National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Gulf Islands National Seashore

Natural Resource Report NPS/GUIS/NRR—2016/1135

ON THE COVER
Clockwise from Top: Sunset at Fort Pickens, Hatchling Kemp's Ridley sea turtle, Davis Bayou salt marsh
Photographs courtesy of National Park Service

Natural Resource Condition Assessment for Gulf Islands National Seashore

Natural Resource Report NPS/GUIS/NRR—2016/1135

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

This report is available in digital format from Gulf Coast I&M Network website (http://science.nature.nps.gov/im/units/guln/index.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Executive Summary

This report provides an assessment of the condition of key natural resources at Gulf Islands National Seashore (GUIS). It discusses stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Gulf Coast Monitoring Network (GULN), and on other attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air quality, weather and climate, coastal dynamics, water quality, terrestrial vegetation, seagrass, animal communities, and landscape dynamics.

Data used in the assessment included NPS Inventory & Monitoring Program (I&M) reports and bio-inventories, spatial datasets, park-commissioned reports, unpublished park data, publicly-available data sets of various types, peer-reviewed publications, and personal communication with GUIS and GULN staff. No new field data were collected for this report. When appropriate, data gaps and opportunities for improved data collection are identified.

GUIS lies along the Mississippi and northwestern Florida coasts. The park contains seven barrier islands, five in Mississippi and two in Florida. GUIS is divided into two management districts according to state, the Florida and Mississippi districts (GUIS-FL and GUIS-MS). As these districts face different pressures on their resources and data are not always available for both areas simultaneously, we assessed them separately throughout this report when necessary.

GUIS encompasses 54,820 hectares and is notable for its expansive dune habitat. GUIS harbors a variety of important natural resources. Differences in geomorphology between the islands of the GUIS districts also have an effect on the habitat structure and composition of the islands. Because Mississippi barrier islands are wider than the Florida islands, a variety of interior habitats are present, such as dunes, marshes, brackish ponds, and sand flats. According to NPSpecies, 795 species of vascular plants are recognized as present in the park, including 17 species of state special concern. Vertebrate inventory and monitoring efforts in the park have reported 271 species of fish, 321 species of bird, and 76 species of reptiles and amphibians. Multiple state or federally endangered or threatened animal species have been reported, including a number of marine turtles. The park supports a notably rich assemblage of native herpetofauna and the greater region has been designated by the National Audubon Conservation Society as an Important Bird Area.

This report identifies and discusses threats or potential threats to natural resources. These include:

- **Decreased air quality—**Observed ozone concentrations as of the writing of this report were in the range of moderate concern for human health. However, ozone levels appear to be declining in the region.

- **Atmospheric pollutants—**There are several sources of atmospheric pollution within the vicinity of GUIS, which can react in the atmosphere to produce acid rain. N and S deposition can debilitate terrestrial and aquatic systems, while Hg deposition can pose human health hazards via bioaccumulation.

- **Coastal dynamics—**The barrier islands of GUIS are facing combined threats from sea-level rise, dredging, and erosion that combine to drive losses in land and alter geomorphologic processes. Overall, the data show that erosion continues within GUIS, and potentially is increasing in more historically stable areas (GUIS-FL). Long-term trends and projections indicate that relative sea-level rise will likely continue into the future and will need to be an area in need of active monitoring within the park.

- **Surface water quality—**The quality of surface waters at GUIS influences the value of the park lands in terms of recreation and suitability for fish, wildlife, other fauna, and vegetation communities. Surface water quality within GUIS is influenced by external inputs that may be beyond the parks control such as: impacts of industrial effluents, stormwater runoff, oil and gas discharges (emissions from watercraft and spills), sewage effluent dumping, and alterations to rates of groundwater recharge. Violations of dissolved oxygen and turbidity standards for GUIS-MS stations are concerning, but may reflect the monitoring schedule.

- **Terrestrial vegetation—**Surveys of the park's vegetative communities have identified a diverse assemblage of species and recognize the resources as being some of the better preserved examples of relic dunes and shrub in the region. These communities and others are in decline because of human development and fire suppression. Future projections indicated that these coastal vegetation communities will likely be affected by increased storm intensity and saltwater intrusion, as well as establishment of invasive species. Recent implementation of a fire management plan at GUIS will help restore these threatened communities, and restore fire-adapted species, including longleaf pine.

- **Non-native vegetation—**Invasive plant species are present in all of the management units of GUIS. The presence of non-native species, and in particular multiple species that have been documented as having moderate to severe impacts to native communities, are a management concern for GUIS. Overall, the threat of exotic species at GUIS remains an ongoing problem, but treatments are also underway to remove many of these exotics.

- **Seagrass—**Seagrass beds are found throughout the US, although the majority of them are located in the Gulf of Mexico, where one of the highest concentrations exists along the MS barrier islands. Many anthropogenic effects associated with coastal activities are detrimental to the health and persistence of seagrass beds, including direct impacts such as dredging, boat scarring, and fishing, as well as indirect impacts such as degraded water quality and sediment flow alteration. In general, seagrass beds of GUIS-MS seem to be in a recovering state, but there are many threats to persistence, such as recreational boating and coastal renourishment.

- **Non-native wildlife—**Non-native animals may alter habitat, compete with native species, or prey directly upon native species. In this report, non-native vertebrate animals were defined to include species or strains intentionally or accidentally introduced outside their native ranges by humans, and species spontaneously expanding their distributions to include areas never previously occupied. Of the three vertebrate assemblages assessed, all three (fish, birds, herpetofauna) included significant numbers of non-native or range-expanding species.

Brown-headed Cowbirds (*Molothrus ater*) are present during the breeding season and have been shown to negatively impact native bird nesting success in other regions of the country. Domestic cats (*Felis catus*) and coyote (*Canis latrans*) inhabit the park and have the potential to negatively affect multiple taxa. Lionfish (*Pterois spp.*) have become an emerging threat to park's fish assemblages, as they are now found throughout the Gulf of Mexico and are a voracious predator. Future assessments of natural resources at GUIS should consider potential hazards of this recent invasion.

- **Adjacent land use—**The most concerning metrics for adjacent land use at GUIS may be road density, impervious surface, and land conversion (natural to converted land cover). Development adjacent to the park is likely to have strong influences on water and air quality, introduction of invasive species, and may fragment the regional network of protected areas that includes the park.

