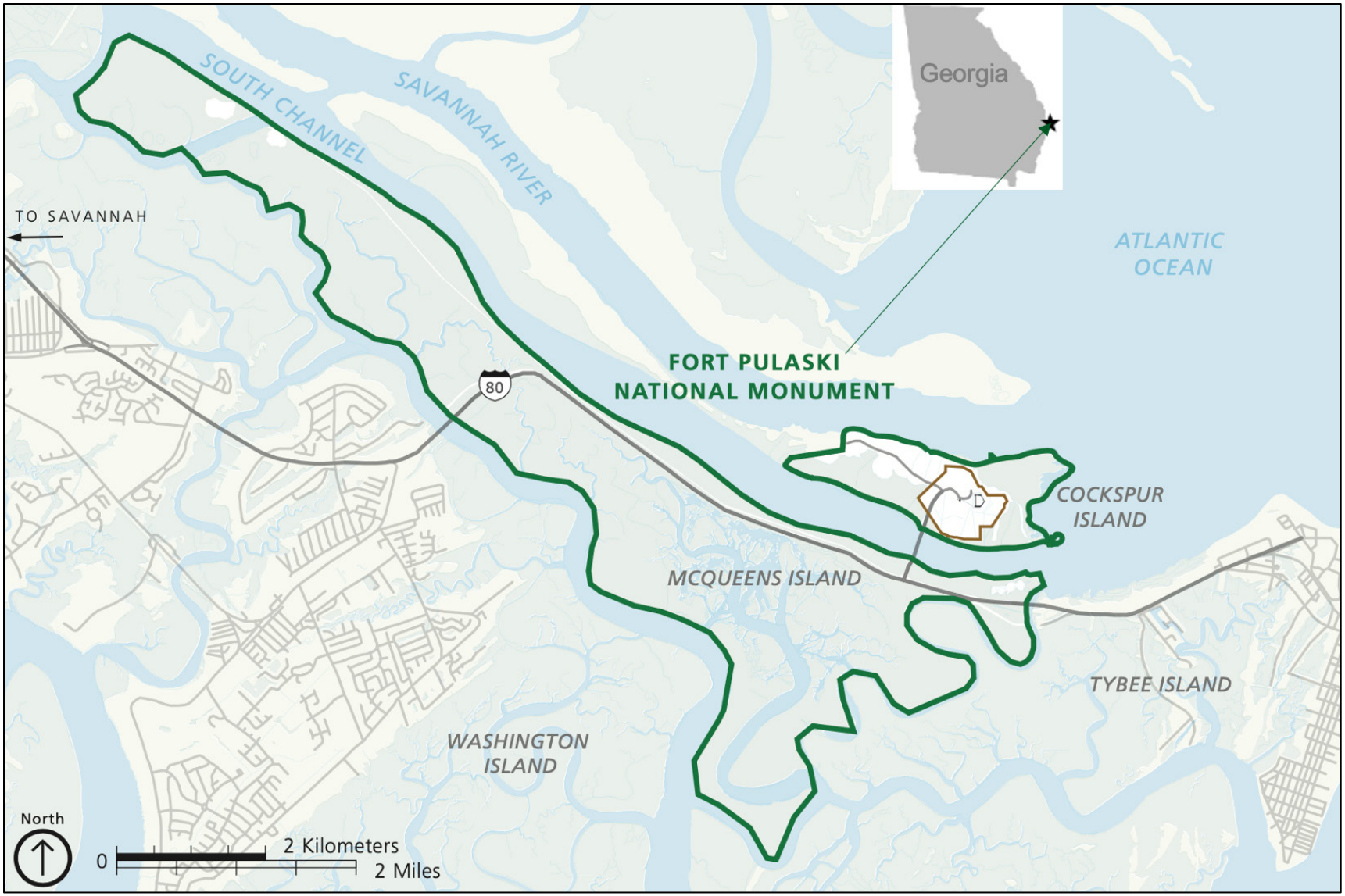


Figure 2. Georgia's Fort Pulaski National Monument (FOPU; outlined in green) is comprised of McQueens and Cockspur islands, which are separated by the south channel of the Savannah River. Figure Credit: NPS (2016).

1.2. Climate

Warm-to-hot summers and cold-to-mild winters characterize FOPU's subtropical climate. From 1948 to 2022, the average warmest temperatures occurred in June and July, with a range of 89.5–91.7 ºF, and the average coldest temperatures occurred in January (39.1 ºF) (Climate Analyzer 2023). Precipitation has been highest during July, with an average of 16.3 cm (6.4 in) (1948–2022). From 1944 to 2020, Atlantic tropical storms and hurricanes have peaked during September and October, and with climate change and associated sea level rise, flooding from storm surge events has increased even though hurricane landfalls have not increased since 1900 (NASA 2023a).

The tide level at the Fort Pulaski tide gage (8670870) observed a 3.2 m (10.45 ft) historic crest on November 7, 2021 (NOAA 2023a), causing flooding. This was the fourth highest level recorded since record keeping began in 1936. Flooding is increasing at Fort Pulaski National Monument as the sea level rises in the Atlantic Ocean. Image Credit: NPS / CANDICE SMITH.

1.3. Marine Protected Area

FOPU is a designated National Oceanic and Atmospheric Administration (NOAA) Marine Protected Area (MPA), which is defined by the International Union for Conservation of Nature (IUCN) as: *...a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008).* Each MPA is designated as one of six IUCN categories, ranging from most protected (I) to least (VI), and varies by permitted and prohibited management activities.

FOPU's designation is an IUCN category V MPA, which is a protected land- or seascape. The monument is surrounded by three MPAs–Turtle Island, SC (Category VI, protected with sustainable use of natural resources), Tybee National Wildlife Refuge, SC (Category Ia, strict nature reserve), and Little Tybee Island/Cabbage Island Natural Area (Category V, same as FOPU) (Figure 3).

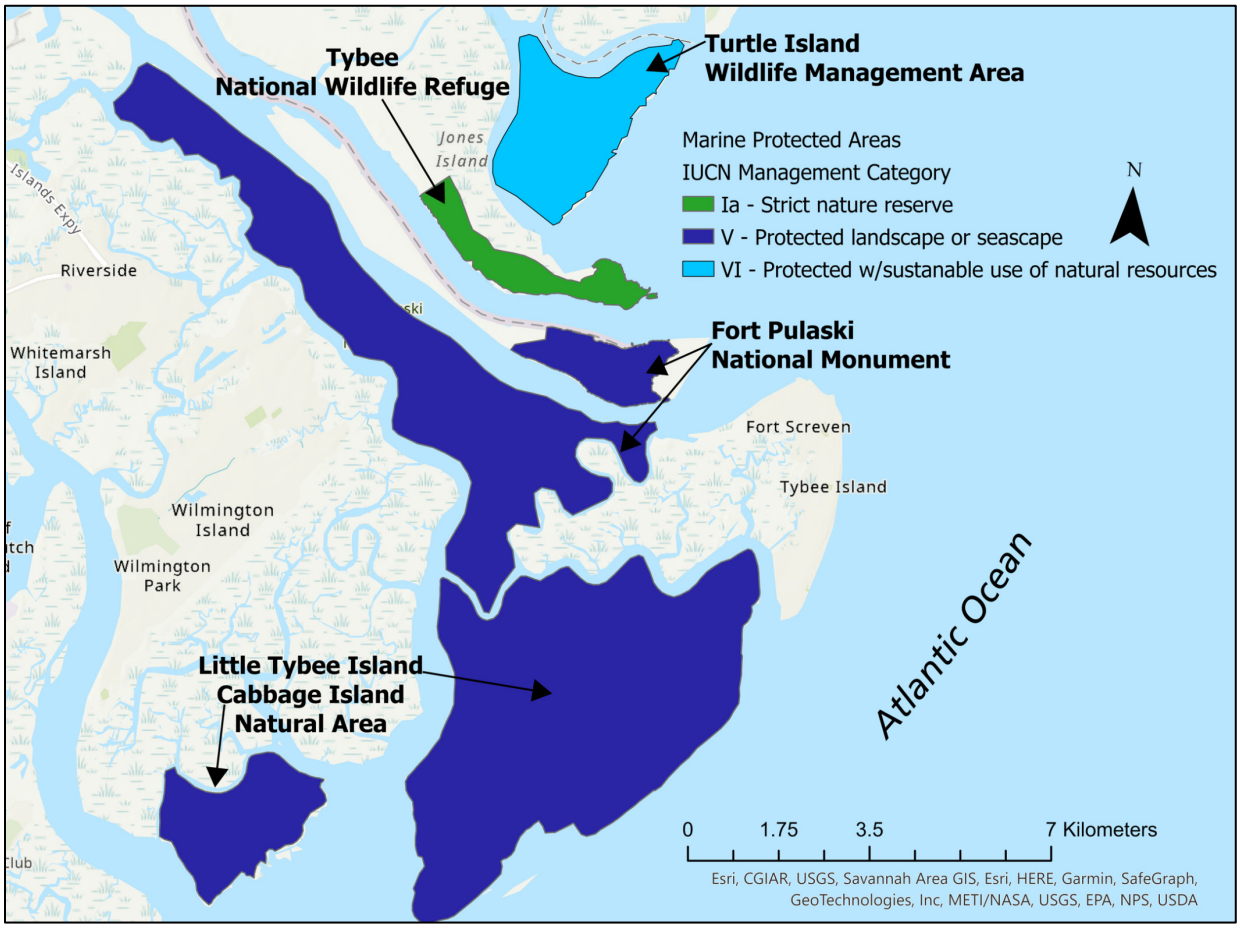


Figure 3. Marine Protected Areas (MPAs), including and surrounding FOPU, and International Union for Conservation of Nature (IUCN) categories and associated level of protection. Data Credit: NOAA (2020).

The primary objective for FOPU as an MPA is to "*protect and sustain important landscapes /seascape and the associated nature conservation and other values created by interactions with humans through traditional management practices*" (Day et al. 2019). Additional objectives include

modeling sustainability practices so lessons learned can be shared by FOPU managers with a wider audience; providing recreation and tourism opportunities; conserving aquatic biodiversity; providing natural products and environmental services; actively promoting a community conservation management framework; balancing nature and culture through protection efforts; and contributing to broad-scale conservation (Day et al. 2019). Activities not permitted include industrial fishing and aquaculture, untreated waste discharge, and mining and oil and gas extraction (Day et al. 2019).

1.4. Cockspur Island

Prior to human intervention, Cockspur Island was comprised of a series of small coastal hammock forests or woodlands surrounded by tidal saltmarsh (DeVivo et al. 2008; Alexander 2008). Then in 1761, the island was selected as a defensive location, initially serving as a British battery, then as an American fort during the Revolutionary War, and finally as Fort Pulaski, whose construction began in 1829 as one of a chain of forts built to protect the eastern coastal cities following the War of 1812 (NPS 2016). After a short Civil War battle in 1862, the fort was surrendered to Union forces then became a refuge for freed slaves after the Emancipation Proclamation was issued. Throughout the island's history, a variety of structures were built, including a lighthouse along its southeastern end that guided vessels up the south channel of the Savannah River until 1909.

Cockspur Island has been physically modified throughout its history by natural and anthropogenic processes. One of the most significant human modifications was the construction of a dike and drainage system, which was initially designed to drain water away from the then existing salt marsh, then from the fort itself into the south channel of the Savannah River via three, one-way tide gates. These gates were also designed to prevent entry of the Atlantic Ocean's high tides, adding additional protection to the fort.

To further protect the fort from erosive forces, starting in the 1830s, a breakwater was built along most of Cockspur's northern shore. In addition, a revetment was constructed in the 1890s, extending from the island's northeast corner to a jetty along the Savannah River, north of the fort. The second revetment was constructed along the central section of the island's north shore in the 1970s to protect the U.S. Coast Guard Station and the Savannah Bar Pilots Association facilities. These groups continue to operate on the western end of Cockspur Island via a special use permit and lease, respectively. The Savannah River Bar pilots guide large ships around the sandbars from the Atlantic Ocean to the Port of Savannah, which is about 29 km (18 mi) upriver from the Savannah River's confluence with the Atlantic Ocean.

The U.S. Army Corps of Engineers (USACE) is the agency responsible for dredging the Savannah River so large shipping vessels can access the Port of Savannah. USACE deposited dredge material from the river onto Cockspur Island until 1992, accounting for 42.4% of the island's made land soil type (USDA NRCS 2022; Figure 4). The island's remaining soil type is poorly drained, salty tidal marsh (USDA NRCS 2022; Figure 4). The areas of made land include the fort and its ditch and dike system and the northern half of the island (northwest of the fort), where upland vegetation grows.

Cockspur Island accounts for approximately 11.5% of FOPU's total area (NPS 2022a), and while over two-thirds of the island's vegetation is wetland (McManamay et al. 2013), the remaining area, primarily on the made land soil, is comprised of upland vegetation communities where monument staff have documented terrestrial species, such as bobcat (*Lynx rufus*), coyote (*Canis latrans*), and white-tailed deer (*Odocoileus virginianus*) using camera traps (NPS, C. Smith, biological science technician, pers. comm., 7 February 2022). In addition, over 100 species of landbirds have been observed at the monument (NPSpecies 2022). The dominant upland vegetation community on Cockspur Island is Cedar–Live Oak–Cabbage Palmetto (*Juniperus virginiana var. silicicola–Q. virginiana–Sabal palmetto*, Marsh Hammock (McManamay et al. 2013).

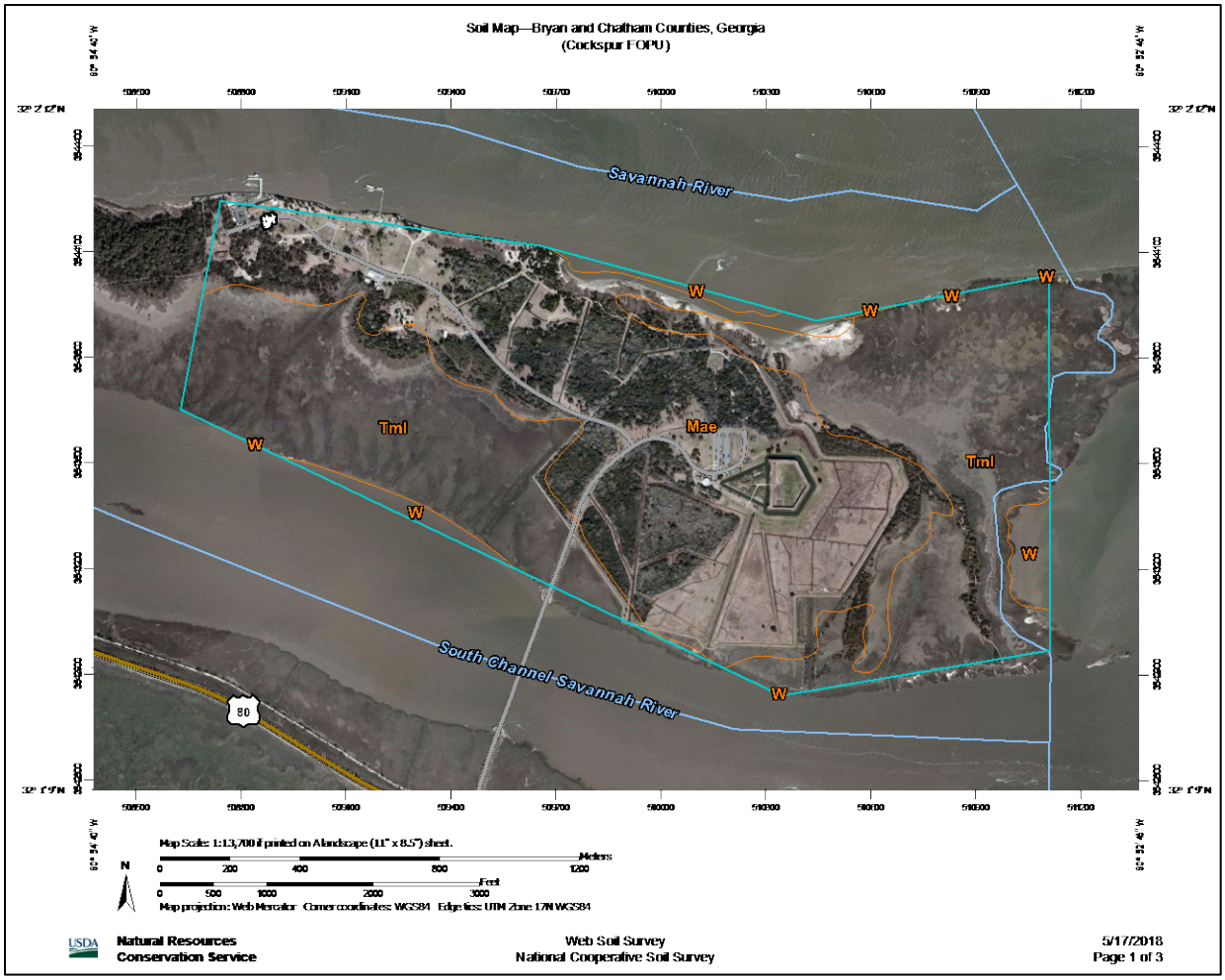


Figure 4. Natural Resource Conservation Service (NRCS) web soil survey map of Cockspur Island, FOPU (Ford 2018). The Mae soil type is made land; Tml is tidal marsh, salty; and W is open water.