Fifteen natural resource attributes were discussed and assessed for this report. Assessed attributes were within four broad categories: air and climate (three attributes), geology and soils (one attribute), water quality (one attribute), biological integrity (nine attributes), and landscape (one attribute). Trends were assigned to a few attributes for which sufficient data existed. Assessment method and data quality were both highly variable among assessed attributes, and therefore condition rankings are not necessarily directly comparable. Based on the number of rankings falling within each condition category, the overall summary of natural resource assessments is as follows: 15.8% good, 36.8% fair, 21.1% poor, and 26.3% not ranked. For assessed attributes, 15.8% had improving trends, 10.5% had stable trends, 0% had declining trends, and no trend was assigned for the remaining 73.7%. Data quality was very good for 31.6%, good for 21.1%, fair for 31.6%, marginal for 10.5%, and poor for 5.2% of assessed attributes.

Acknowledgments

We would like to thank staff of Gulf Coast Network (principally Whitney Granger and Martha Segura), and Linda York and Tim Pinion of the Southeast Regional Office (part of the Southeast Region Science and Natural Resource Management Division) for their contributions, edits, and overall assistance with this project. We are also grateful to staff at Gulf Islands National Seashore, including Cassity Bromley for insightful comments and edits. Finally, we give thanks to R. Dale McPherson of the Southeast Regional Office for his comments and logistical support throughout the NRCA process

Acronyms and Abbreviations

ABC – American Bird Conservancy

ARD – (NPS) Air Resources Division

BBS – Breeding Bird Survey

BOD – Biochemical Oxygen Demand

CASTNET – Clean Air Status and Trends Network

CRI – Conservation Risk Index

DO – Dissolved Oxygen

EMF – Ecological Monitoring Framework

EPA – Environmental Protection Agency

EVT – Existing Vegetation Type

FWC – Florida Fish and Wildlife Conservation Commission

GAP – Gap Analysis Program

GHCN – Global Historical Climatology Network

GIS – Geographic Information System

GUIS – Gulf Islands National Seashore

GULN – Gulf Coast Inventory & Monitoring Network

IBI – Index of Biotic Integrity

I&M – Inventory and Monitoring

IUCN – International Union for Conservation of Nature

MsCIP – Mississippi Coastal Improvement Program

MNHP – Mississippi Natural Heritage Program

MDN – Mercury Deposition Network

MRLC – Multi-Resolution Land Characteristics Consortium

MSPA – Morphological Spatial Pattern Analysis

NAAQS – National Ambient Air Quality Standards

NABCI – North American Bird Conservation Initiative

NADP – National Atmospheric Deposition Program

NLCD – National Landcover Dataset

NLO – Naval Live Oaks

NNE – North-northeast

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NTU – Nephelometric Turbidity Unit

PAD – Protected Areas Database

PIF – Partners in Flight

PKBM – Perdido Key Beach Mouse

SRBM – Santa Rosa Beach Mouse

SSURGO – Soil Survey Geographic

SSW – South-southwest

UGA – University of Georgia

USGS – United States Geological Survey

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

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[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components. NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important p ark resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/nrca/index.cfm.

NRCA Reporting Products…

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

Chapter 2 Introduction and Resource Setting

2.1 Introduction and Resource Setting

2.1.1 Enabling Legislation

Gulf Islands National Seashore (GUIS) was established in 1971 to protect the variety of coastal resources found along Florida (FL) and Mississippi (MS). Protected areas include a variety of unique natural features, such as white sandy beaches, coastal marshes, maritime forest, and pristine barrier islands (Figure 1). In addition, over 80% of the park protected area is underwater and contains several features attractive to divers. In addition to the abundant marine life, the *USS Massachusetts*, a Spanish-American War era battleship, rests outside the Pensacola Pass (NPS 2012a).

Figure 1. Gulf Islands National Seashore protects unique coastal habitat along the Mississippi and Florida coasts, and is also home to several significant cultural sites. [Photo: Thomas C. Gray]

Besides its natural features, GUIS contains numerous historical sites and structures. Forts Pickens, Barrancas, and McRee, were constructed prior to the Civil War to protect the Pensacola Bay area, whereas Fort Massachusetts was constructed around the same period to secure the natural deep water harbor on the north side of West Ship Island (Figure 2, NPS 2012a).

2.1.2 Geographic Setting

The 240-km length of seashore of GUIS preserves an example of the natural environment typical of the Gulf Coast region with a variety of habitats including scrub shrub, freshwater and saltwater marsh, oak hammocks, and beach dunes. Gulf Islands National Seashore is located on the Gulf Coast in parts of FL and MS (Figure 3). Small portions of GUIS are situated on the mainland in each state, though most of the area of the park is on barrier islands. Overall, GUIS stretches around 100 miles along the coasts of MS and FL.

Figure 2. Though incomplete, construction of Fort Massachusetts halted in 1866. Despite strong storms and weathering influences, the fort still stands on West Ship Island. [Photo: Thomas C. Gary]

GUIS is managed by NPS as two districts, one in Florida (GUIS-FL) and one in Mississippi (GUIS-MS). GUIS-FL is in close proximity to Pensacola, FL and barrier islands of GUIS-MS are much further from the mainland, with the nearest mainland location at least 5 miles away. One small unit of GUIS-MS is located on the mainland (Davis Bayou), adjacent to Ocean Springs, MS.

The Florida district of GUIS features the mainland area of Naval Live Oaks, established in 1828, recognized by the federal government as providing valuable timber for ship building. Santa Rosa Island was originally established in 1939 as a National Monument, due to its natural interest as an exemplary barrier island. On Santa Rosa Island there are three disjunct areas. Just east of Pensacola Beach is the Santa Rosa Area unit, which includes about 650 ha and Opal Beach. The west side of the island includes the 1090 ha Ft. Pickens unit, which stretches out into Pensacola Pass. On the east end, below Fort Walton Beach, is the 8-ha Okaloosa Area unit. To the west of the pass is Perdido Key, part of the Florida mainland which includes Rosamond Johnson Beach. On the north side of Santa Rosa Sound is the small disjunct unit where Ft. Barrancas and the Advanced Redoubt are located (NPS 2012a).

The MS district of GUIS features the set of five barrier islands: Petit Bois, Sand, Horn, Ship, and Cat Islands. Ship Island is commonly divided into East and West Ship Island. These islands are located off the coast between the mainland cities of Gulfport and Pascagoula and are accessible only by boat. A passenger ferry from Gulfport provides service to Ft. Massachusetts on West Ship Island. A sixth barrier island, Dauphin Island, lies off the coast of Alabama but is not part of GUIS. The MS mainland includes two disjunct units associated with Davis Bayou, including a small tract in Ocean Springs associated with Stark Bayou, and an estuarine inlet stretching from Biloxi Bay (NPS 2012a).

Figure 3. Gulf Islands National Seashore includes several barrier islands as well as mainland tracts. Although 100 km of Alabama coast line are included between the main FL and MS districts, much of the land is protected or public use.