1.5. McQueens Island

McQueens Island accounts for approximately 89% of FOPU's area and was added to the monument in 1936 (NPS 2016). Prior to access by road, a railroad was built in 1887 along the northern portion of the island, connecting the city of Savannah, GA to Tybee Island, GA. The railway was converted to the multipurpose McQueen's Island rails-to-trails in 1994 but was impacted by Hurricane Matthew in 2016, shortening the trail's original length. FOPU manages the trail east of the Fort Pulaski Road bridge. U.S. Highway 80, built in 1923, serves as the main access and evacuation route during hurricane season for FOPU and Tybee Island visitors and residents. The highway and rails-to-trails areas, in addition to the Lazaretto Creek public fishing and boat ramp on the eastern end of the island and an abandoned section of U.S. Highway 80, leading to the Bull River on McQueens west end, are the island's main developments.

Eligible Wilderness

Because of McQueens Island's natural character, a federal wilderness eligibility assessment determined that approximately 1,821 ha (4,500 ac) of McQueens Island salt marsh met criteria for eligible wilderness (NPS 2013). NPS (2013) stated that the eligible lands "*generally appear to have been affected primarily by the forces of nature with minimal evidence of human activity. These areas of Fort Pulaski National Monument offer outstanding opportunities for solitude or for primitive and unconfined recreation.*"

The majority of McQueens Island is designated as eligible wilderness and contains the Oyster Creek Recreational Harvest Area where the public can harvest shellfish with a state permit. Image Credit: NPS.

Almost 87% of McQueens Island is tidal salt marsh habitat (USFWS 2019). The marsh is dominated by *Spartina* grass (cordgrass) and is in the intertidal zone, where twice-daily tides mix fresh (from the Savannah River) and salt (from the Atlantic Ocean) waters, flooding the area and supplying nutrients and sediments, both of which are necessary for maintaining the health of salt marsh habitat.

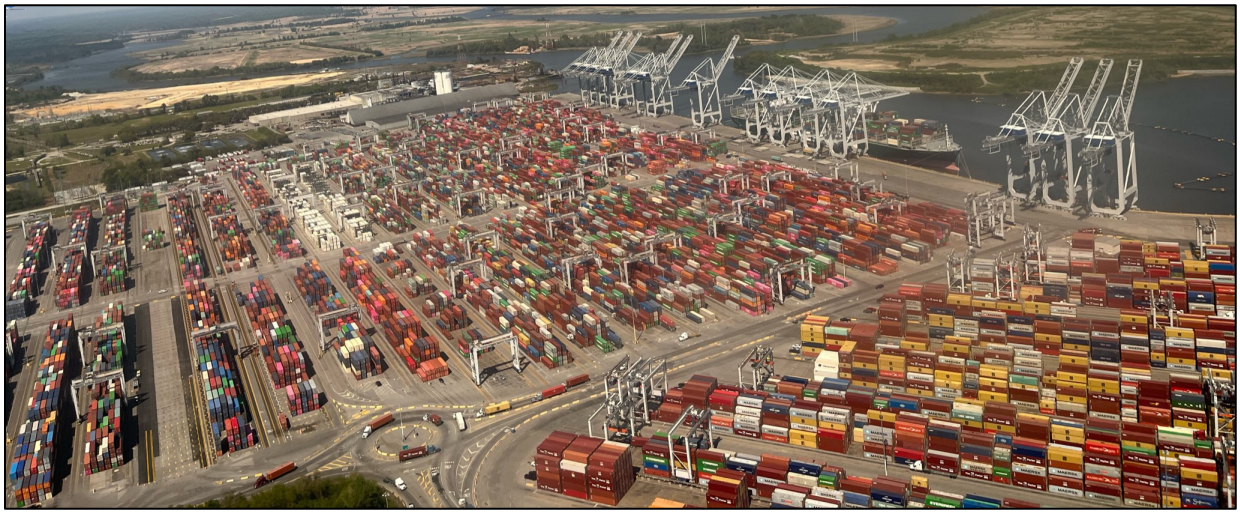
Salt marsh buffers erosive impacts from storms, improves water quality, and supports a highly productive food chain (GADNR 1997) that produces "…*more food energy than any estuarine zone on the eastern Seaboard*" (GADNR n.d.(a)). More than 75% of Georgia's fisheries, including shrimp, crabs, and fish, along with oysters and clams, are found in this coastal habitat (GADNR n.d.(a)). When the tide recedes, it exposes the intertidal mud flats that are along the edges of the salt marsh vegetation where critical food sources, such as snails, worms, and mud fiddler crabs (*Uca pugnax*), feed on cordgrass debris, and are important prey for wading and shorebirds, such as the whimbrel (*Numenius phaeopus*) and willet (*Tringa semipalmata*).

The Oyster Creek Recreational Harvest Area (RHAs), which is one of Georgia's seven public RHAs for harvesting Eastern oysters (*Crassostrea virginica*), is in McQueens Island salt marsh, entirely within its eligible wilderness area, and is accessed via the Lazaretto Creek public ramp.

Chapter 2. Drivers and Stressors

The drivers and stressors that are likely influencing FOPU's natural resource conditions were discussed among the invited subject matter experts and monument managers during the 2022 NRCA scoping workshop. Because FOPU is surrounded by water and over 80% of the monument's area is wetland, the drivers and stressors identified were primarily water-related, such as shoreline erosion, sea level rise, and water pollution. Summaries of the workshop discussions related to the landscape-scale drivers and stressors, combined with a literature review, are presented in this chapter, and the more localized resource-specific stressors are presented in Chapters 3 and 4.

Shipping: As of 2021, the Port of Savannah, GA is the fourth largest container cargo port in the U.S. (second largest along the Eastern Seaboard) when ranked by twenty-foot equivalent units (TEU, which measures 2.6 m x 2.4 m x 6.1 m [8.5 ft x 8 ft x 20 ft]) (USDOT 2023). It is also the third busiest container gateway according to the Georgia Ports Authority (2023). Between January 2019 and August 2022, the greatest increase in cargo handling occurred along the Atlantic Coast (USDOT 2023), with the Port of Savannah increasing by 28% over three years (Georgia Ports Authority 2023). The Port of Savannah now provides access to New-Panamax container ships, which are approximately 366 m (1,201 ft) long. In addition, a new container terminal is expected by 2035 along the Savannah River (USACE n.d.). The terminal will be across from Elba Island, GA in Jasper County, SC, which is across from McQueens Island's western end. In the 1880s, Elba, Long (which is immediately west of Cockspur), and Cockspur islands were joined by the placement of dredge spoils (Alexander 2008).



An aerial view of containers at the Port of Savannah. Image Credit: NPS / DANA WITWICKI.

For ships to access the Port of Savannah from the Atlantic Ocean, routine maintenance dredging within the river channel is necessary. The first known maintenance dredging of the Savannah River occurred in 1867 and continues today, with the Savannah Harbor Expansion Project completed in 2022, deepening the river channel from 14 m (47 ft) at mean low tide to 16 m (54 ft) at mean high

tide. When medium-large ships travel in narrow channels such as the Savannah River, oscillating waves and deep depression bores are created resulting in coastal erosion (Muscalus 2022).

Cockspur Island Shoreline Alteration: The current large-scale, long-term issue on Cockspur Island is shoreline erosion. Alexander (2008) mapped shoreline positions, calculating change rates around Cockspur. The general cumulative change from 1852 to 2005 showed that the east shoreline has been primarily accretionary, with the highest rates of accretion occurring to the north and lessening to the south. Cockspur Island's south shoreline, along the Savannah River's south channel, has been mostly stable with some erosion. The north shoreline, which receives the highest amount of energy from shipping activity and weather events, has been dominantly erosional. The erosion of the north shoreline has coincided with the cessation of placing dredge material on Cockspur Island (Alexander 2008).

Peffer (2019) also monitored shoreline change rates around Cockspur Island and evaluated the effectiveness of a beneficial use berm placed on the island's north shore by the USACE in the fall of 2015 to protect FOPU's North Pier and Battery Hambright cultural resources from erosion. The protective berm was effective (as a berm) until late 2018, when erosion began on its western end and decreased in width along its eastern end (refer to Figure 3 in Peffer 2019). However, the dredge material that filled a deep hole adjacent to the north shoreline remained, making it easier to design a future beneficial use project with better placement of dredge spoil (UGA, C. Alexander, professor, 30 March 2022, scoping workshop.). Peffer (2019) did not report any significant increase in the shoreline change rates for Cockspur Island's northern and southern shores from what Alexander (2008) reported except for the accretionary rates along the eastern shore, which had substantially increased since 2008 (Peffer 2019). Traditionally, the eastern side of Cockspur has been very shallow, which has helped to stabilize the shoreline.

In 2008, the connection between Cockspur Island's west end and Long/Bird islands breached, increasing the channel to over 300 m (984 ft) wide, as reported in Peffer (2019). Muscalus (2022) studied the propagation of ship wake around Bird-Long islands, which front the north and south channels of the Savannah River, west of Cockspur Island. Modeling of wake propagation showed that the erosion potential from ships is more powerful than natural processes, such as waves created by wind and tides for both the main shipping channel (north shore) and the south shore of the Savannah River (Muscalus 2022). Several factors may influence the erosion potential for Cockspur Island differently than those for Bird-Long islands. For example, the Savannah Bar Pilots' vessels pass along Cockspur Island but do not extend upriver to Bird-Long islands. Houser (2010) cited these vessels as the dominant source of erosion along Cockspur Island's north shore (as cited in Muscalus 2022). Vessel speeds also affect wave energy, which are the fastest as they transition from the open Atlantic Ocean into the mouth of the Savannah River (closest to Cockspur Island's northeastern end). Vessels are at their slowest speeds along Cockspur Island's west end because of U.S. Coast Guard speed restrictions (Muscalus 2022). These factors create spatial variation in erosional processes (Muscalus 2022).

Altered Hydrology: FOPU managers are actively engaged with USACE to repair and rehabilitate the hydrology of the ditch and dike system surrounding Fort Pulaski (a summary of the system is

presented in section 1.4 of this report). In the fall of 2002, Martin et al. (2002) conducted a hydrology study to evaluate the tidal flushing of the system through two high tide cycles. In the summer of 2019, Ford (2019) reconducted the Martin et al. (2002) tidal flushing study through four successive high tide cycles to provide an update on the system's hydrology.

During both studies, three, one-way tide gates were opened to observe tidal flows throughout the system. Ford (2019) reported that constrictions at all three gates impeded normal tide flows, but that restoration was possible. The observed fishes, including *Gambusia* spp., suggested that regular water exchanges in the ditches could potentially maintain suitable habitat, which in addition to restoring the hydrology of the system, would help with mosquito control (Ford 2019). Portions of the southern and eastern sides of Cockspur Island would be inundated by diurnal high tides under natural conditions (Martin et al. 2002) and degraded areas, such as where trees have died in the southwest area of the system due to high salinity levels, could be restored. Ford (2019) suggested the use of prescribed fire to remove the dead timber and to help restore the degraded area to its natural state of tidal salt marsh.

Climate Change/Sea Level Rise: Sea levels are rising from melting ice sheets and glaciers and from the expansion of warming seawater (NASA 2023b). Boon et al. (2018) ranked Savannah, GA as the third highest sea level rise out of 16 locations along the East Coast. The relative mean sea level trend at the Fort Pulaski, GA tidal gauge (#8670870) is 3.52 mm/yr with a 95% confidence interval of +/- 0.27 mm/yr (1935–2022), which equates to a 0.35 m (1.15 ft) change in 100 years (Figure 5; NOAA 2023b).

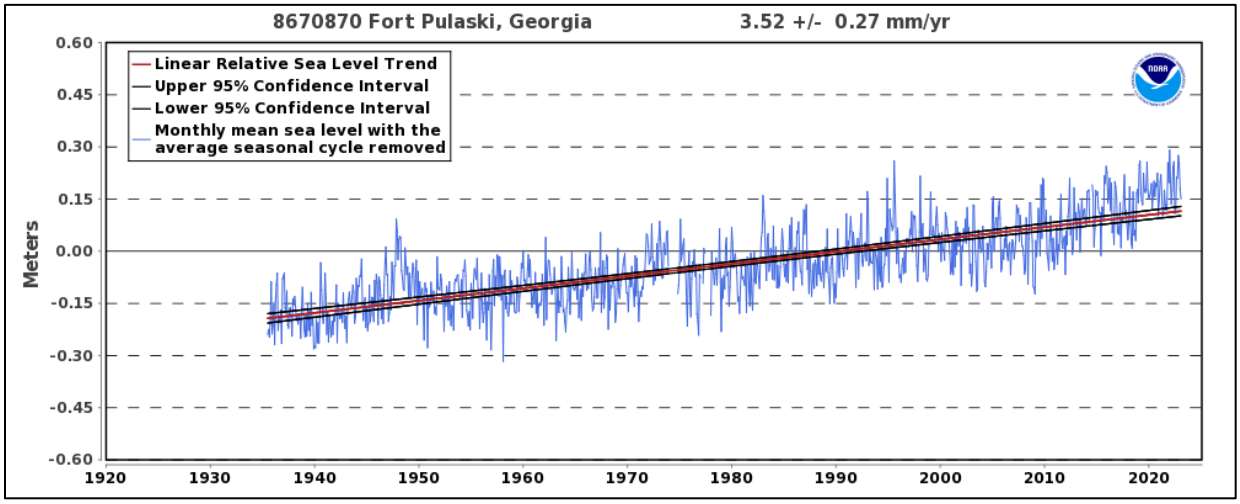


Figure 5. The relative mean sea level trend at the Fort Pulaski, GA tidal gauge (#8670870) is 3.52 mm/yr, with a 95% confidence interval of +/-0.27 mm/yr (1935–2022). This equates to a 0.35 m (1.15 ft) change in 100 years. Figure Credit: NOAA (2023b).

With continued climate change, FOPU could experience a 0.5–3.9 ºC increase in temperature by 2100, combined with a 6–9% increase in precipitation (Gonzalez et al. 2018). With the area subsiding at a rate of 1.36 mm/year, by 2030, sea level is expected to rise 0.13–0.14 m (0.43–0.46 ft), which could increase to 0.24–0.25 m (0.79–0.82 ft) by 2050. While hurricane landfalls haven't

increased around FOPU, the region has a history of exposure to hurricane strength storms (Caffrey et al. 2018). These storms combined with sea level rise will create higher storm surges.

Peek et al. (2022) evaluated the vulnerability of FOPU structures to coastal hazards and sea level rise and concluded that the majority (89%) of the monument's roads, buildings, and structures are highly vulnerable, which is consistent with the predicted 2050 sea level rise area of impact mapped by the NPS Climate Change Response Program (2022; Figure 6).

Figure 6. FOPU's Mission 66 Visitor Center is a white dot to the left of the triangular portion of the fort. The top image is an aerial photo of present day FOPU, and the aqua green areas shown in the bottom image represent inundation based on estimated 2050 sea level rise. Figure Credit: NPS Climate Change Response Program (2022).

Additional impacts from sea level rise may include saltwater intrusion into the groundwater and soils; increased erosion of the land and archeological sites; and flooding (drowning) of the salt marsh. Chatham and Effingham counties are in a "red zone" area of GA where saltwater intrusion has occurred and continues to be highly vulnerable to intrusion into drinking water based on recent modeling (Ecological Planning Group, LLC 2018). The permitted private water systems in the Red Zone include FOPU, which reported an estimated average use of 55,385 gallons per day for its

transient, non-community population of 912 and 1,533 gallons per day for its non-transient, non-community population of 133 (Ecological Planning Group, LLC 2018).

A 2006 *Chatham County Plan* identified management strategies, which were effective in reducing groundwater withdrawals since the plan was implemented (GAEPD 2006). But as population increases in Chatham and Effingham counties, the conservation of water usage and improved wastewater infrastructure become increasingly important (Ecological Planning Group, LLC 2018). Recently, FOPU Superintendent Melissa Memory worked with the University of Georgia (UGA) to identify a wastewater treatment system for the monument that considered impacts from sea level rise and storm resilience. The wastewater system redesign would connect Cockspur Island to Tybee Island's municipal sewer, which would likely address the frequent monument facility closures on Cockspur Island (UGA n.d.).

Graham (2009) noted that shoreline erosion at FOPU may also increase as the sea level rises. This has implications for the monument's archeological sites and fossils, with the latter including those that are natural and those that are associated with human-modified cultural resources (Tweet et al. 2009). Because FOPU is geologically young, Tweet et al. (2009) state that it's difficult to determine whether an artifact is fossil or a modern artifact. Regardless, salt corrodes, and with increased water intrusion, exposed and buried cultural resources are likely to be impacted. In addition, with eroding coastal sites, increased looting can occur as fossils and artifacts become exposed (NPS 2010). The ability of the surrounding salt marsh environment to accrete with rising sea levels will also determine the degree to which erosion and saltwater intrusion has on FOPU's cultural and natural resources.

Salt Marsh Accretion: The GADNR (2015) cites sea level rise as the greatest threat to Georgia's tidal salt marsh habitat. To keep pace with rising sea levels, salt marshes must accrete vertically, which occurs through sediment deposition and accumulation of organic material (this is further discussed in the salt marsh evaluation in section 3.1). Marshes may also need to migrate up-slope, which can be hindered by armored shorelines, such as bulkheads or revetments, altering a marsh's ability to naturally migrate.

Alexander (2010) delineated armored shorelines along coastal Georgia, including Chatham County. Of the demographics examined for each county, population significantly correlated with the length of armored shoreline (Alexander 2010). With Chatham County ranking the highest in the population reported for Georgia's coastal counties, the cumulative length of armored shorelines was also the highest. The bulkhead and revetments on Cockspur Island and the causeway, U.S. Highway 80, paralleling McQueens Island northern boundary, were mapped and are shown in Figure 7 (adapted from Figure 1 in Alexander 2010). While the Coastal Marshlands Protection Act (1970) has been effective at protecting marshlands during nonexempt activities, losses of tidal wetlands have been higher for Georgia public works projects, such as highway construction (USFWS n.d.(a)).

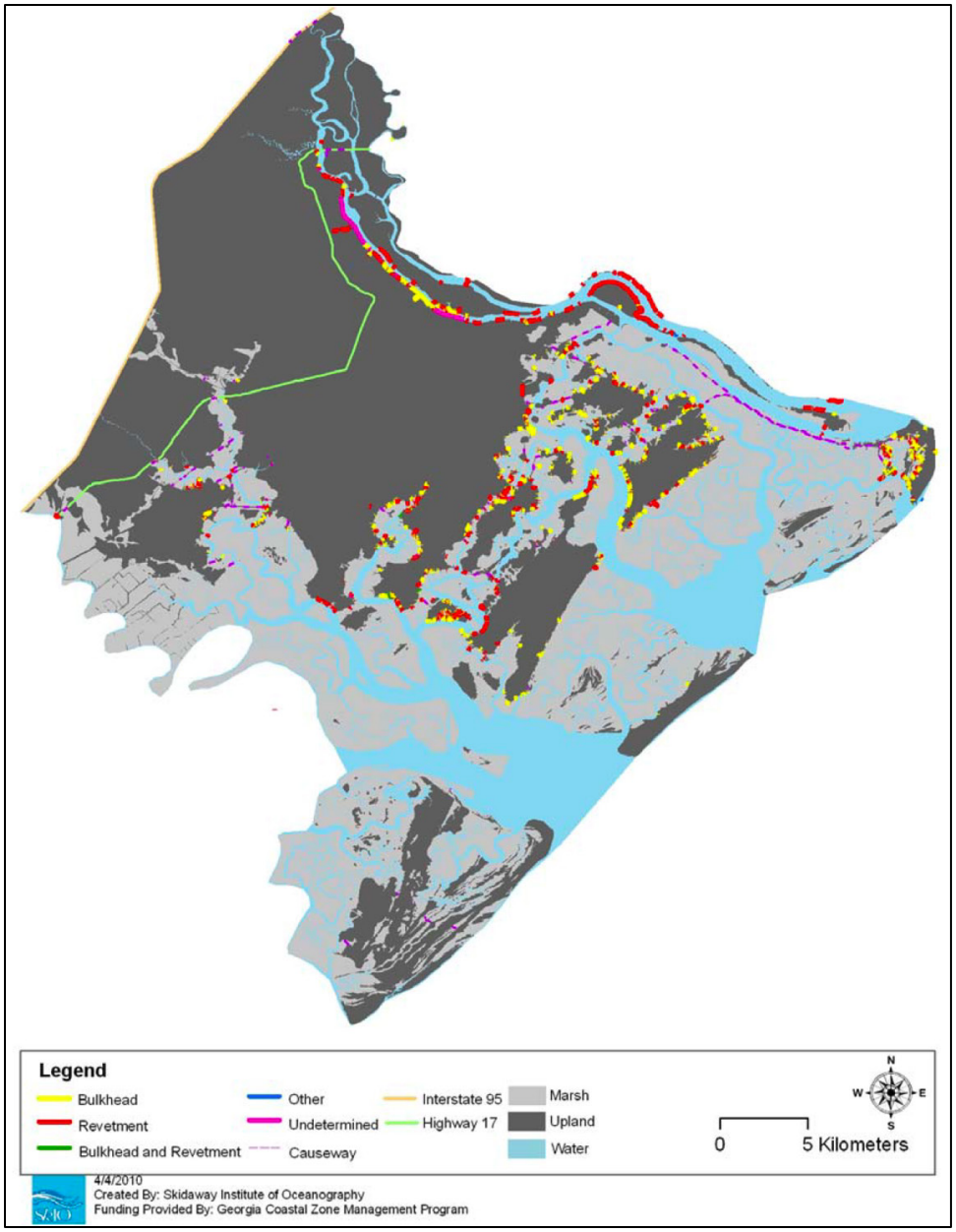


Figure 7. The types of armored shorelines mapped in 2010 by the Skidaway Institute of Oceanography. Figure Credit: Figure 1 in Alexander (2010).

Water Quality/Pollution: One of the primary ecosystem functions of tidal salt marsh is to dilute and filter pollutants in the water column and in sediments. Certain contaminants can become sediment-bound and remain trapped if left undisturbed, but become mobilized through activities, such as river dredging (Winger et al. 1999). To monitor water quality, nutrient, and sediment conditions at FOPU, the NPS Southeast Coast Inventory and Monitoring Network (SECN) collects data using two sampling techniques: fixed station and coastal assessment.

FOPU's fixed station is at the Lazaretto Creek fishing dock and a data logger collects core water quality metrics (i.e., temperature, pH, dissolved oxygen, salinity, specific conductance, turbidity, and

depth) every 30 minutes since August 2006–present. NPS SECN also samples monthly for nutrients (i.e., nitrogen and phosphorus), water clarity, and chlorophyll *a* at the Lazaretto Creek fishing dock fixed station. The results are compared to the U.S. Environmental Protection Agency (USEPA) water quality standards (USEPA 2012) and reported as good, fair, or poor condition (Starkey and McCay 2021).

For the fixed station water quality data (2017–2019), most core water quality parameters were rated as fair, primarily due to higher nutrient levels (Starkey and McCay 2021), with the source likely originating from leaking septic systems (NPS, E. Starkey, aquatic ecologist, 30 March 2022, scoping workshop).

A view of the Lazaretto Creek dock across the intertidal salt marsh adjacent to the boat ramp parking area. Image Credit: NPS.

GADNR staff also collect the same core water quality parameters as NPS SECN, with the addition of fecal coliform. Sampling is conducted monthly (2008–present) in and around Oyster Creek RHA at six repeat-sample plots (Guadagnoli n.d.; GADNR 2022a). Previous sampling occurred from 2005 to 2007 at four of those same plots. The focus of the GADNR's water quality program is to protect public health by identifying when higher concentrations of *Vibrio parahaemolyticus* (Vp)—a naturally occurring bacterium—are found in shellfish. Higher concentrations typically occur when water temperature exceeds 81° F (27.2° C), usually from June through September in GA. During this timeframe, GADNR restricts recreational oyster harvesting because oysters are usually consumed raw versus cooking at a high temperature, which kills the bacterium (GADNR n.d.(b)).

Results for GADNR's water quality monitoring in and around FOPU were good in 2022 from Oyster Creek's headwaters to Lazaretto Creek (USEPA 2022a); however, the 8-km (5-mi) stretch of Bull Creek between Wilmington Island and FOPU (from Richardson Creek to Lazaretto) was listed as impaired on Georgia's 303(d) list in 2022 based on fish consumption (shellfish) criteria. The probable source that was cited was non-point sources of fecal coliform (USEPA 2022b). No plans were specified to restore the water quality for this impairment (USEPA 2022b).

The NPS SECN also conducts a coastal assessment at FOPU every five years to evaluate monument-wide (n=30) water quality and every 10 years to evaluate concentrations of metals, organic contaminants, and industrial pollutants and chemicals, including polycyclic aromatic hydrocarbons (PAHs), DDT (and DDE, which is a breakdown product of DDT), and Polychlorinated biphenyls (PCBs) from sediment cores (Starkey et al. 2019).

NPS SECN assigned an overall water quality condition summary index of fair for the monument based on the July 2018 sampling results ((Starkey et al. 2019). The ecological condition for sediment chemistry based on the USEPA (2010) thresholds was good at all sites except for three, which were rated as fair. Two of those "fair" sampling sites were in the Oyster Creek RHA and the third site was along the Bull River outside the monument's boundary across from the southern end of McQueens Island (Starkey et al. 2019). All three sites had elevated levels of heavy metals, arsenic, chromium, copper, lead, nickel, and zinc, warranting further study (Starkey et al. 2019).

Eastern oysters filter large volumes of water and are critical to improving water quality by filtering and bioaccumulating pollutants. Oysters can be used as estuarine health indicators since they incorporate contaminants in their soft tissues, are sessile, and are long-lived. NOAA's Mussel Watch Program assessment of contaminants (1986–2005), monitoring 140 analytes that included trace metals and organics, sampled a site in the Savannah River estuary near Tybee Island (Kimbrough et al. 2008). Kimbrough et al. (2008) reported that arsenic concentrations in oysters throughout the Southeast were among the highest compared to concentrations throughout the U.S., but that high levels of arsenic are of geologic origin in Georgia (Valette-Silver et al. 1999). High concentrations of mercury and nickel in oysters were reported for all the Georgia study sites (n=3). In addition, butyltin (and associated compounds) was detected at medium levels from the Savannah River study site only. It's an antifouling agent added to marine paints that is on boat hulls, which accumulates and persists in sediments (Gibbs and Bryan 1994; USEPA 2003, as cited in Kimbrough et al. 2008).

While no status and trends for the remaining trace metals or organics were reported for Georgia, Kimbrough et al. (2008) cite the Department of Energy Superfund site along the Savannah River as one of the primary sources of elevated levels of metal contaminants in the river basin. Based on an analysis of organics and metals from a series of sediment cores sampled at Bird Island and at a site in the city of Savannah, GA, a pollution history of the Savannah River estuary was reconstructed (Alexander et al. 1999). An eventual decrease in the concentrations of chemicals associated with industry suggested that "…pollution control laws have been effective, even while industrial and population growth was taking place" (Alexander et al. 1999), underscoring the need for policy-level responses to manage for human-caused driver impacts on ecosystem functions.

Chapter 3. Focal Resource Evaluations

Chapter 3 reports on the conditions (states) of FOPU's selected focal natural resources. For focal resources that lack adequate data for credible evaluations of their current conditions, we develop a gap analysis. A literature review, combined with expert input, is provided for a focal resource gap analysis, which include a combination of its ecological importance, the general status of knowledge regarding factors influencing conditions, indicators, and measures, and studies to consider in the future for improving the knowledge base of the resource.

For focal resources that have adequate data to assess current conditions for one or more indicators of condition, we develop a condition assessment. For each indicator, data for one or more measures are evaluated either qualitatively and/or quantitatively and combined to report a condition rating at the indicator level. Rating statements include the combined measures' qualitative characteristics, and, when available, quantitative values, for a rating range of good to poor (see Figure 8 for rating classes and colors). If the indicator of condition is unknown, it is shown as gray.

Figure 8. Indicators of condition rating classes and colors.

Condition rating statements are presented in each NRCA report's Appendix A and include logical and defensible criteria for assigning condition. We do not report a condition rating for the focal resource itself because of the complexity of adequately characterizing the condition at that level.

Each condition rating is then assigned a confidence level, reported as high, medium, or low, depending on factors such as study repeatability, age of data, and whether data were collected or modeled. If available, a statistical trend is reported as improving, stable, deteriorating, or unknown.

All FOPU's natural resources were reported as gap analyses and include salt marsh, shorebirds, Eastern oyster, and butterflies. Manager questions that were posed during FOPU's NRCA scoping workshop are shown (in bold text) in each of the Chapter 3 evaluations.

3.1. Salt Marsh (McQueens Island focus)

FOPU is primarily wetland, covering 1,837.11 ha (4,539.60 ac) or 83.81% of the monument's area (USFWS 2019; NPS 2022a). Three types of wetlands occur at the monument: riverine, freshwater (pond, forested/shrub, and emergent), and estuarine. The riverine and freshwater wetlands combined account for only 1.1% of FOPU's total wetland area (19.7 ha [48.7 ac]), whereas estuarine wetlands account for the remaining area of 1,817.4 ha (4,490.9 ac) (USFWS 2019; NPS 2022a).

Coastal Georgia is dominated by salt marsh, which is a type of estuarine wetland dominated by emergent vegetation and situated between the higher uplands and lower waterbodies where fresh and salt waters mix twice daily. The Fort Pulaski NOAA tide gage (#8670870) in the Savannah River reports a mean diurnal tidal range of 2.3 m (7.5 ft) (NOAA 2023b), which is one of the highest along the East Coast of the United States. The salt marsh's transitional position along the coast and natural resource adaptations filter pollutants and excess sediments and nutrients, with the latter function contributing to its high productivity. The high productivity provides important habitat as feeding, breeding, and nursery grounds for a wide variety of marine organisms. Salt marsh habitat is connected through numerous tidal creeks, protecting communities from storm surges and sea level rise by its ability to buffer and to stabilize shorelines provided its functional capacities remain intact.

Photo of McQueens Island salt marsh adjacent to Lazaretto Creek. Image Credit: NPS.

Gap Analysis Summary

The majority (91.6%) of FOPU's estuarine wetlands are on McQueens Island and have been less of a management focus at the monument. As a result, FOPU managers requested a gap analysis emphasis on McQueens Island's wetlands. We summarized estuarine wetland types for both islands using the (1) U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (NWI) data (USFWS 2019) and landscape-level functional assessment data (NWIPlus) (GADNR 2012), and (2) NPS SECN salt marsh monitoring (Baron et al. *in draft*). Data summaries are presented in Figure 9.