2.1.3 Visitation Statistics

Data for annual number of visitors at GUIS is available starting in 1973. Visitation rose until a peak in 1985, at which point it remained mostly around 4,000,000 in the years following (Figure 4, NPS 2012b). Park visitation "peaked" in 1985, although this data point is attributed to counting vehicles that passed through park areas, which was fixed in counts thereafter (NPS 2009b). Visitation declined in 2005 because of damage to roads to Fort Pickens sustained in hurricanes of 2004 and 2005, but has since been increasing.

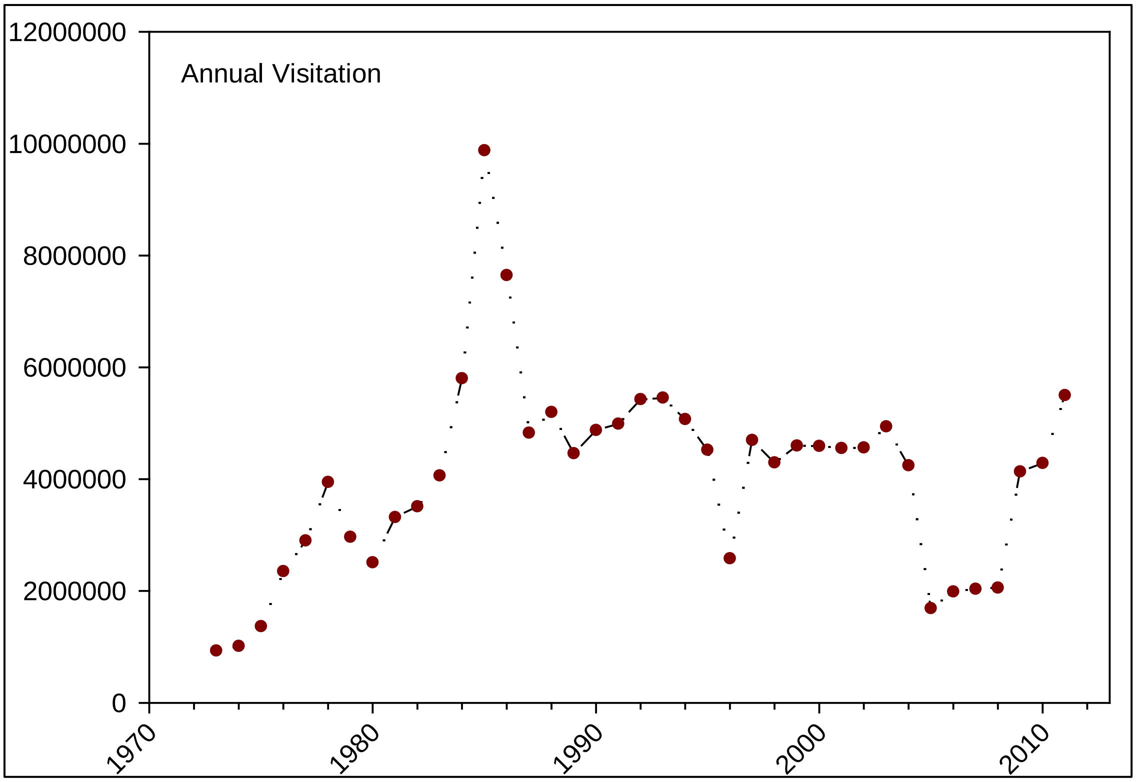

Figure 4. Annual visitation at GUIS from 1973 to 2011.

2.2 Natural Resources

2.2.1 Geology and Soils

Much of the coastal land around the Gulf of Mexico was created and continues to be influenced by the historical pattern of deposition and distribution of sediments transported into the Gulf by river mouths over a very long time period. The barrier islands at GUIS began as submerged sand bars formed by offshore accretion, when sea levels were lower than present. Santa Rosa Island emerged approximately 4,000 years ago and continues to accrete, while the MS and AL barrier islands appeared over a thousand years earlier (NPS 2007). During the early stages of formation, the GUIS barrier islands were regressive (or seaward building) with growth occurring both seaward and alongshore (laterally) due to the transport of large volumes of sand by littoral drift (NPS 2007). For MS barriers excepting Cat Island, "rapid lateral accretion on the downdrift end of the islands and attendant rapid inlet migration resulted in low, narrow, shore-parallel elongate spits." (Morton 2007). The ridge and swale complexes of the MS barrier island cores were likely formed during a period of slow inlet migration, allowing inland transport of sand from the beach and dune accumulation. GUIS barrier islands have generally kept pace with rising sea level since their formation, but anthropogenic activities such as channel dredging, and periodic storm destruction and island segmentation have played a role in their evolution (NPS 2007).

Islands of GUIS-FL and GUIS-MS differ considerably in processes and sediment sources that formed them. Stone et al. (1992) found three main sources of sediment that maintain the stretch of coast line from Morgan Point, AL to Grayton Beach, FL, which includes the Ft. Pickens and Santa Rosa Island sections of GUIS. The movement of sediment generally travels from east to west from the following areas: 1) the barrier island complex associated with the Grayton-Mirimar Beach area in FL, which mainly transports sediment to eastern Santa Rosa Island, 2) Pensacola Beach, which supplies sediment mainly to western Santa Rosa Island, and 3) onshore transport between Pensacola, FL and Morgan Point, AL, which supplies the area between Pensacola Pass to Morgan Point. Santa Rosa Island is believed to have arisen from the erosion and transport of sediment from a Pleistocene headland east of Destin, FL (Houser 2012). For the MS barrier islands, Morton et al. (2000) and Otvos (1981) have suggested that the islands originated as submerged sand shoals that emerged from the Gulf of Mexico and then aggraded during falling water levels of the mid-Holocene highstand in sea level. In MS, there are two theories that inform island formation: 1) sediment was transported from Mobile Bay, AL to an offshore continental shelf source that provided sediment to the islands via onshore bar progression (Shepard 1960), and 2) broad shoals of soft and unconsolidated sands between Mobile Bay and Pensacola supplied sands west across the Mobile tidal inlet (Kwon 1969). Prevailing easterly winds influence westward sediment movements via longshore currents (Waller and Malbrough 1976). However, the mechanisms of sediment transport, barrier islands of MS formed during a period of surplus sand in the alongshore sediment transport that is no longer present (Morton 2007).

GUIS consists of seven barrier islands, five in Mississippi (Cat Island, Sand Island, Ship Island, Horn Island, and Petit Bois Island) and two in Florida (Perdido Key and Santa Rosa Island). Mississippi islands are 7 to 15 miles from the mainland, whereas Florida islands are no more than 2 miles from the mainland. These islands also differ in their geomorphological stability (Pendleton et al. 2004), with Mississippi islands historically experiencing greater instability regarding shoreline change. However, all of these barrier islands are undergoing constant change due to coastal processes and are especially vulnerable to storm events. In 2005, the storm surge from Hurricane Katrina temporarily submerged all of the MS barrier islands (Figure 5; NPS 2007). During the past century and a half, combined land area of Ship, Horn, and Petit Bois Islands has been reduced by roughly a quarter (Figure 6, NPS 2007). Santa Rosa Island was nearly completely overwashed by multiple hurricane events, including Hurricane Frederic in 1979, Hurricane Opal in 1995, and Hurricane Ivan in 2004 (Pendleton et al. 2004, Hapke and Christiano 2007).

GUIS barrier islands vary in geologic makeup, as sources of sediment accretion vary considerably along the Gulf coast. Compared to other nearby beaches along the Gulf Coast, the sand at GUIS-FL is exceptionally white due to the lack of clay mixed with the quartz content (Resource Planning Office 1966). Sediment inflow is primarily driven by upstream conditions, and the shorter drainages of Pensacola Bay predominantly transport sand-rich sediment from upstream areas that were previously coastal areas during higher sea levels. GUIS-MS beaches include more clay, likely because of the long, far-reaching drainages of the Apalachicola and Pearl Rivers that transport clay-rich waters (Resource Planning Office 1966). According to the Soil Survey Geographic (SSURGO) database for GUIS, the most commonly mapped soil association within the park unit is the Newhan-Corolla complex, comprising 3055 ha or approximately 40% of the land area. This association is mapped as the predominant soil association on Horn, Petit Bois, and Santa Rosa Islands, in addition to Perdido Key. These soils contain relatively underdeveloped layers and represent a typic series of coastal dunes and beaches. Newhan soils may occur on slightly elevated dune areas, whereas Corolla soils typically are found on flat low-lying areas. Vegetation in these areas may typically be coastal shrub. The next most common association is the Duckston-Corolla complex, which comprise roughly 2065 ha – about 27% of the land area. These soils are typically further inland and are common on the same islands, though less so on Perdido Key. Another 680 ha (9%) of the land area is sandy beach with no soil development.

Differences in geomorphology between the islands of the GUIS districts also have an effect on the habitat structure and composition of the islands. Because Mississippi barrier islands are wider than the Florida islands, a variety of interior habitats are present, such as dunes, marshes, brackish ponds, and sand flats. The majority of the Gulf Islands consist of low-elevation barriers with numerous washovers, but East Ship, Petit Bois, and Santa Rosa Islands all have mature dune ridges, making them less susceptible to shoreline change (Pendleton et al. 2004). As late as the 18th century, Dauphin and Petit Bois Islands were joined together, while today Petit Bois, along with Horn and Ship Islands, continue to make a slow westward migration (Figure 5). Today, along with these natural influences, artificial processes such as dredging, beach nourishment, and sediment diversion continue to shape these coastal habitats.

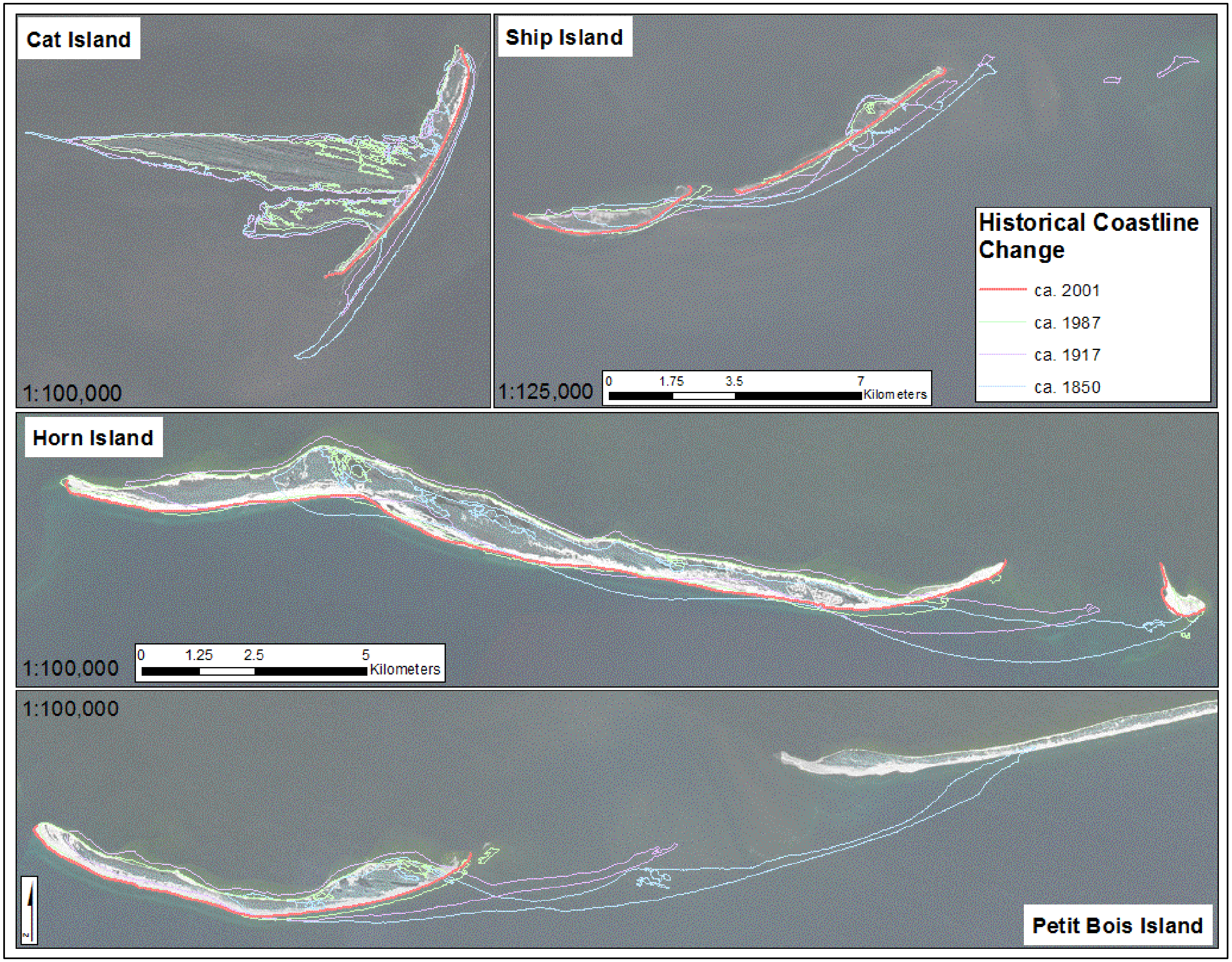

Figure 5. Historical coast line change on the Mississippi barrier islands. Westward migration of Petit Bois, Horn and Ship Islands can also be seen.