NWI Summary: The USFWS (2019) wetlands classification is based on the Federal Geographic Data Committee (revised in 2013) system, which is hierarchical and emphasizes hydrology (i.e., degree of flooding or soil saturation), vegetation (i.e., hydrophytes), and hydric (i.e., undrained) soils. All FOPU's estuarine wetlands (denoted by E) are intertidal (denoted by 2) in the code column in Table 1. The next two letters denote the dominant vegetation, or substrate if vegetation is less than 30%. Emergent vegetation (EM) accounts for 61.6–79.2% of McQueens Island wetland types and for 86.5% of Cockspur Island's wetlands (Table 1 and Figure 9), which are dominated by *Spartina* spp. (smooth cordgrass). The remaining wetland vegetation types of forested and scrub-shrub occur on the western and eastern ends of McQueens Island and account for only 1.1% of the island's estuarine wetland types. The unconsolidated shore wetland types (denoted as US) are muddy, silty, or sandy and "represent the most extensive submerged habitat in estuarine areas in the Southeast" (GADNR 2012). Unconsolidated shore (US) accounts for 36.8–54.4% of McQueens and 13.3% of Cockspur's wetland types. The last letters in the codes include M (irregularly exposed), N (regularly flooded), or P (irregularly flooded), denoting the tidal saltwater regime, with the majority of FOPU's wetland types (58.7% of McQueens and 72.6% of Cockspur) being regularly inundated with Atlantic Ocean tides.

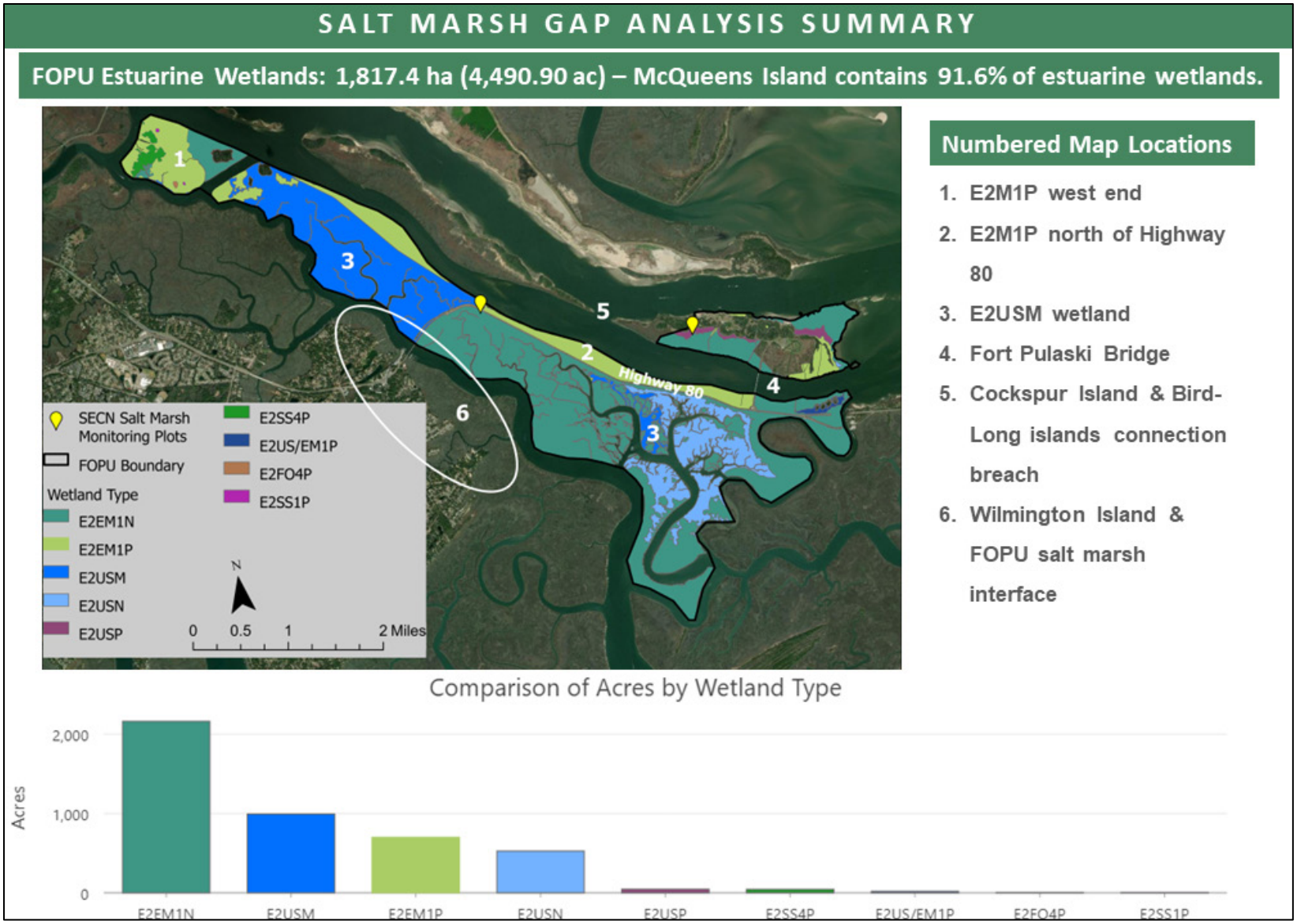


Figure 9. Data summaries for salt marsh: estuarine wetland types and acreage and numbered locations that correspond to the gap analysis text.

Table 1. Summary of FOPU's estuarine intertidal wetlands, which account for 98.93% of all FOPU wetlands (USFWS 2019).

Wetland Type	Code	Acres (% of estuarine wetland type)		Total Acres
		McQueens	Cockspur	
Persistently Emergent Vegetation	E2EM1N*	1,896 (46.1%)	267.2 (71.2%)	2,163.2
	E2EM1P	639.8 (15.5%)	58.3 (15.3%)	698.1
Persistently Emergent Vegetation and Unconsolidated Shore	E2US / EM1P	17.63	n/a	17.63
Unconsolidated Shore	E2USN	520.5 (12.6%)	5.4 (1.4%)	525.9
	E2USM	994.9 (24.2%)	n/a	994.9
	E2USP	n/a	44.6 (11.9%)	44.6
Forested or Scrub-shrub Vegetation	E2FO4P	1.96	n/a	1.96
	E2SS1P	1.52	n/a	1.52
	E2SS4P	43.2	n/a	43.2
Total	–	**4,115.50 (91.6%)**	**375.40 (8.4%)**	**4,490.90**

* The NPS SECN RSET monitoring sites are in this wetland type (see Figure 9).

NWIPlus Landscape-level Functional Assessment: The GADNR (2012) conducted a landscape-scale functional assessment of all wetlands throughout Georgia. Wetland functions included (1) surface water detention, (2) coastal storm surge detention, (3) streamflow maintenance, (4) nutrient transformation, (5) carbon sequestration, (6) retention of sediments/particulates, (7) bank/shoreline stabilization, and (8–11) provision of habitat for fish, aquatic invertebrates, waterbirds, wildlife, and unique or diverse plant communities. A summary of the assessment results for McQueens Island intertidal estuarine wetland types is presented in Table 2.

Tidal salt marsh wetlands do not hold surface water, maintain streamflow, or provide habitat for unique or diverse plant communities, which is reflected in the low rating for McQueens Island estuarine wetlands (and throughout the remaining tidal salt marsh habitat in Chatham County). Whereas all remaining functions were rated as high for McQueens Island estuarine wetland types except for an area of the E2EM1P wetland, north of the causeway (Highway 80), and for the E2USM wetland type, which is primarily west of the Highway 80 bend. All expected functions for the wetland area north of Highway 80 were rated as low because of the causeway. The unconsolidated shoreline wetland (E2USM) received low ratings for nutrient transformation and wildlife habitat and moderate ratings for carbon sequestration, sediment retention, and shore stabilization (GADNR 2012). In contrast, E2USN, which is also unconsolidated shore, received high ratings for all expected wetland functions. The E2USN wetland occupies most of the Oyster Creek RHA area where oysters provide ecosystem functions that maintain high quality wetland function and habitat.

Table 2. McQueens Island estuarine wetland functional assessment results summary (GADNR 2012).

Wetland Function	E2EM1N	E2EM1P*		E2USM	E2USN	Remaining Types
		West end	North of Hwy. 80			
Surface water detention	Low	Low	Low	Low	Low	Low
Coastal storm surge detention	High	High	Low	High	High	High
Streamflow maintenance	Low	Low	Low	Low	Low	Low
Nutrient transformation	High	High	Low	Low	High	High
Carbon sequestration	High	High	Low	Moderate	High	High
Retention of sediments/particulates	High	High	Low	Moderate	High	High
Bank/shoreline stabilization	High	High	Low	Moderate	High	High
Habitat for fish, aquatic invertebrates	High	High	Low	High	High	High
Habitat for waterbirds	High	High	Low	High	High	High
Habitat for wildlife	High	High	Low	Low	High	High
Habitat for unique or diverse plant communities	Low	Low	Low	Low	Low	Low

* Wetland type E2M1P is comprised of wetlands on the western end of McQueens Island and to the north of the causeway (Highway 80). Functions differ between these locations so are presented in two columns for E2EM1P.

SECN Coastal Wetland Elevation Monitoring: In addition to the water and sediment quality monitoring that is conducted by the NPS SECN in and around FOPU's wetlands (summarized in Chapter 2), SECN also monitors coastal wetland elevation at two sites in FOPU (Figure 9). At the time of this writing, SECN was finalizing revisions to its *Coastal Wetland Elevation Monitoring Protocol* (Baron et al. *in draft*), but scientists were able to begin baseline data collection in 2022.

SECN measures the wetland surface elevation and accretion/deposition at each site, which includes three Surface Elevation Table (SET) leveling devices equipped with a rod SET (or RSET) instrument. SECN samples biannually and compares the data over a period of approximately 5 years (or longer, if necessary, based on the degree of variability in elevation change; NPS SECN, C. Vervaeke, Coastal Ecologist, pers. comm. 19 January 2023). The rate of elevation change will be compared to the local rate of sea level rise. Marker horizon data are also collected from sediment cores biannually from nine plots within each study site. These data will provide information about the sources and processes of wetland elevation change. In addition, SECN scientists will survey RSET benchmarks at the study sites relative to the vertical datum every five years to determine absolute elevation. According to SECN Coastal Ecologist, William "Chesley" Vervaeke, "The SET measurements taken here along with others in throughout the southeast will be combined to make inferences about elevation changes in these marshes…. I suspect that both sites [at FOPU] will be representative of the areas that extend beyond the site itself, again allowing us to make inferences about these areas" (21 March 2023, pers. comm.). The SECN monitoring will help determine whether FOPU's wetlands are sufficiently accreting to keep pace with rising sea level.

What is the best strategy for managing McQueens Island salt marsh? Inland salt marsh migration is the most important factor in protecting salt marsh from sea level rise (Schuerch et al. 2018). Creating living shorelines with marsh plants and oyster shells to replace hardened shorelines is a direct action that improves a marsh's ability to migrate (Atlantic Coast Joint Venture 2019; GADNR 2013a). Approximately 0.22 ha (0.54 ac) of living shoreline was created in 2018 and regraded and replanted in 2020 on the north and south sides of the Fort Pulaski bridge to mitigate for wetland loss when the new bridge was built. After four years, the living shoreline's hydrology and wildlife habitat functions met the restoration reference standards, and the vegetation stem density standard was partially met (CDM Smith 2021). Coordinating the long-term monitoring findings for water quality, sediment, nutrients, and wetland elevation, along with the research that is being conducted in and around FOPU (e.g., Alexander and Calabria 2019), would focus efforts such as creating living shorelines in areas where wetland functionality has been degraded. This requires a landscape-level approach because of the scale of activities that impact the overall condition of the salt marsh (e.g., developments, shipping, sea level rise). Partnering and meeting annually with an integrated team of scientists, agencies, and adjacent Marine Protected Area managers would help FOPU managers set priorities and identify actions. Reinforcing the significance of McQueens Island eligible wilderness by identifying FOPU's desired wilderness values would provide further management direction and protect wetland functions. While Zinnert et al. (2021) expect Georgia's coastal marshes to persist over the next 100 years with sea level rise, maintaining functional wetlands at FOPU is crucial for protecting the marine life that depends on this habitat and to the surrounding communities, especially as the regional population continues to increase.

3.2. Shorebirds

The Georgia Barrier Islands (GBI) Western Hemisphere Shorebird Reserve Network (WHSRN) is a 32,257 ha (79,709 ac) area of hemispheric importance for migrating, wintering, and breeding shorebirds (Manomet n.d.). The GBI supports more than 30% of the biogeographic population of the *rufa* subspecies of Red Knot (*Calidris canutus rufa*) and of the Great Lakes breeding population of Piping Plover (*Charadrius melodus circumcinctus*); more than 10% of the biogeographic populations of American Oystercatcher (*Haematopus palliates*), Short-billed Dowitcher (*Limnodromus griseus*), and Black-bellied Plover (*Pluvialis squatarola*); and serves as one of the largest spring Whimbrel (*Numenius phaeopus*) gathering areas in North America (Manomet 2019). The Georgia Shorebird Alliance (GSA) is a collaborative partnership, which includes FOPU, whose goal is to stabilize declining shorebird populations in Georgia's section of the Atlantic Flyway—a major north-south fly route that follows the U.S. Eastern Seaboard, beginning in Greenland and extending to the tropical areas of the Caribbean, and South America (Manomet 2023a).

FOPU's shorebird habitats include the mud flats exposed at low tide throughout the monument's extensive salt marsh ecosystem and Cockspur Island's north and east shoreline beaches. Cockspur Island supports a significant horseshoe crab (*Limulus polyphemus*) spawning site in Georgia (GADNR, F. Smith, wildlife biologist, 30 March 2022, scoping workshop), whose eggs serve as a critical food source for long distance migratory shorebirds, such as the Red Knot, Ruddy Turnstone (*Arenaria interpres*), and Sanderling (*Calidris alba*). Fiddler crabs (*Uca pugnax*) are an important food source for Whimbrels and Willets (*Tringa semipalmata*), and local and regional scientists have witnessed the abundance of these crabs in FOPU's salt marshes. FOPU's salt marsh environment also supports Eastern oysters (*Crassostrea virginica*), which are an important food source for the American Oystercatcher—the only bird in its environment that can open large mollusks with its bill (Cornell University 2023).

Black-bellied plovers in non-breeding plumage observed in early spring during the International Shorebird Surveys (ISS) at FOPU. Image Credit: © PAM SMITH.

Gap Analysis Summary

We summarized shorebird data using the (1) International Shorebird Surveys (ISS) at FOPU (Manomet 2023b, c), and (2) focal shorebird species' relative abundance and trend estimates (Fink et al. 2022). Data summaries are presented in Figure 10.