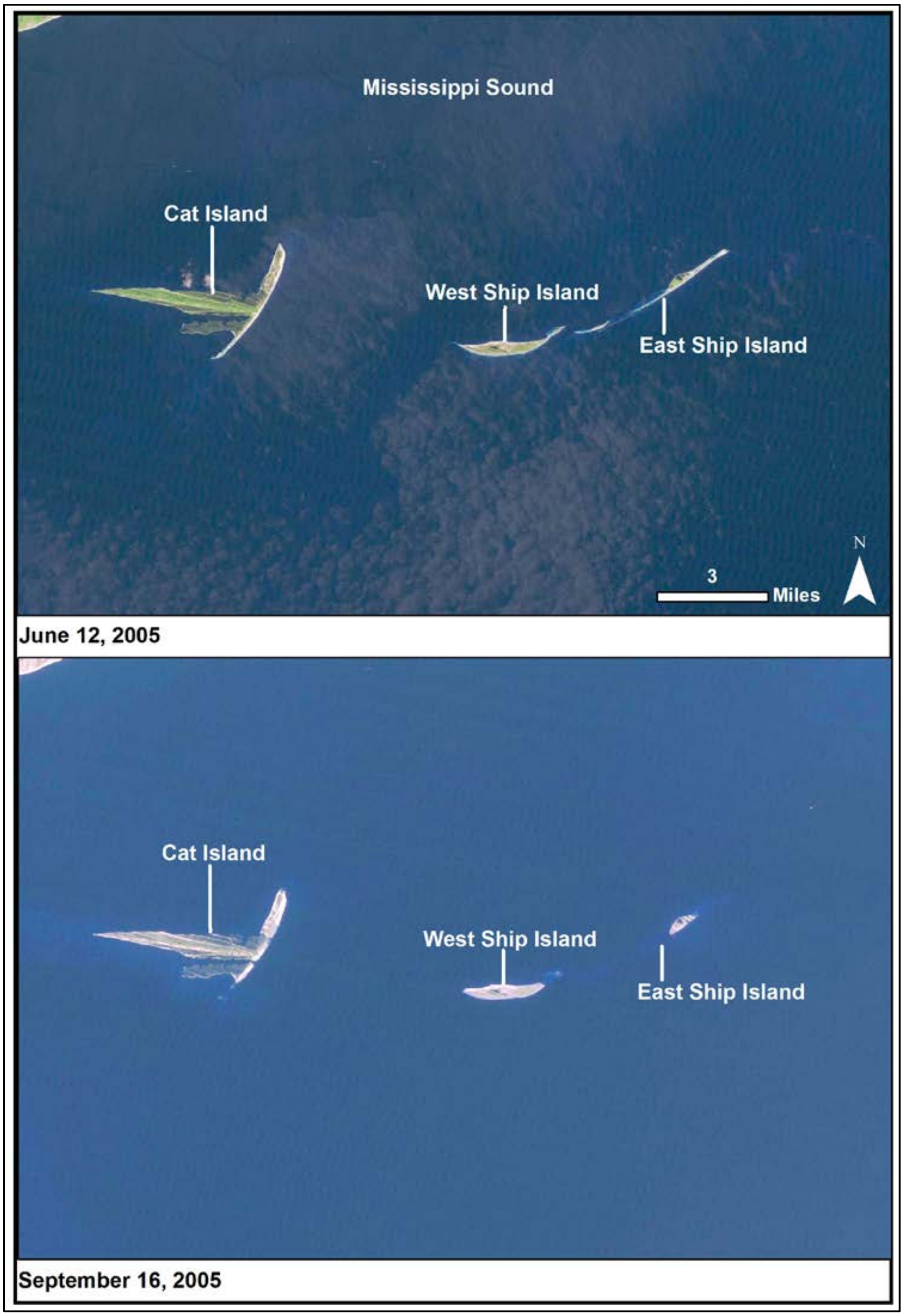

Figure 6. Satellite imagery showing Ship and Cat Islands before Hurricane Katrina (top) and after the storm (bottom) [Source imagery: USGS 2014].

2.2.2 Hydrology

Gulf Island National Seashore falls within four major hydrologic cataloging units: Mississippi Coastal, Perdido Bay, Pensacola Bay, and Choctawhatchee Bay (USGS 2013). Each of these cataloging units is in turn divided into a total of 10 finer scale watersheds within the park (Figure 7). All of the hydrologic units comprising the park are terminal drainages, meaning they flow into the

Gulf of Mexico rather than into another unit. Although the barrier islands are separated from the mainland, they are grouped with the watersheds on the mainland due to the common flow outlet. In addition, although not within park boundaries, the Pascagoula and Mobile Bay hydrologic cataloging units north of park boundaries are a significant source of sediment, pollution, and freshwater influxes to GUIS.

Many of the perennial streams within the park are essentially inlet tributaries in the Davis Bayou region or small streams on Santa Rosa Island. Very few perennial streams are found on the barrier islands. Only two small sections of water in GUIS-FL were included on the 2010 EPA 303(d) list of impaired waters. This was a short length of coastline along the north side of Naval Live Oaks, part of a longer listed area, which was impaired due to elevated mercury concentrations, organic enrichment due to depleted oxygen, and microorganism contamination.