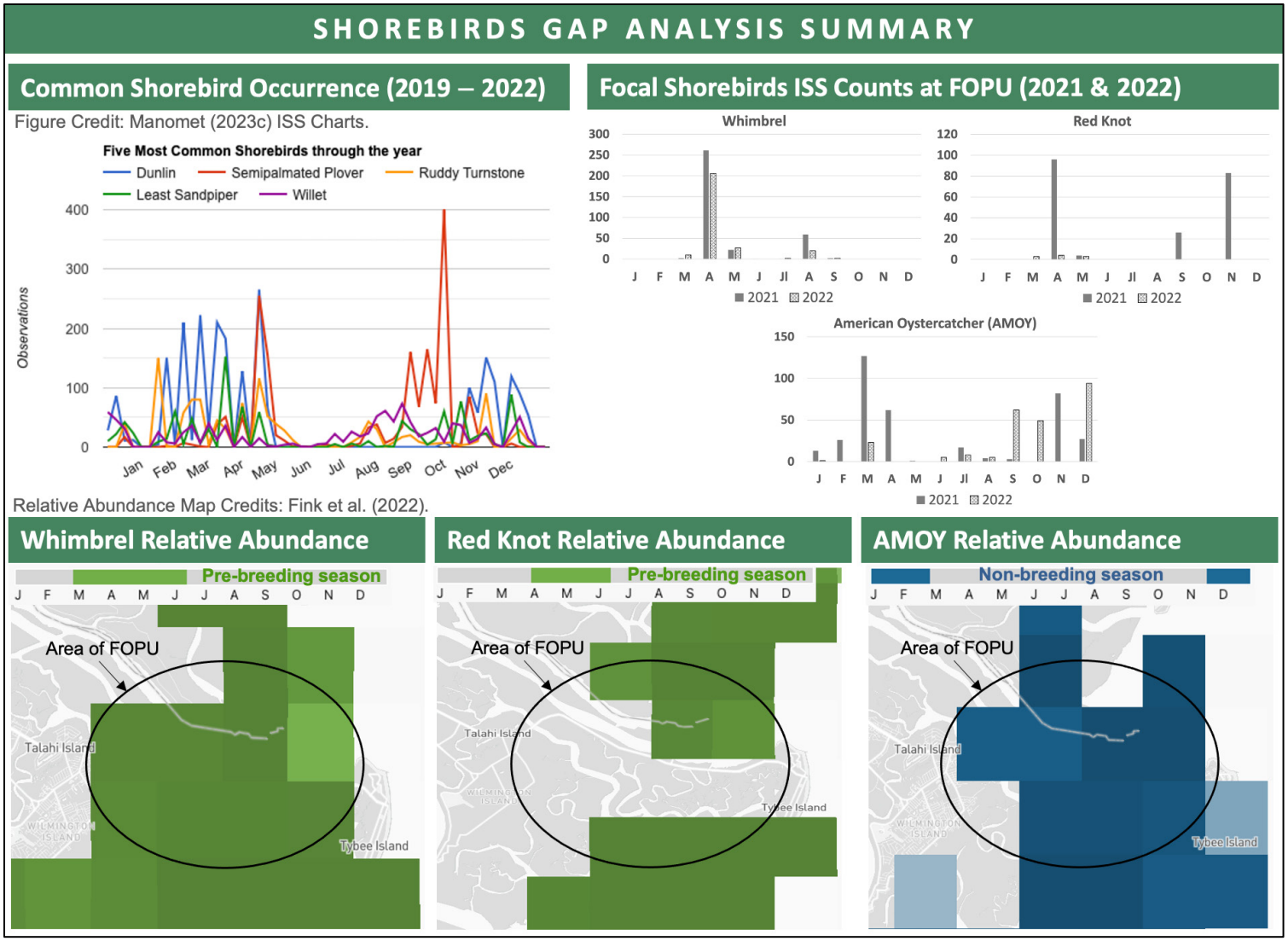


Figure 10. Data summaries for shorebirds: occurrence of the five most observed species (2019–2022); International Shorebird Survey (ISS) counts (2021 and 2022) for the three focal species; and the highest relative abundance season for the three focal species. The darker the shades of green or blue in the relative abundance maps, the higher the abundance for the focal species in that area.

International Shorebird Surveys: Manomet ISS surveys began at FOPU in 2019 along Cockspur Island's shoreline, with more consistent year-round survey efforts occurring in 2021 and 2022 (Manomet 2023c). Twenty-two shorebird species were recorded; however, not all species were observed every year. Of FOPU's 22 shorebird species, 11 are Atlantic Flyway focal species, whose life cycle needs reflect those of the additional shorebirds that use the flyway as breeding, staging, and/or wintering sites (NFWF 2018). The five most common shorebirds observed throughout the year at FOPU include Dunlin (*Calidris alpina*), Semipalmated Plover (*Charadrius semipalmatus*), Ruddy Turnstone, Least Sandpiper (*Calidris minutilla*), and Willet, although the Willet is more often observed during the fall (August–November) surveys (Figure 10). Of these five species, the Dunlin, Ruddy Turnstone, and Willet populations are declining (Cornell University 2023).

Additional shorebirds that are routinely observed at FOPU include the Semipalmated Sandpiper (*Calidris pusilla*), Sanderling, and Whimbrel during the spring (April–June) surveys and the Western Sandpiper (*Calidris mauri*) and Black-bellied Plover during the fall (August–November) surveys. During both the spring and fall ISS surveys, the Red Knot, American Oystercatcher, and Short-billed Dowitcher are commonly observed and are the focal species for conservation efforts in the flyway.

Focal Shorebird Relative Abundance and Trend: The National Fish and Wildlife Foundation (NFWF 2018) focuses its conservation actions on the Whimbrel, Red Knot, and American Oystercatcher (out of 15) high priority shorebirds. These three were selected as the focal species for the remaining shorebirds within the Atlantic Flyway because they have sufficient data to establish population goals and to identify changes over time (NFWF 2018). Characteristics of the focal species are summarized in Table 3, including the habitat types that are targeted for their conservation.

Table 3. Characteristics of the focal shorebird.

Species	Listing Status	Migration Distance	Target Habitat for Conservation Actions at FOPU (NFWF 2018)	Diet
American Oystercatcher	Rare species of concern in Georgia	Short, year-round	Breeding sites of beaches, estuaries, and marshes	Shellfish, marine invertebrates, bivalves
Red Knot	Federal and state threatened	Long	Coastal roosting and foraging beaches, islands, and marshes	Horseshoe crab eggs in spring, bivalves
Whimbrel	Not protected	Middle	Coastal roosting and foraging beaches, islands, marshes	Fiddler crabs, marine invertebrates

Statistical models of the relative abundance and trend for shorebirds are available using eBird data (Fink et al. 2022). Relative abundance is calculated as the count of a species for 52 weeks in a year, then grouped by each species' season of activity (i.e., breeding, non-breeding, pre-breeding, or post-breeding) across a spatial grid of 2.96 km x 2.96 km (1.8 mi x 1.8 mi) (Fink et al. 2022). The average relative abundance estimates for the Whimbrel, Red Knot, and American Oystercatcher at FOPU, and the surrounding region, are shown in Figure 10 for the season with the highest estimated abundance. In addition, ISS counts for these species at FOPU for the survey seasons of 2021 and 2022 are shown in Figure 10.

Focal Species, Whimbrel: The Whimbrel is a medium distance migratory species of high concern due to its declining 30-year estimated U.S. population trend of 40,000 (low confidence estimate; Andres et al. 2012, as cited in NFWF 2018). Its average estimated relative abundance is highest during the pre-breeding migratory season (1 March–14 June), with the highest estimate of 12.46 occurring just south of McQueens Island at Little Tybee Island State Heritage Preserve (as compared to 1.40 at McQueens Island and 3.10 for Cockspur Island) (Figure 10). FOPU's ISS spring survey counts for the Whimbrel were highest in April, during 2021 (n=261) and 2022 (n=206). The Whimbrel does not breed within the region but is estimated as present in lower numbers during the post-migratory season (28 June–2 November) and negligible during the non-breeding season (9 November–22 February). No trend was estimated for the Whimbrel.

Focal Species, Red Knot: The Red Knot is a long-distance migratory species that is highly imperiled due to its declining 30-year estimated U.S. population trend of 42,000 (high confidence estimate; Andres et al. 2012, as cited in NFWF 2018). The Red Knot's average estimated relative abundance is highest during the pre-breeding migratory season (5 April–14 June), especially to the north (24.75) and south (164.6) of FOPU (2.90 for Cockspur Island) (Figure 10). FOPU's highest Red Knot ISS survey count was in April 2021 (n=96), although 83 individuals were observed during November of that same year. High numbers of Red Knots have been observed on Little Tybee Island State Heritage Preserve, south of McQueens Island, where a few pairs remain year-round to breed (Fink et al. 2022). However, the region is far more significant to its pre-breeding migratory needs as compared to the post-breeding migratory season (6 July–7 December), then increases in abundance during its non-breeding season (14 December–29 March). The 2021 estimated trend for the Red Knot's relative abundance during its non-breeding season (14 December–15 March) from 2007 to 2020 is a decrease of 81% (with an upper confidence level of −71% and a lower confidence level of -87% within a 27 km x 27 km (16.8 mi x 16.8 mi) area surrounding FOPU (Fink et al. 2022). It's important to note that all estimated trends for Red Knot abundance are declining (Fink et al. 2022), but the USFWS (2023) is seeking additional critical habitat, which will include Cockspur Island.

Focal Species, American Oystercatcher: The American Oystercatcher is a short distance migratory species that is of high concern, but because of focused conservation efforts, its 30-year estimated U.S. population trend of 11,284 is improving, with a 95% confidence interval of 10,700–11,300 individuals (Andres et al. 2012, as cited in NFWF 2018). Of the three focal species, the American Oystercatcher has the highest year-round average estimated relative abundance and is most widespread throughout the region (Figure 10). It is estimated at its highest abundance at FOPU during its post-breeding migration (31 August–16 November; 8.27) and non-breeding (23 November–22 February; 7.32) seasons. FOPU's ISS counts were highest during the non-breeding and pre-breeding seasons. In March 2021, a high count of 127 oystercatchers was observed, underscoring the region's year-round importance to the conservation of this species. The 2021 estimated trend for the American Oystercatcher's relative abundance during its breeding season (17 May–18 June) from 2007 to 2020 is a decrease of 30% (with an upper confidence level of −3.3% and a lower confidence level of −48% within a 27 km x 27 km (16.8 mi x 16.8 mi) region that includes FOPU (Fink et al. 2022). American Oystercatcher trends are unknown for the coastal habitats to the north and south of FOPU.

How can the dredge spoils from the Savannah River maximize FOPU's shorebird habitat? The NFWF (2018) targets habitats for the lifecycle needs of the American Oystercatcher, which include breeding sites in estuaries, marshes, and beaches. The high priority habitats for the Whimbrel and Red Knot include coastal roosting and foraging beaches, islands, and marshes. FOPU's contribution to shorebird conservation is especially relevant to the region because the monument is surrounded by three National Audubon Important Bird Areas (IBAs) (NAS n.d.). The IBAs are Turtle and Tomkins islands, north of Cockspur Island in Jasper County SC, and Little Tybee Island State Heritage Preserve, GA, south of McQueens Island. Because migratory shorebirds follow their food sources to obtain energy for their migrations, FOPU's beach habitat, where dredge material can improve conditions for shorebirds, should include areas that are suitable for the focal species' diets of marine invertebrates and horseshoe crab (HSC) spawning areas, especially to support the conservation of the *rufa* Red Knot, which is listed as a federal and state threatened species.

In 2015, the U.S. Army Corps of Engineers (USACE) placed dredge spoil on the north shore of Cockspur Island to protect cultural resources from erosion (Peffer 2019), while also creating a larger footprint for shorebirds. More recently, the USACE created a bird island using reclaimed dredge material from the Altamaha River to provide habitat for sea and shorebird roosting and foraging, and for HSC spawning (USACE 2022). The USACE is gathering information to address the issues encountered (e.g., elevations) during the bird island creation project and is currently evaluating the placement of dredge material at FOPU (USACE, S. Hill, NEPA team lead, personal communication, 14 March 2023). The USACE is also consulting with HSC experts about the use of dredged material to identify the best methods for constructing the physical characteristics necessary for HSC spawning (USACE, S. Hill, NEPA team lead, personal communication, 14 March 2023).

Adult HSCs arrive onto sandy beaches in the spring to spawn from the Atlantic Ocean, which is cued by water temperature and the moon cycle (Smith et al. 2019). Georgia's peak spawning activity typically occurs in late April to late May during full and new moon high tide evenings. During several successive tides, female HSCs lay clusters of eggs in sandy substrates, then males fertilize the eggs. The fertilized eggs remain buried, serving as a critical food source, especially for spring-staging Red Knots, until hatching occurs. HSC reproductive success has been greatest when the substrate around the eggs is well oxygenated (Note: grain sizes differ along the Atlantic Coast, with finer sediments found in SC to FL compared to DE), eggs are sufficiently moistened by tides without being washed away, the beach is exposed to sunlight for incubation, and the beach slope enables larvae to orient and travel to the water after hatching (Shuster 1994, as cited in ERDG 2003–2009).

The Red Knot's estimated relative abundance was highest at all three IBAs and the map in Figure 10 shows that there's a gap in their habitat usage at FOPU. This represents a significant data gap that, if explored, could contribute to a top priority goal of conserving this species through habitat improvements, especially for its foraging needs, since FOPU already supports a significant HSC spawning site in Georgia. ISS surveyors commented that on the days of "extraordinary numbers of shorebirds [at FOPU], there was an abundance of horseshoe crab eggs, it was high tide, and there had been no disturbances by people", with the latter comment reflecting the monument's beach closure due to the COVID-19 pandemic.

3.3. Eastern Oyster

The Eastern (American) oyster (*Crassostrea virginica*) is a keystone species in estuaries along America's Atlantic and Gulf coasts, filtering water, stabilizing salt marshes, and providing habitat for crabs, fish, invertebrates, and a variety of macrofauna (NOAA 2022). In the early 1900s, Georgia led the U.S. oyster harvest with nearly 8 million pounds (GADNR n.d.(c)). Since then, a decrease in oysters has occurred due to over harvest, pollution, including increased impacts from microplastics (Yu et al. 2018; Whitmire and Toline 2018), diseases, and altered hydrology and salinity regimes (Zu Ermagassen et al. 2012; Baggett et al. 2014).

The Georgia Department of Natural Resources (GADNR) Coastal Resources Division manages the state's oysters in five shellfish growing areas (SGAs) along the coast. SGAs may include recreational harvest areas (RHAs) and commercial harvest areas, with the latter including wild harvest and mariculture zones. In 2022, three, 3-ha (7.5-ac) leases were permitted within an 11.3-ha (28-ac) subtidal mariculture zone in Chatham County's SGA, with the lease's closest boundary located approximately 2.7 km (1.7 mi) from FOPU's nearest boundary. The Chatham County SGA also includes Oyster Creek RHA—a 513-ha (1,267-ac) area that is entirely within FOPU and comprises ~23% of the monument's McQueens Island salt marsh habitat. FOPU manages most of McQueens Island, including Oyster Creek RHA, as proposed wilderness within the Tybee and Bull rivers, the Lazaretto and St. Augustine creeks, and the intra-coastal waterway (NPS 2013). While oysters occur at other locations in the monument, approximately 70% of FOPU's oysters, as mapped by GADNR (2013b), are concentrated within Oyster Creek RHA's boundary.

Eastern oysters (center) in McQueens Island's Oyster Creek Recreational Harvest Area. Image Credit: NPS.

Gap Analysis Summary

We summarized data for (1) oyster area, (2) oyster density, and (3) spat recruitment for a GADNR 2013 oyster enhancement project in Oyster Creek RHA. Data summaries are presented in Figure 11.

Oyster Area: The earliest survey of oysters within and nearby present-day FOPU was in 1889 (Drake 1891), who recorded an area of 0.71 ha (1.75 ac) for Oyster Creek. Two more surveys of GA's oysters were conducted in 1925 (Galtsoff and Luce 1930) and from 1966 to 1967 (Linton 1969). Harris (1980), who conducted a survey from 1974 to 1977, recorded an oyster area of 0.08 ha (0.2

ac) for Oyster Creek. Harris (1980) concluded that the distribution of intertidal GA oysters was similar to that in 1889, but the extent was "much reduced" and that the reasons for the decline were complex. Harris (1980) noted that failing to replace shells in harvested areas, which was GA law since at least 1889, was "probably the most significant reason for the depletion of GA's oysters." Harris (1980) cited difficulty in enforcing shell replacement to harvested areas, diseases, lack of an adequate shellfish sanitation program, and ownership of riparian rights as factors influencing the state's oyster decline between 1889 and 1977. Because different methods were employed for the oyster surveys, areas should not be compared.

In 2013, GADNR mapped oysters for GA's coastal counties of Chatham, Liberty, McIntosh, and Glynn, using 2012–2013 imagery, with a minimum mapping unit (MMU) of 5 m^2. Camden County was excluded from the analysis, which includes three RHAs that are in Cumberland Island National Seashore. Oysters in Chatham County's Oyster Creek RHA accounted for over 75% of the total oyster area mapped in the four coastal counties' RHAs. GADNR (2013b) mapped 21.6 ha (53.3 ac) in FOPU, with 70.5% of the total (15.2 ha [37.6 ac]) in the Oyster Creek RHA boundary. An additional 3.4 ha (8.5 ac) of oysters were mapped to the east of Cockspur Island's east side—an area that is accreting beyond FOPU's boundary. Using 2018 imagery, Hoover and White (2022) remapped the GADNR (2013b) oyster areas within FOPU, with a MMU of 0.427 m^2. While a comparison between the GADNR (2013b) and Hoover and White (2022) oyster areas is not recommended, Hoover and White (2022) evaluated oyster densities between the datasets.

Oyster Density: Hoover and White (2022) spectrally analyzed the 2013 and 2018 imagery to derive oyster densities between the two oyster area datasets (GADNR 2013b; Hoover and White 2022). Image pixels were grouped into segments by an average color (i.e., spectral signature), resulting in three oyster density classes: high, moderate-low, and non-oyster. The high-density oyster class was most accurate because there were fewer land cover types (e.g., mud flat) present that would confound the oyster spectral signature. The high-density oyster areas accounted for 5.6% (2013) and 9.7% (2018) of the mapped areas, which were primarily in and around Oyster Creek. The moderate-low density oyster class accounted for most of the mapped oysters in both years (78.1% in 2013 and 69.1% in 2018), with more mud flats influencing the spectral characteristics and the performance of the segmentation. Paul Medders with GADNR stated, "that the resolution [used to map the 2013 oyster dataset] is not good enough to distinguish the sparser reefs. The really dense and medium density reefs were probably captured" (pers. comm. 5 April 2023).

Hoover and White (2022) reported that "the non-oyster class achieved higher accuracy in 2013 due to the tighter polygons digitized around the oyster colonies. Since the 2018 polygons were digitized slightly larger than the 2013 polygons, more land cover types were included in the non-oyster classification…", accounting for 21.1% and 16.3% of the mapped areas, respectively. The additional land cover types would inflate the actual area of oysters.

Spat Recruitment: In 2013, the GADNR placed 15 marked bags of oyster shells to recruit wild oyster spat within a cumulative length of 296 m (970 ft) along Oyster Creek (GADNR 2022b). Biologists counted the mean number of spat on five separate occasions, beginning in August 2013, and ending

in January 2015 (Figure 11; GADNR 2022b). GADNR (2013b) reported 2.68 m2 (28.8 ft2) of oysters within the pre-enhancement area.

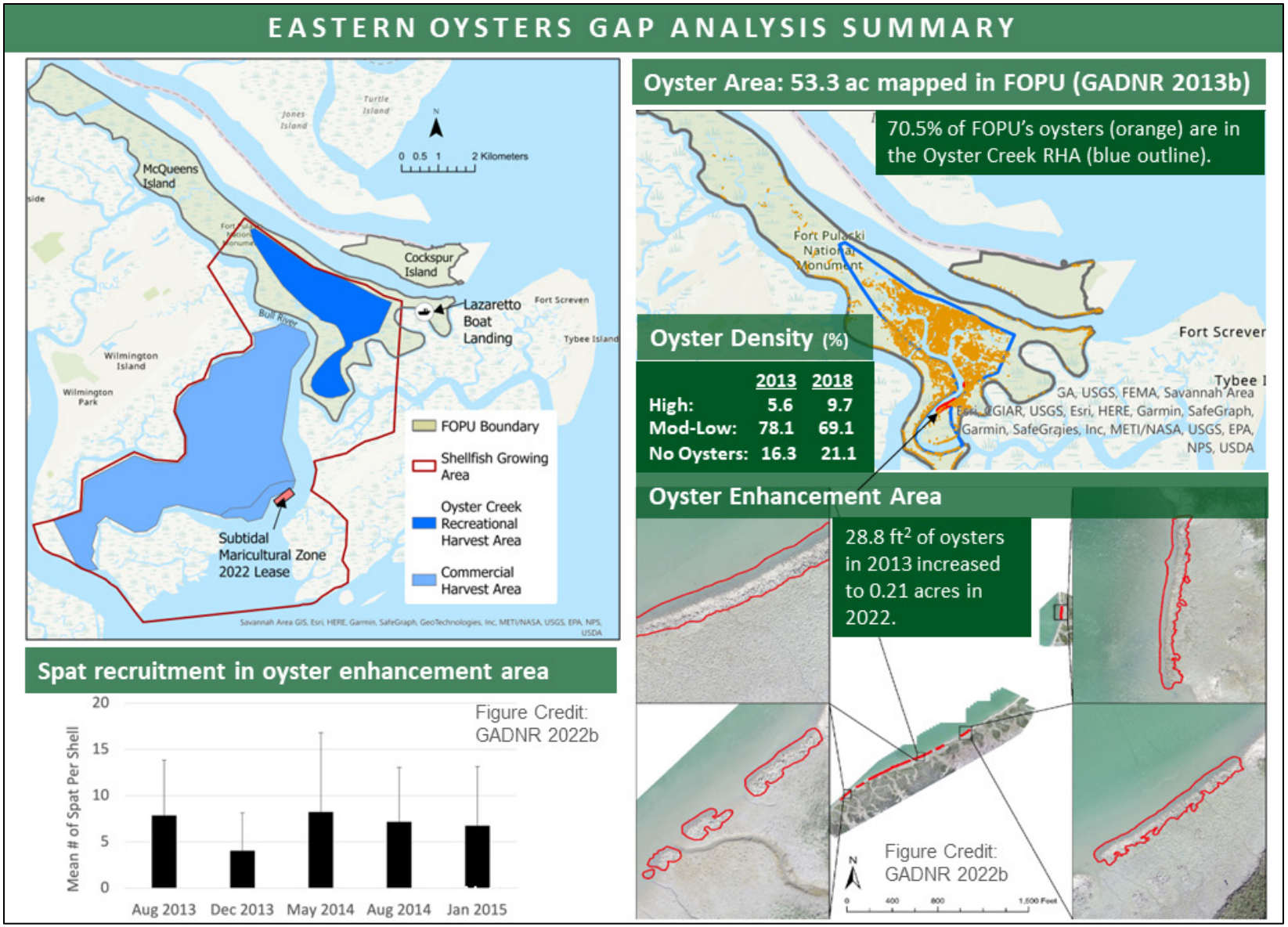


Figure 11. Data summaries for Eastern oysters: location map, oyster area, density, enhancement area, and spat recruitment mean count.

Hoover and White (2022) reported 894.2 m^2 (0.22 ac) of oysters within the enhancement area, using 2018 imagery, which is consistent with GADNR's (2022b) aerial and visual survey results of 849.8 m^2 (0.21 ac). The enhanced oyster area accounts for approximately 0.62% of the total oyster area in Oyster Creek RHA (Hoover and White 2022), and GADNR (2022b) reported that the enhanced reef remains self-sustaining after nine years.

Is recreational harvesting of oysters in Oyster Creek RHA sustainable? Long-term monitoring is needed to detect a change in oyster sustainability. Appendix A, Table A-1, lists proposed indicators, measures, and reference criteria to evaluate the natural quality of oysters at FOPU. The framework is based on NOAA's *Oyster Habitat Monitoring and Assessment Handbook* (Baggett et al. 2014) and on the MarineGEO *Oyster Reef Habitat Monitoring Protocol* (2021), with the latter being largely based on Baggett et al. (2014). Data need to be standardized, quantitative, and delivered in a timely manner for effective oyster management to occur, and remote sensing techniques are becoming increasingly promising as a tool to map and monitor intertidal oysters (Kingsley-Smith 2022). Hoover and White (2022) suggest that "an unmanned aerial vehicle (UAV) could collect imagery at a pixel resolution of 2 cm^2 at low tide that would result in a resolution, where individual oysters could be identified. This type of high-resolution imagery would greatly improve all oyster and non-oyster cover classes. However, it would most improve the moderate-low and non-oyster [density] classes, where sparsely distributed and smaller colonies exist. In addition, the data collection could cover the entire tidal flat instead of the limited area analyzed here [in Hoover and White (2022)]. A UAV also collects images with a high percentage of overlap that result in a 3D dataset that has a similar spatial resolution. The 3D elevation data or digital elevation model (DEM), with a high spatial resolution, could provide accurate height data of each oyster colony, and volume could be calculated." Working in partnership with GADNR could ensure that goals, especially related to preserving McQueens Island wilderness character, would be based on a mutual understanding of monitoring metrics, methods, and reporting cycles. Natural or reference sites will need to be included in the monitoring design for a reliable comparison to areas that are harvested.

Paul Medders with GADNR stated that the GADNR obtained the Harris (1980) and Drake (1891) oyster survey maps and will be scanning, photographing, and georeferencing them. Even though the methods were different between the surveys, GADNR will overlay these older surveys with the 2013 oyster dataset, which should assist future mapping projects. This information will help inform the reference criteria for GA's oysters and how to enhance the population to mitigate climate change and population growth (GADNR, P. Medders, marine biologist, pers. comm., 5 April 2023).

Is recreational harvesting of oysters impacting the wilderness character of McQueens Island salt marsh? The wilderness characteristics that are cited in FOPU's General Management Plan and Wilderness Study (NPS 2013) are from the Wilderness Act (1964). These are general statements and are listed in Table 4. Specific indicators, measures, and reference criteria need to be identified by FOPU managers to track the wilderness character trend. Landres et al. (2014) suggest reporting a trend every five years.

We propose a monitoring framework in Appendix A, Table A-1, to monitor the natural condition or character of oysters, but without specific measures and associated data to compare to the monument's

wilderness character goal(s), we can only discuss the *potential* impacts from oyster harvesting and associated activities, such as boating, to FOPU's wilderness character on McQueens Island.

Table 4. Wilderness character statements and descriptions.

Wilderness Character Statement (NPS 2013 Sec. 2(c))	**Description (Landres et al. 2014)**
The earth and its community of life are untrammeled by humans, where humans are visitors and do not remain.	This includes authorized and unauthorized actions that manipulate the biophysical environment, such as oyster reef restoration, illegal harvesting, or scientific research.
The area is undeveloped and retains its primeval character and influence without permanent improvements or human habitation.	Undeveloped includes physical structures and the use of motorized equipment or mechanical transport.
The area is protected and managed to preserve its natural conditions.	This means that "ecological systems are substantially free from the effects of modern civilization." Indicators may include plant and animal communities, physical resources, and biophysical processes and impacts to the indicators. The proposed monitoring framework in Appendix A, Table A-1 would address this aspect of wilderness character for oysters.
The area offers outstanding opportunities for solitude or a primitive and unconfined type of recreation.	Solitude includes remoteness from developed sights and sounds both in and out of the wilderness area. It also includes self-reliant recreation and management restrictions on visitors.
The area generally appears to have been affected primarily by the forces of nature, with the imprint of humans' work substantially unnoticeable.	This combines many of the characteristics of wilderness described above and refers to additional aspects of the area that contribute to the wilderness character (e.g., species of concern).

To recreationally harvest oysters in FOPU's proposed wilderness, a motorboat is needed for access, but no physical structures are present within the monument's wilderness boundary. Instead, Chatham County manages the Lazaretto Creek public ramp, which provides boat access to the Oyster Creek RHA, which is in FOPU's wilderness in its entirety. When boats launch from the ramp, they are not in (but adjacent to) FOPU's proposed wilderness because of GA's public trust tidewater areas. Motorboating is considered a traditional use of the area prior to being designated as eligible wilderness, thus is allowed (NPS 2013). However, noise and visual intrusions from boat motors and visitors may impact opportunities of solitude, especially depending on the number of boaters. The GADNR implements annual harvest restrictions when the water temperature reaches 81° F (27.2° C), which is usually from June through September. It's a difficult area to patrol because of accessibility, and illegal harvesting may occur. Adding signage at the Lazaretto Creek boat ramp may help inform and educate visitors of FOPU's desired characteristics of its eligible wilderness area, especially as it relates to activities that may impact the plant and animal communities, including research activities. One example is a research study that was conducted in the Oyster Creek RHA during a typical seasonal closure timeframe. The study methods included oyster collection, apparently without the required NPS permit (NPS 2022b). This serves as an example of how signage may help with the monument's enforcement of best practices, for oyster harvesting or scientific research that is conducted within FOPU's eligible wilderness.

3.4. Butterflies

Birds, bats, invertebrates (e.g., butterflies, bees, beetles), and many small mammals serve as pollinators. Pollinators are important because they transfer genetic materials between plants that are necessary for approximately 75–95% of all flowering plant reproduction (Ollerton et al. 2011). Pollinated plants contribute to healthy ecosystems by stabilizing soils, cleaning the air, and supporting other wildlife populations (Costanza et al. 1997). In recent years, the importance of pollination has received more focused attention because of declines in pollinator populations (Pollinator Partnership 2022). In 2014, a Presidential Memorandum "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," was issued to reduce stressors on pollinator health, which include the loss in feeding and nesting habitats, disease, exposure to chemicals, and changes in climate patterns (Pollinator Health Task Force 2015; National Research Council of the National Academies 2006; Kremen et al. 2002).

Butterflies are an important group of pollinators that are highly sensitive indicators of ecosystem health (USFWS n.d.(b)). Georgia hosts approximately 171 species of butterfly, accounting for almost 23% of North America's 750 species documented north of Mexico (GADNR n.d.(d)). Georgia's coastal region supports 69% (118) of the state's butterflies, with 19 species restricted to this region alone.

Habitat destruction and climate change threaten the migratory monarch butterfly. FOPU managers began working with Butterflies of the Atlantic Flyway Alliance (BAFA) scientists in 2021 to record the number of migratory monarchs at the monument. Image Credit: © PATRICIA VALENTINE-DARBY.

Gap Analysis Summary

We summarized data for (1) butterfly occurrence (i.e., presence, abundance, diversity); and (2) plants for a) adult egg-laying (host), b) larva food sources (host), c) nectar sources, and d) migratory butterfly roosts. The plants data were further analyzed to identify butterfly habitat. Data summaries are presented in Figure 12.

Butterfly Occurrence: Scientists with the Butterflies of the Atlantic Flyway Alliance (BAFA) began monitoring the fall butterfly migration in 2021 at three sites in FOPU. Monitoring occurs annually from August to November for three target species: monarch (*Danaus plexippus*), gulf fritillary (*Agraulis vanillae*), and cloudless sulphur (*Phoebis sennae*). BAFA surveyors document four additional species which include the American lady (*Vanessa virginiensis*), painted lady (*Vanessa cardui*), common buckeye (*Junonia coenia*), and long-tailed skipper (*Urbanus proteus*). The target species observed on 13 occasions from August 9 to November 11, 2021, was highest between September to October (BAFA 2021) (see Figure 12). BAFA data serve as a baseline for future comparisons and represent approximately 3% (4/118) of the butterfly species that potentially occur at FOPU based on checklists (Georgia Butterflies 2009; GADNR n.d.(d); Coastal Wildscapes n.d. a, b; Howard 2020) and from local or regional sightings in iNaturalist (2022) and Butterflies and Moths of North America (BAMONA 2022, with attribution to Lotts and Naberhaus 2022) databases. However, it's important to note that some of the 118 species' host plants may not occur at FOPU, such as *Cardamine* spp. for falcate orangetip (*Anthocharis midea*), so the potential number of butterfly species may be fewer because the plant for a species' lifecycle is absent versus undocumented.

Butterfly Plants: We compiled a list of butterfly host, nectar, and roost plants that occur in coastal GA using Hayes (2019, 2022), Coastal Wildscapes (n.d. (a, b)), and Tweedy (2022a, b). The nectar species reflect the more commonly known sources, but there are likely more than what we listed because butterflies will use any blooming flower as a nectar source. We then compared the comprehensive plant list to plant occurrence records from vegetation surveys at FOPU (Byrne et al. 2012; McManamay et al. 2013; Boyle and Rico 2021; and NPSpecies 2022, which includes Southeastern Wildlife Services, Inc. (1980) and Govus (1998) surveys). We also compared the list to Fisichelli et al. (2014) to identify climate change-sensitive species.