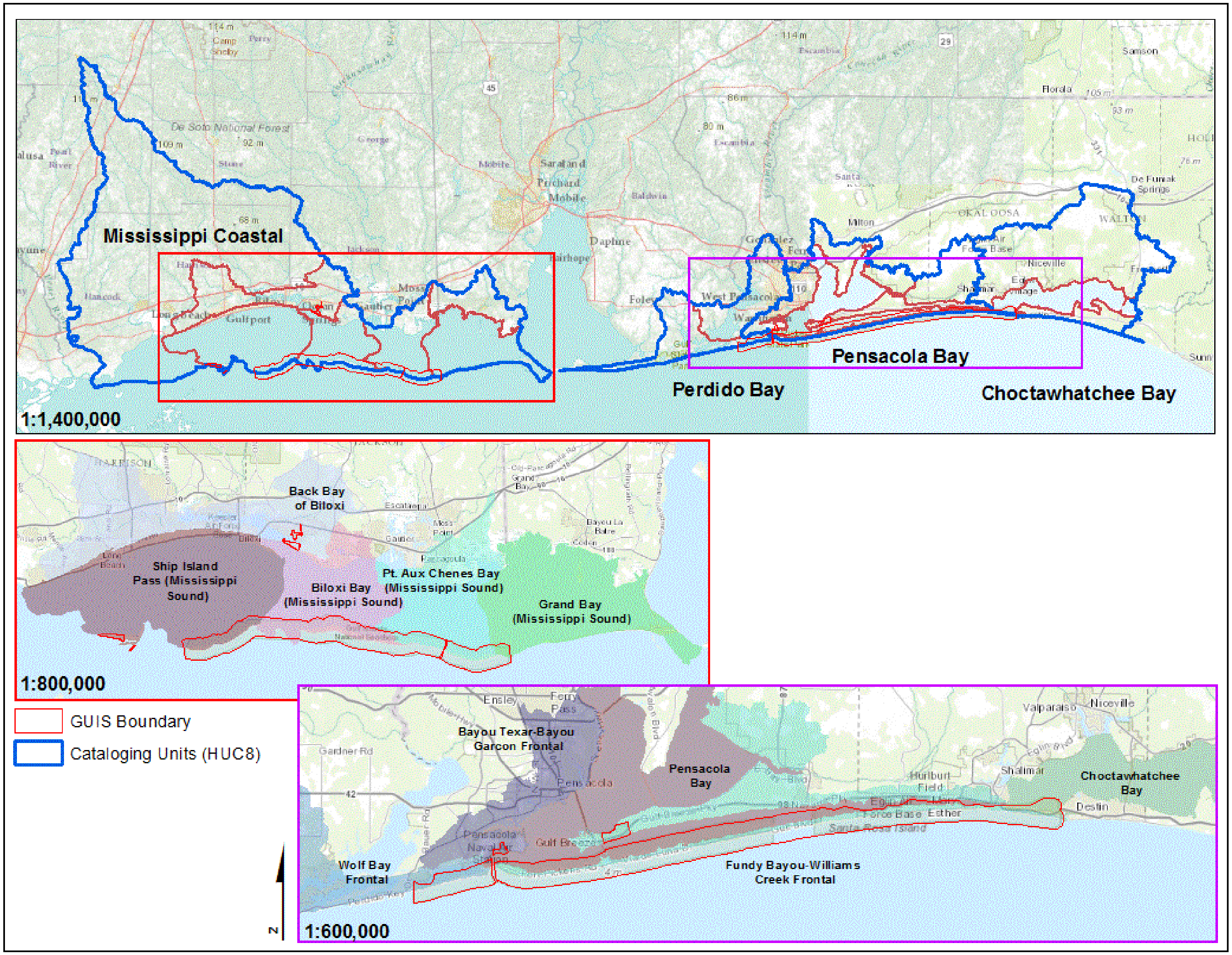

Figure 7. Gulf Islands National Seashore is located within four main hydrologic cataloging units (top, in blue), which are in turn divided into a series of 10 smaller watersheds (bottom, in color). Source: [USGS 2013].

2.2.3 Resource Descriptions

Water Quality

Water resources at GUIS are a significant management concern, as they can affect aquatic vegetation, wildlife, and recreational use. Unlike small rivers and streams flowing through mainly terrestrial areas, the aquatic setting of GUIS leads to its vulnerability to broad-scale processes. The Gulf of Mexico is the terminal outlet to several major river systems, which can interact to create unpredictable patterns of water quality at GUIS. Circulation within the Gulf also affects water quality, as do shipping, commercial fishing, and oil refinery activities within the immediate region. Because the majority of the park is aquatic, monitoring water quality is a considerable undertaking. In 2010, the Gulf Coast Inventory and Monitoring (I&M) Network (GULN) deployed multi-parameter datasondes to monitor water quality at three locations at GUIS. Data collection from these locations still continues.

Terrestrial Vegetation

Although most of GUIS protects marine habitat, a wide variety of terrestrial communities are found on the mainland and barrier island portions of the park unit. Broadly, these include upland coastal forests, palustrine wetlands, estuarine tidal marshes, and dune communities. GUIS habitats represent some of the better preserved examples of threatened habitats in the region, including relic dunes and scrub (Urbatsch et al. 2007). These communities and others are threatened from a number of sources including human development, fire suppression, increased storm intensity, saltwater intrusion and invasions of non-native species. Recent implementation of a fire management plan at GUIS will help restore these threatened communities and restore fire-adapted species (e.g., longleaf pine, *Pinus palustris*).

Seagrass

Marine vegetation is also an important resource to GUIS. Seagrass beds are found throughout the US, but GUIS harbors one of the highest concentrations along the MS barrier islands. These beds serve many essential roles in these shallow aquatic ecosystems, where they stabilize sediment, reduce turbulence and currents, improve nutrient flow, as well as provide habitat for many aquatic species (Carter et al. 2011). Many anthropogenic effects associated with coastal activities are detrimental to the health and persistence of seagrass beds, including direct impacts such as dredging, boat scarring, and fishing, as well as indirect impacts such as degraded water quality and sediment flow alteration. Extensive analysis by Carter et al. (2011) for GUIS-MS showed a considerable decline between the period 1960 and 1990, though more recent analysis indicated signs of recovery. Recent efforts from the Florida Fish and Wildlife Commission (FWC) to develop a Seagrass Integrated Monitoring and Mapping (SIMM) program will likely prove useful in monitoring and assessing the health of Florida's seagrass communities in the future (FWC 2013).

Fishes

As a barrier island complex, GUIS offers a variety of potential fish habitats across a gradient of salinity and productivity (Wilborn and Bennett 2006). GUIS supports seasonal reproduction, critical nursery habitat, and a shifting mosaic of adult fish year-round. Few studies have addressed actual effects of various stressors on fish communities in and around GUIS (Cooper et al. 2005); however extensive toxicological work has been conducted in the northern Gulf of Mexico since the 2010 BP oil spill (FDA 2014). Efforts by Wilborn and Bennett (2006) reported 271 fish species present within park boundaries, and an additional 110 species that were probably present. Only one federally threatened species was reported from the park (Atlantic surgeon, *Acipenser oxyrinchus desotoi*). Recent expansion of lionfish (*Pterois volitans* and *Pterois miles*) into the northern Gulf of Mexico is a new management concern for the park (M. Segura personal communication).

Birds

GUIS has been declared an Important Bird Area by the National Audubon Society. A great diversity of bird species migrate across the Gulf of Mexico and GUIS provides stopover habitat to many of those species. A variety of efforts have reported around 345 bird species from the park. Considering only confirmed records, we found that 321 species have been reliably reported in recent years. Multiple state-listed species are present in the park, as well as several birds of broad conservation concern. Current monitoring efforts by the GULN (Granger 2013) will aid in understanding the density and distribution of GUIS breeding bird assemblages.