Sixty-nine host (n=49), nectar (n=29), or roost (n=3) plant species were recorded in 33 vegetation monitoring plots (Byrne et al. 2012; McManamay et al. 2013; Boyle and Rico 2021) at FOPU. Fisichelli et al. (2014) identified white oaks (*Quercus* spp.) as the only species that are expected to experience a large increase with a changing climate, which serve as host species for four of the 118 potential butterfly species at FOPU.

Are there certain habitats to restore to encourage pollinators? McManamay et al. (2013) mapped 12 natural vegetation types (1,832.1 ha [4,527 ac] and two cultural vegetation types (57.6 ha [142.3 ac] at FOPU. The Southern Atlantic salt marsh habitat alone accounts for a little over 80% of FOPU's total vegetation, which serves as habitat for three species of skippers, as compared to the remaining 402.5 ha (994.6 ac), primarily on Cockspur Island, supporting most of the potential species of butterfly. To identify the habitats containing plants for butterflies, we overlaid the 33 vegetation plots containing at least one beneficial plant onto the 14 vegetation classes.

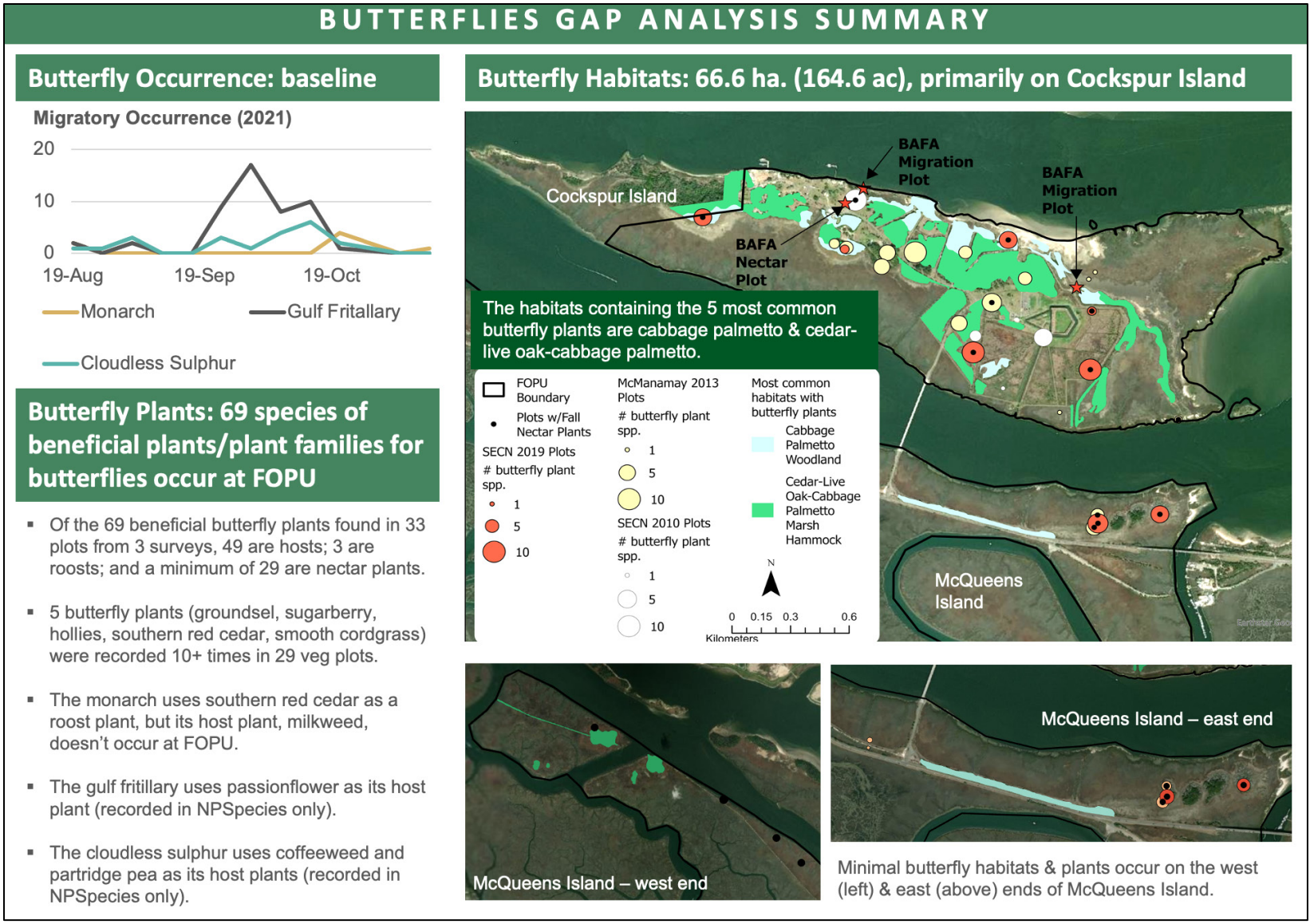


Figure 12. Data summaries for butterfly occurrence, butterfly plants (shown as circles in the map), and butterfly habitats.

Because nearly every vegetation type at FOPU contains at least one beneficial butterfly plant, we selected plots in habitats containing the most observed butterfly plants. The Cedar–Live Oak–Cabbage Palmetto (*Juniperus virginiana var. silicicola–Q. virginiana–Sabal palmetto,* 52.9 ha [130.7 ac]) Marsh Hammock and the Cabbage Palmetto Woodland (13.7 ha [33.9 ac]) contained the most diversity of beneficial butterfly plants. The largest area of the marsh hammock community grows on the older dredge spoil deposits on Cockspur Island's highest elevations (McManamay et al. 2013), primarily north of the salt marsh on the south side of the island and west of the fort. This forest is dense with 70–90% tree canopy cover of 10–20 m (32.8–65.6 ft) tall trees (McManamay et al. 2013). The woodland has a more open tree canopy cover of approximately 60% (McManamay et al. 2013), and as a result, may be more susceptible to invasions of non-native plants. Typically, more open landscapes benefit butterflies, but because managers need to consider other species' needs, such as neotropical migrants, a diversity of habitat types typically ensures a diverse mixture of species.

Where are the prime areas for fall-blooming plants? We identified 27 plant species at FOPU as fall nectar sources. Of these species, only 10 were observed in 16 vegetation plots, with groundsel tree (*Baccharis halimifolia / B. angustifolia,* n=10) and goldenrod (*Solidago* spp., n=6) most observed in the Cabbage Palmetto Woodland, a maintained lawn area southeast of the fort, and in the South Atlantic Coastal Shell Midden Woodland habitats, with the latter habitat overrepresented due to the close proximity of several vegetation plots. The plots containing the fall nectar species tend to be along the perimeter of the marsh hammock and Cabbage Palmetto Woodland where sun exposure is greatest. Fall nectar plants (primarily asters [*Symphyotrichum* spp.]) were recorded in the Atlantic Giant Cordgrass Marsh (*Spartina cynosuroides*) habitat on the west end of McQueens Island. Sixteen of the remaining nectar plants are on NPSpecies only and haven't been observed by Byrne et al. (2012), McManamay et al. (2013), and Boyle and Rico (2021), and Hayes (2022) been the only survey to document the presence of moss vervain (*Verbena aristigera*).

What potential actions can FOPU managers take to improve conditions for pollinators? Pollinator habitat needs to include a mixture of plants for food, shelter for protection, including roosting sites, and sources of water targeted for the butterfly species that are present. Pollinator Partnership (n.d.) identifies several activities to increase pollinators for public land managers in the Outer Coastal Plain Mixed Province where FOPU is located. Some of these activities include connecting areas of vegetation, minimizing lawn areas that support recreational needs, and restricting the use of pesticides and herbicides. Because FOPU's prime butterfly habitats are next to areas that are mowed, any areas that managers can naturalize would improve habitat connectivity and species protection. FOPU managers are currently restoring the open area near the maintenance building and headquarters to increase nectar plant species and have experimented with a reduction in mowing at the visitor picnic area based on mowing management recommendations from J. Calabria with the University of GA (Figure 12). Further identification of areas to naturalize while mowing the priority cultural, recreational, and human health and safety areas will support visitors' needs and all species of pollinator. A reduction in mowing areas also minimizes the potential for transporting non-native invasive plant seeds or runners that adhere to equipment.

The mowed areas on Cockspur Island, north of the salt marsh and along the Tybee Coast Guard Station Drive bisect habitat, further exacerbating the impact of the drive. Also, continuing to restore open, mowed areas to native meadows that are next to butterfly habitat(s) not only improves habitat for host and nectar plants but also serves as educational opportunities to help visitors (and staff) understand the important ecosystem role pollinators have in the environment. The pollinator meadow that is currently being restored at FOPU can inform future restoration efforts in other locations at the monument, ideally in areas where vehicular traffic is less likely to result in butterfly mortality.

Exposure to chemicals is one of the primary stressors negatively impacting pollinator populations (Pollinator Health Task Force 2015) but controlling for mosquito-borne viruses is a priority at FOPU, which may include chemical applications. Of the 40 species of mosquito in Chatham County, 11 are nuisance or disease vectors (Georgia Mosquito Control Association, n.d.). The mosquitos of concern at FOPU are salt marsh mosquitos (SMM) (*Aedes sollicitans, A. taeniorhynchus*), which breed in temporary or isolated pools within salt marshes and are a prime vector of the Eastern Equine Encephalitis (EEE) virus—a virus that attacks the central nervous system. No EEE cases have been reported from FOPU; however, the last reported human disease case elsewhere in Chatham County was in 2019 (CDC 2023) but is considered "relatively rare" by county officials (Mosquito Control Memorandum 2013). In 2017, non-human EEE infections were reported in the county (CDC 2023).

According to the Chatham County Mosquito Control (CCMC) Department, the primary breeding sites for SMMs at FOPU are the islands of Jasper County, SC where the U.S. Army Corps of Engineers (USACE) deposit dredge spoils from the Savannah River, inadvertently creating "ideal salt marsh mosquito breeding habitat" (Mosquito Control Memorandum 2013). SMMs can fly up to 64.4 km (40 mi) from an original source of water and the larva can tolerate brackish wetlands, from dense marshes to shallow pools fed by rainwater and high tides. The areas of FOPU where the SMMs are of concern are the upland areas of Cockspur Island—the same areas of prime butterfly habitat.

FOPU managers are currently reevaluating their Integrated Pest Management (IPM) program to reduce risks to the public and monument resources by evaluating the efficacy of larvicide and adulticide applications to control mosquitos on Cockspur Island. CCMC applies chemicals between April 11 and October 31, but in some years have sprayed in December because it's a rain-driven operation (CCMC, R. Moulis, assistant director, personal communication, 19 July 2022). The county uses the spring tides during the full and no moon cycles to its control advantage since they flood the high marsh areas. CCMC also applies more chemical (10 lbs. sand/1 oz. of chemical) on the sandy soil at FOPU because of its high porosity (CCMC, R. Moulis, assistant director, personal communication, 19 July 2022). FOPU managers are also actively consulting with NPS IPM coordinators about the use of chemicals to update the monument's Mosquito Control Memorandum with CCMC and are also working with the USACE to restore the hydrology of the canal network that flushed and drained water from Cockspur Island. Approximately 1.2 ha (3 ac) of canals bisect the monument's butterfly habitat (USACE 2021). Draining areas of standing water where mosquitos breed and using chemical suppression to control mosquito larvae and adults are effective management approaches to control *Aedes* spp. in salt marshes, ideally areawide, to address the latter control effort, given the species' ability to disperse over long distances.

Chapter 4. Management Considerations

The Chapter 4 management considerations are presented by the focal resources evaluated in Chapter 3 and are based on the NRCA findings and information gathered to provide managers with next steps for furthering science-informed management. While the purpose of an NRCA is to synthesize information to deliver natural resource conditions or status of knowledge summaries for topics of park interest, the purpose of the NPS Resource Stewardship Strategy (RSS) and other park planning processes is to establish resource goals and strategies to achieve desired resource outcomes.

4.1. Salt Marsh

- **Assemble an interagency team to manage salt marsh at the landscape-level.** FOPU's salt marsh is an interconnected network of tidal creeks and habitat. The scale of impacts to this system warrants a coordinated effort across the various monitoring and research efforts and from the regulatory agencies that manage some of the impacts, such as dredging, transportation, and housing. In addition, FOPU is next to other Marine Protected Areas, which could become an ad hoc network, working together to manage the salt marsh habitat that is critically situated near Savannah, GA, providing protection from storm surges and sea level rise.
- **Explore the protective connection to Bird-Long islands.** Muscalus (2022) confirmed the propagation of ship wakes in the Savannah River's south channel from a breach between Bird-Long islands and Cockspur Island. The south channel separates Cockspur and McQueens islands, so the potential for increased erosion from ship wakes may become a major impact to McQueens Island salt marsh habitat. At the time of the Muscalus (2022) study, the size of ships entering the Savannah River was smaller than the New-Panamax container ships that now can enter after the Savannah Harbor Expansion Project was completed in 2022, deepening the channel. Muscalus (2022) recommended a study that modelled the wave propagation in the south channel by obtaining bathymetry of the river depth. FOPU could submit a STAR request to the NPS Water Resources Division Ocean and Coastal Resources Program.
- **Promote living shorelines.** Living shorelines have been successful at FOPU and identifying areas that have been degraded by recreational activities (e.g., boating) or erosion could be restored with the living shoreline techniques outlined in GADNR (2013a). Inventorying along the tidal creeks that are accessible by boat, especially in and around Oyster Creek and along the Bull River across from Wilmington Island would focus efforts in areas that provide significant ecosystem services and/or have been impacted as evidenced in the water quality results.
- **Manage feral cat area on McQueens Island.** FOPU is located between Important Birding Areas and supports many migratory bird species that depend on coastal habitat for their survival. Unfortunately, conservative estimates suggest that cats kill 1.3–4 billion birds (and 6.3–22.3 billion mammals) per year (Loss et al. 2015). Enlisting assistance from the NPS Biological Resources Division, Manomet, and local communities to highlight the importance of protecting the native wildlife would help protect the integrity of the salt marsh habitat.
- **Promote the significance of the salt marsh habitat's role in protecting the adjacent communities.** Incorporating an interpretive message of how FOPU's salt marsh habitat is the 21st century's "fortress," protecting the surrounding communities from sea level rise and storm surges would raise awareness of this habitat's significance.

4.2. Shorebirds

After the success in reversing the decline in American Oystercatcher through conservation actions along the Atlantic coast, the NFWF and U.S. Fish and Wildlife Service expanded their efforts to include a multispecies conservation effort via the Atlantic Flyway Shorebird Initiative (NFWF n.d.(a), 2018). Ten priority areas for shorebird conservation within the flyway were identified, including the Georgia-South Carolina Coast, which includes FOPU. Conservation efforts that were informed by the oystercatcher recovery have been identified for the focal species—Whimbrel, Red Knot, and American Oystercatcher—in the 10 priority areas. The six shorebird conservation action categories for the Georgia-South Carolina Coast are presented in Table 5 by the focal species and are described below.

Table 5. Conservation actions for the focal shorebird species in the Georgia-South Carolina Coast priority area (adapted from NFWF 2018, Table 2).

Focal Area	Habitat		Reduce Human Disturbance	Reduce Incompatible Management	Reduce Predation	Fill Information Gaps
	Conserve	Restore				
Georgia-South Carolina Coast	AMOY, REKN, WHIM	AMOY, REKN, WHIM	AMOY	REKN	AMOY	REKN, WHIM

Note: AMOY = American Oystercatcher, REKN = Red Knot, WHIM = Whimbrel

- **Continue improving shorebird habitat on Cockspur Island.** Applying the USACE lessons learned from recent island-building efforts in the Altamaha River, GA region to Cockspur Island's beach restoration projects, especially keeping the dredge quality (e.g., sediment type, grain size), and placement (e.g., elevation, slope) relevant to the horseshoe crab spawning requirements, will benefit all shorebirds, in particular, the Red Knot. High quality roosting sites include areas with shallow water, exposed saturated sediments, and dry terrestrial ground where the landscape is open, with minimal tall vegetation for clear sight lines to minimize vulnerability to predation (Iglecia and Winn 2021). An Early Detection Rapid Response plan should be implemented on newly placed dredge material to eliminate any non-native invasive plants that may become established (NPS, L. Serra, Invasive Plant Management Teams biologist, Liaison, 30 March 2022, scoping workshop).
- **Monitor shorebird usage of Oyster Creek.** Many species require multiple habitats to meet their lifecycle needs, with usage varying during their annual cycles. However, dense vegetation can prevent accessibility for shorebirds and prey species, such as HSCs. Understanding how the Oyster Creek area is used by shorebirds can help inform Cockspur Island beach restoration efforts and provide valuable data for regional conservation strategies. A study could inform potential impacts from oyster harvesting within the Oyster Creek Recreational Harvest Area and the importance of fiddler crabs to the conservation of Whimbrels, which are declining.
- **Coordinate management activities (e.g., dredge placement) when least disruptive for shorebird activity.** While ISS data show year-round shorebird use, March through June appears to be the peak season, which includes the timeframe for HSC spawning.