Shorebirds and Seabirds

Gulf Islands National Seashore supports a large and diverse population of migrating and nesting shorebird and seabird species, and many species of conservation concern use the park for nesting, overwintering, or migratory stopover habitat. The northern Gulf region of FL may be the most important region for the nesting of the state threatened Snowy Plover (Himes et al. 2006, Burney 2009). At least 16 species of special management concern, including three federal or state threatened species (Least Tern—*Sternula antillarum,* Piping Plover—*Charadrius melodus,* Snowy Plover—*Charadrius nivosus*), were reported from GUIS during regular monitoring by NPS. Of 14 high priority species included in a regional shorebird conservation plan (Hunter et al. 2002), 13 were reported to occur in GUIS. In general, GUIS provides critical nesting habitat for a variety of shorebird and seabird species, and recent increases in nesting success by the state-threatened Snowy Plover indicates that this habitat may be becoming increasingly important for shorebirds.

Rare Beach Mice

Two species of beach mice are known to occur in Gulf Island National Seashore: the Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*) and the Santa Rosa beach mouse (*Peromyscus polionotus leucocephalus*). The Perdido Key beach mouse (PKBM) is found only on the Perdido Key barrier island, and this island comprises its entire native range (Holler et al. 1989, Gore and Greene 2011). The PKBM is listed as endangered federally and by the state of FL, and is one of the most critically imperiled subspecies of beach mouse. The Santa Rosa beach mouse (SRBM) occurs on Santa Rosa Island, and the island comprises its entire native range (Gore and Shaefer 1993). The SRBM is not listed at the state or federal level. Beach mice face a variety of natural and anthropogenic threats including: loss of habitat from development, hurricanes and strong storms, and introduction of exotic and feral animals (predators and competitors). The PKBM population remains threatened. Although highly-defensible estimates of population size were not available in the studies discussed in this report, the entire existing population is obviously small and highly isolated, likely numbering at best several hundred individuals. The SRBM has been pressured by loss of habitat from beach development and apparently does not exist in some habitats it previously occupied. However, the species remains relatively widely-distributed and is generally found throughout suitable undeveloped habitat as it occurs on Santa Rosa Island.

Reptiles and Amphibians

A 2004- 2007 herpetofaunal inventory (Mohrman and Qualls 2008), combined with ongoing GULN monitoring efforts (Woodman 2013) have reported 53 species of reptiles and amphibians at GUIS, including the non-native greenhouse frog (*Eleutherodactylus planirostris*). This represents around 76% of the expected richness for the area, when compared to species reported in historical park surveys and other survey efforts conducted in the region. Greatest richness and abundance of amphibian species occurred during the spring and summer. Multiple federal or state listed threatened or endangered herpetofauna species have been reported from the park, including the American alligator (*Alligator mississippiensis*) and gopher tortoise (*Gopherus polyphemus*). Multiple anthropogenic sources likely represent significant threats to park herpetofauna including feral animals, exotic vegetation, saltwater intrusion, and pollution.

Marine Turtles

Marine turtles breed on GUIS beaches and have been monitored in the park using standardized protocols in the Florida district since the 1990's (Cooper et al. 2005). Federal and state listed marine turtles have been reported to nest on the beaches of GUIS-FL, including green sea turtle (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and Kemp's ridley (*Lepidochelys kempii*; Shabica 1980, Nicholas 2010). Given their vagile nature, marine turtles may be affected by pollution within GUIS and within the greater Gulf of Mexico region. Marine turtles are particularly susceptible to threats such as environmental contaminants (e.g., Deepwater Horizon Gulf Oil Spill), vehicular traffic on nesting beaches, and light pollution. Marine turtle monitoring at GUIS-FL indicates that sea turtle nest success has remained relatively stable over the last 20 years. From 1996-2012, mean number of hatchling sea turtles exceeded the average number for this time period in seven years of data collection. Notably, five of these seven years occurred in the last decade of monitoring, suggesting that sea turtle nest success is improving in this region.

2.2.4 Resource Issues Overview

In addition to the specific resources outlined above, there are other factors that actively affect natural resources at GUIS and deserve continued monitoring and management attention. Prescribed burning, for example, is an effective management practice that can result in several ecological benefits. In addition, changes in the larger landscape scale surrounding the park can represent significant factors that may also affect visitor experience. Because of these considerations at virtually all NPS units, they are a common target for monitoring throughout all I&M networks, including GULN.

Weather and Climate

The purpose of weather monitoring within the GULN is to develop a long-term record of meteorological data, which may in turn be used to track changes and help understand other ecosystem processes. Weather can influence water quality, vegetation dynamics, and wildlife behavior, among other things. Several monitoring stations in the Cooperative Observer Program (COOP) are located around the park and provide long-term datasets. These stations monitor mainly temperature and precipitation, though additional parameters are included. If the frequency or intensity of weather events changes over a longer-term (decades to centuries), this can alter the essential properties of natural resource systems. For this reason, the analysis of long-term records can reveal gradual and more permanent changes in climate, which may in turn cause fundamental alterations in the environment of the GULN region. Sea-level rise and increased storm frequency and intensity are two ways that GUIS habitats may be directly affected by a warming climate (IPCC 2007).

Coastal Processes

The geomorphology of the coastal areas and barrier islands comprising GUIS is constantly changing. Through the combined forces of anthropogenic changes, such as dredging and channelization, along with natural processes like storm events and island migration, protecting natural and cultural resources at GUIS is an ongoing management concern. Protecting coastal resources from human impact is one of the most effective means of preservation, although restoration efforts are also undertaken to counteract the effects following an extreme weather event. The Mississippi Coastal Improvement Program (MsCIP), via efforts by the U.S. Corps of Engineers, is a project to restore Ship Island by filling in the gap between East and West Ship with about 19 million cubic yards of sand, with work beginning in 2015. The main goal of this project is to mitigate hurricane/storm damage, control erosion, and prevent salt water intrusion (U.S. Army Corps of Engineers 2009). GULN also recently began mapping coastal areas and barrier islands using LiDAR (Light Technology and Ranging) in order to closely monitor geomorphic changes. These restoration and monitoring efforts combined will aid in mitigating GUIS beaches and dunes from sea-level rise and increased storm intensity and frequency as expected with climate change (IPCC 2007).