- **Continue to manage visitor and/or pet beach access.** FOPU managers have already implemented beach restrictions on Cockspur Island to limit disturbances to shorebirds. This management action has been proven elsewhere in successfully protecting shorebirds at breeding, foraging, and roosting sites and may become increasingly important if higher pairs of shorebirds nest on Cockspur Island.
- **Share best management practices.** The USACE constructed Tomkins Island, SC prior to the 2005 nesting shorebird season using dredge material (NAS n.d.), which provides an important night roost site for Whimbrels (GADNR, F. Smith, wildlife biologist, 30 March 2022, scoping workshop); Turtle Island, SC is primarily tidal salt marsh, but its 4 km (2.5 mi) beach is important for many of the same shorebirds observed at FOPU and HSCs are abundant; Salt marshes and tidal creeks comprise almost 90% of the Little Tybee Island State Heritage Preserve, GA, supporting a rich estuarine ecosystem that is next to McQueens Island. These three IBAs surround FOPU and present an incredible opportunity to share information that can inform adaptive shorebird management actions.
- **Promote species tracking technology.** FOPU is between three IBAs, but limited information is known about shorebird use in the monument's salt marsh habitat, especially on McQueens Island. The Audubon South Carolina Tower Network (#253) is an active Motus Wildlife Tracking Network station whose antenna range to the south includes most of Cockspur Island and an area to the east of Bull River on McQueens Island over to Tybee Island. It may be a resource to address information gaps and to gain an understanding of species' regional distributions (NFWF n.d.(b)).
- **Promote Interpretive Programs.** Shorebirds are "great ambassadors for sea level rise and climate change" (Manomet, A. Hayser, shorebird technician, 30 March 2022, scoping workshop). Sharing success stories with the public can promote awareness and enlist citizen scientists to help support conservation efforts.

4.3. Eastern Oyster

- **Establish wilderness character measures and goals.** Establishing indicators and measures that meet FOPU's desired wilderness character is necessary to know whether goals are achieved. This will include all aspects of wilderness character (e.g., soundscape, viewscape, oysters) that are evaluated collectively.
- **Monitor oyster population**. A monitoring framework, with key indicators and measures, is presented in Appendix A, Table A-1. However, sampling sites, a re-visitation schedule, and outputs (e.g., reports) need to be identified. The oyster GIS data (GADNR 2013b; Hoover and White 2022) can inform the framework. Natural or reference sites need to be included for a reliable comparison to harvested sites. Remote sensing techniques for monitoring are becoming increasingly promising and would streamline monitoring efforts (refer to Kingsley-Smith et al. 2022; Puckett et al. 2021 pre-proposal draft; Hoover and White 2022).
- **Update PMIS ##323225 proposal (NPS 2021).** Update the PMIS proposal (Study sustainability of Recreational Oyster Harvest in Oyster Creek- Fort Pulaski National Monument) with content from the Eastern oyster gap analysis to receive assistance with oyster monitoring design.
- **Refine Hoover and White (2022) oyster GIS data**. Hoover and White (2022) performed a Normalized Difference Vegetation Index (NDVI) analysis on the 2018 imagery to create a point GIS layer of potential oyster locations in FOPU (in addition to the GADNR (2013b) and Hoover and White (2022) mapped oysters). However, a manual review and field verification are needed to further refine the point dataset to focus on oyster locations. This dataset is provided in FOPU's final deliverables packet, and according to J. Hoover, would require a GIS analyst approximately 40 hours to differentiate the points dataset. The results would show the extent of oysters within FOPU's boundary.
- **Identify oyster enhancement criteria/thresholds**. An understanding of when oyster enhancement activities are required would assist FOPU with managing the proposed wilderness area on McQueens Island, which includes Oyster Creek RHA in its entirety.
- **Add interpretive materials to the Lazaretto boat landing sign board**. This could help FOPU managers inform the public of their efforts to manage the area as proposed wilderness to protect the resources and values for future generations.
- **Develop a shell-shucking and collection station at the Lazaretto boat landing.** Developing a community partnership to engage citizens to shuck and deposit oyster shells to a collection station at the Lazaretto boat landing would improve the sustainability of oysters in Oyster Creek RHA and inform adaptive management strategies. FOPU managers could work with the regional biologists to return the shells (cultch) to locations in the RHA. UGA Marine Extension and Georgia Sea Grant (2023) have developed methods for returning shells.

4.4. Butterflies

- **Need a comprehensive butterfly inventory to identify the species at FOPU**. Consider submitting a study proposal (e.g., NPS Inventory 2.0, enlist existing Georgia groups/surveys) to conduct an inventory for butterflies on Cockspur Island. FOPU's currently monitors migratory species, which is approximately 3% of the potential number of species.
- **Narrow the habitat management focus to those areas that support the species' life cycle needs that are present at FOPU.** This can be considered in three parts: (1) mowing footprint reduction, (2) creating nectar plant areas, and (3) management of wooded habitats. The first two can occur without a butterfly inventory, whereas the third should occur after an inventory has been completed so efforts are adequately guided by species presence and needs. Creating nectar plant areas will benefit all pollinator species, so knowing which pollinator species are present is unnecessary. Addressing the management of wooded habitats requires more information than what the monument currently has. Here's a reviewer comment by Andy Davis with the University of Georgia (22 March 2023 email correspondence) that illustrates this point: "I'm not that surprised that the majority of the [BAFA] target species fly through the site during the fall. This region of the country is indeed a flyway for these three species. Though, whether that means it is an "important" flyway is anyone's guess. I have had this conversation with Christa Hayes as well – just because butterflies fly through this region does not mean that the region itself needs to be enhanced. For monarchs, we do know that many travel along the coast and head into Florida, though they do not ever come back. It is a one-way trip. With this in mind, it is hard to know if we (you [FOPU]) should be "enhancing" their flyway to Florida or not. Most people simply assume that more butterflies are better, but this is not always the case. Also, for monarchs, we know that a lot of the monarchs in this region are heavily infected with a debilitating parasite, and so for this reason too, this site may not "need" more monarch habitat, because this would be akin to helping the pathogen to linger and infect more monarchs. So, as you can see, it is not simply a matter of "getting more butterflies." I would encourage the people involved to consider not just watching for monarchs, but also capturing some and testing them (using a simple, non-destructive method) for this parasite, which would help to resolve some of these questions, before moving forward, at least for the monarch habitat. I agree that one of the best management things to do to enhance butterfly habitat in general is to reduce the mowing footprint of the site."
- **Further reduce the mowing footprint at FOPU.** Managers can implement this without knowing the specific butterfly species at FOPU because "messier" habitat is beneficial for pollinators (Pollinator Partnership n.d.). Areas of consideration are shown in Figure 13.

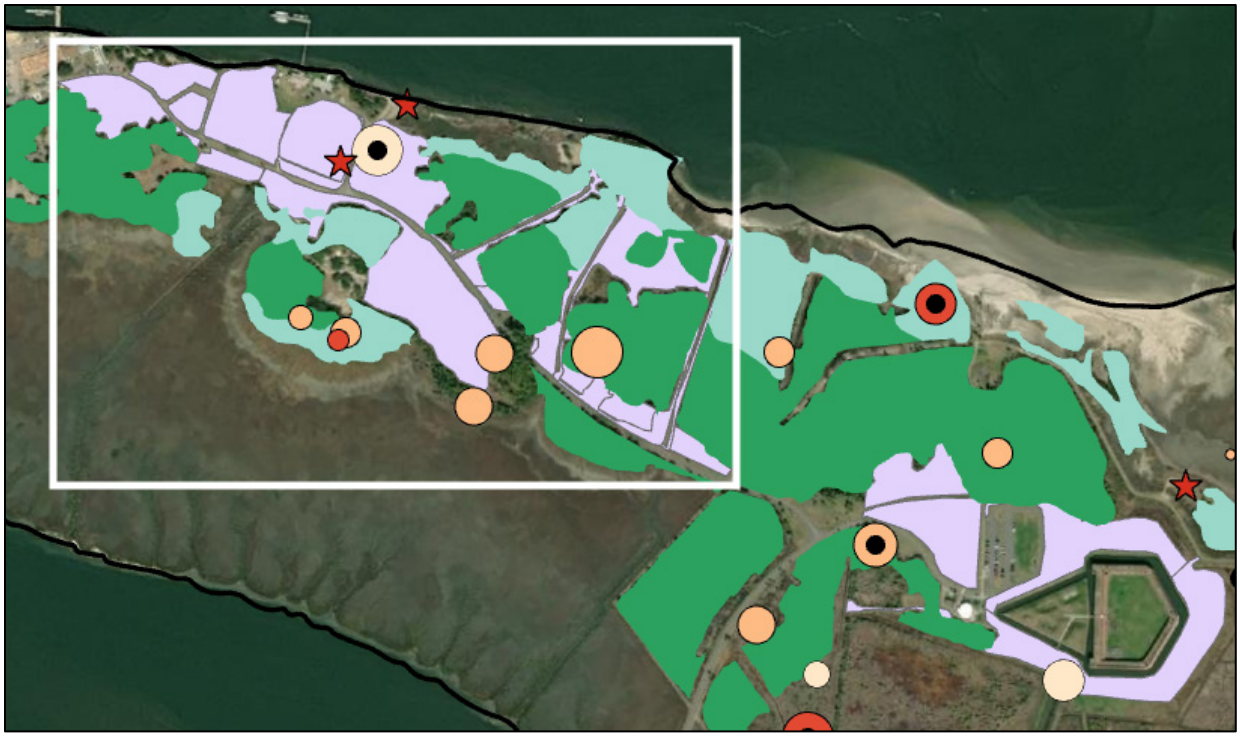


Figure 13. The areas shown in light purple represent the current areas mowed at FOPU using a tractor and zero turn mower. The high priority areas for mowing reduction consideration are shown as light purple polygons within the white box. Data (Smith 2022) were provided by NPS / C. Smith.

- To maximize butterfly habitat connectivity, the light purple areas shown in Figure 13 that are along both sides of the Tybee Coast Guard Station Drive and within the white frame could be further reduced in mowing unless other considerations are higher priority. Areas closer to the visitor center and parking lot are next to roads with a higher number of vehicles, which may lead to increased butterfly mortality.
- **FOPU managers are working with USACE to restore the functionality of the canal network.** Approximately 1.2 ha (3 ac) of canals bisect prime butterfly habitat (Figure 14). A hydrologically functioning system will reduce areas of standing water, which should further reduce the need to apply pesticides for mosquito control. If the restoration of these ditches is not necessary from a hydrology perspective, they should be filled to remove the standing water and minimize or eliminate the need for pesticide applications.

Figure 14. Ditch numbers 10–13 and 15 bisect prime butterfly habitat at FOPU (USACE 2021).

- **Fine tune management actions with timing of butterfly species' activities and lifecycle needs.** After a more comprehensive understanding of which species are present at FOPU, the timing of chemical applications or habitat management actions are most beneficial to the species that are present will focus management efforts. Tweedy (2022b) summarizes activity for a calendar year when a "species is reliably present in suitable habitat and conditions," with April–October representing the months with the highest diversity present. Pollinator Partnership (n.d.) lists bloom periods for the Outer Coastal Plain Mixed Province and plants that attract pollinators. Both sources can focus management activities for butterflies. But because many pollinators overwinter in the south, it would be best to eliminate chemical applications for mosquito control, if possible. This would be the most beneficial activity from an ecological perspective for all pollinator species at the monument.
- **Citizen Science:** Further refine FOPU's butterfly checklist as more species are observed and encourage photo documentation to enlist citizen scientists and staff to record presence in the monument, with a high level of confidence.

FOPU managers have observed significant landscape changes at the monument over the last 10–15 years and are especially interested in management actions they can operationalize to improve natural resource conditions. The management considerations presented in this chapter are intended to inform an integrated planning effort, such as an RSS, which will help FOPU managers identify strategies to achieve their conservation goals. Many of the considerations can be grouped to manage from an integrated and ecosystem management framework, especially when working across jurisdictional

boundaries with managers from the surrounding Marine Protected Areas and Important Birding Areas.

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Appendix A. Condition Rating Statements

A proposed monitoring framework is presented in Table A-1 to evaluate the natural quality of Eastern oysters in Oyster Creek RHA. The framework includes indicators of condition, measures, and reference criteria based on the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish, (2019 Revision), U.S. Food and Drug Administration (as recommended in GAEPD's (2021) USEPA-approved water use classifications and water quality standards), Baggett et al. (2014), and MarineGEO (2021). Reference criteria are based on specific values, so rating statements for good, fair, or poor were not developed. The GADNR is georeferencing and digitizing maps from previous oyster surveys in Georgia. This information may be used as a source to assist with establishing certain reference criteria.

Table A-1. Proposed monitoring framework to evaluate the condition of Eastern oyster (adapted from Baggett et al. 2014; MarineGEO 2021).

Indicator of Condition	Measure	Reference Criteria
Water Quality	Water temp. (°C)	GADNR collects this measure approximately monthly at sites in and around Oyster Creek. Baggett et al. (2014) recommend monitoring continuously as preferred, otherwise as often as possible. A temperature of 81° F (27.2° C) is the threshold for closing recreational harvesting of oysters. Baggett et al. (2014) cite Shumway (1996) as suggesting that higher temperatures increase oyster exposure to disease and predators.
	Salinity (psu)	GADNR collects this measure approximately monthly at sites in and around Oyster Creek. Baggett et al. (2014) recommend monitoring continuously as preferred, otherwise as often as possible and that a salinity range of 14–34 psu in habitats that experience a fluctuation in salinity is optimum for *C. virginica*. Baggett et al. (2014) cite Shumway (1996) and Ewart and Ford (1993) as suggesting that higher salinities are associated with greater instances of disease and predators than temperature.
Reef Attributes	Area (m^2)	No reference criteria were identified but monitoring Oyster Creek RHA's oyster extent and distribution would serve as a comparison over time.
	Height/rugosity (cm)	Baggett et al. (2014) identify a positive or neutral change as good.
	Oyster or recruitment density (ind./m^2)	Baggett et al. (2014) suggest that this metric should be "based on short and long-term goals developed using available regional and project-type data, as well as current and/or historical local/regional densities." UGA Marine Extension and Georgia Sea Grant (2023) state that recruitment of spat in Georgia may be very high, even as much as 204,700 per m^2.
	Oyster size-frequency (mm, # or % per bin)	No reference criteria were identified. Oysters usually grow about two inches/year, but in GA, oysters can reach full maturity in approximately four months (GADNR, n.d.(d)). The

Table A-1 (continued). Proposed monitoring framework to evaluate the condition of Eastern oyster (adapted from Baggett et al. 2014; MarineGEO 2021).

Indicator of Condition	Measure	Reference Criteria
Reef Composition	Competitors and predators (ind./m^2)	Density per m^2 of each species present.
	Disease prevalence (%)	It's recommended that disease be monitored if disease prevalence and/or intensity are believed to be high (Baggett et al. 2014).
	Associated fauna (presence)	This metric can help identify benefits that oysters provide for other species.
Reef Enhancement/ Restoration	Live oysters/m^2 (measures vary based on restoration goals)	This metric is the number of live oysters/m^2 and is based on the goals of the restoration project.

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