Fire Management

GUIS completed a fire management plan in 2009, which outlined its goal of using prescribed burns to reduce fuel buildup and maintain natural ecosystems (NPS 2009a). Much of the vegetation at GUIS is fire-adapted, and the recent reintroduction of fire in 1998 has helped restore these ecosystems. Many communities at GUIS historically burned frequently as a result of lightning-strikes. Prescribed burns can help maintain these communities by providing fire-tolerant plants such as longleaf pine with a competitive advantage. They also maintain habitat essential to many types of wildlife such as gopher tortoises, who rely on herbaceous browse that would otherwise be outcompeted by woody understory species in the absence of fire.

GUIS is divided into 12 fire management units – one for each of the disparate units comprising the park. Prescribed burns are only conducted in the Davis Bayou and Naval Live Oaks units; these units are subdivided into sections managed for individual burns. Main vegetation types in the Davis Bayou unit include pine flatwoods and savanna, marsh, and live oak hammock. Similar habitat types are present at Naval Live Oaks, with the addition of pine-scrub and sandhill areas (NPS 2009a).

Non-native Species

Non-native and invasive species are a management concern at GUIS and in some cases have substantial influence on floral and faunal communities (Urbatsch et al. 2007, EPMT 2000). Although data on the extent and abundance of invasives within the GUIS units are generally lacking, the most recent vascular plant inventory (Urbatsch et al. 2007) provides a description of the non-native plant species present within the park. Urbatsch et al. (2007) reported 968 taxa at GUIS. Of these species, 12% were non-native species. In total, nine species were ranked as either high or medium threats, four of which were present in a variety of terrestrial habitats—torpedo grass (*Panicum repens*), bermudagrass (*Cynodon dactylon*), annual bluegrass (*Poa annua*), and hop clover (*Trifolium campestre*). Cogongrass (*Imperata cylindrica*), Chinese tallow tree (*Sapium sebiferum*), Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), torpedo grass, and common reed (*Phragmites australis*) have all been specifically referenced as being serious management concerns for GUIS (EPMT 2000). Non-native animals (e.g., nutria—*Myocastor coypus*, coyote—*Canis latrans*, red lionfish) exist in a variety of habitats at GUIS and are addressed in this report where applicable to the resources they threaten.

Landscape Change

Many of the other vital signs established for GUIS interact and respond to changes of the landscape within and surrounding the park, including invasive species introductions, water quality issues, and air quality problems. At GUIS, the landscape is undergoing constant changes due to both human alteration and natural processes. Changes in the periphery of the park area can not only affect the biological health of the park unit, but also the scenic integrity.

The NPScape landscape dynamics program created an organized protocol for landscape scale assessment for all park units in the US. To achieve that goal, landscape analysis was divided into five main categories: (1) landcover, (2) roads, (3) population and housing, (4) pattern, and (5) conservation status. Each of these categories has an associated set of data sources and data products that provide the foundation for further analysis. For each section, the NPScape interpretative guide provides a literature review, including lists of thresholds that can serve as metric guidelines.

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Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

During December 2010, an initial scoping meeting was held to discuss natural resource issues at GUIS (See Appendix A. for list of attendees). The purpose of this meeting was to provide an introduction to the scope of the NRCA report and identify potential sources of data. Using the list of vital signs outlined by the GULN as a starting point, additional points of interest and important natural resource issues at the park unit were added as focal points to the assessment. Other discussion was devoted to how the report could maximize its utility at the park unit level.

3.2 Study Design

3.2.1 Indicator Framework

The ranking framework used for the NPS natural resource condition assessments draws from the National Park Service's ecological monitoring framework (EMF) (Fancy et al. 2009, Table 1; see also Table 2). The NPS framework divides monitoring into six general categories: air and climate, geology and soils, water, biological integrity, human use, and landscape pattern and processes. Each of these general categories, referred to as level-one, are further subdivided into level-two and level-three categories, with each park vital sign most closely associated with this fine-scale level-three division. Biological integrity, a level-one category for example, is divided into 4 level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Invasive species, in turn, includes 2 level-three categories: invasive/exotic plants and invasive/exotic animals. As the categories move from level-one to level-three, the resolution of the data involved also increases.

Table 1. General Ecological Monitoring Framework used to organize and identify natural resource areas of interest at GUIS (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest [a]
Air and Climate [b]	Air Quality [b]	Ozone [b, d]	Measures: Ozone levels and impact on native plants [b]
		Wet and Dry Deposition [b, d]	Measures: Trends in wet deposition from nearby NADP stations [b]
		Visibility and Particulate Matter	-
		Air Contaminants	-
	Weather and Climate [b]	Weather and Climate [b, c]	Measures: Temperature, barometric pressure, humidity, precipitation, wind direction [b]
Geology and Soils [b]	Geomorphology [b]	Windblown Features and Processes	-
		Glacial Features and Processes	-
		Hillslope Features and Processes	-
		Coastal/Oceanographic Features and Processes [b, c]	Measures: Beach erosion and shoreline movements; passageway dredging and sand relocation; presence of hydrocarbons in sediments [b]
		Marine Features and Processes [b, c]	Measures: Beach erosion and shoreline movements; passageway dredging and sand relocation; presence of hydrocarbons in sediments [b]
		Stream/River Channel Characteristics	-
		Lake Features and Processes	-
	Subsurface Geologic Processes	Geothermal Features and Processes	-
		Cave/Karst Features and Processes	-
		Volcanic Features and Processes	-
		Seismic Activity	-
	Soil Quality	Soil Function and Dynamics	-
	Paleontology	Paleontology	-

[a] Measures listed in column 4 describe general areas of study interest and include suggested measures or ones already available from existing data.

[b] Represents relevant vital signs specifically selected for Gulf Islands National Seashore (also in light-blue font).

[c] Denotes an official vital sign as identified by the GULN for GUIS by the network monitoring plan.

[d] Denotes significant natural resources mentioned elsewhere or sampled as part of network inventory and monitoring efforts.

Table 1 (continued). General Ecological Monitoring Framework used to organize and identify natural resource areas of interest at GUIS (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest a
Water [b]	Hydrology [b]	Groundwater Dynamics	-
		Surface Water Dynamics [b, c]	Measures: Discharge [b]
		Marine Hydrology	-
	Water Quality [b]	Water Chemistry [b, c]	Measures: Temperature, pH, specific conductivity, DO, ANC [b]
		Nutrient Dynamics	-
		Toxics	-
		Microorganisms [b, c]	Measures: Bacterial contaminants [b]
		Aquatic Macroinvertebrates and Algae	-
Biological Integrity [b]	Invasive Species [b]	Invasive/Exotic Plants [b, c]	Measures: I-Ranks, treatment efficacy; effect on other plants [b]
		Invasive/Exotic Animals	-
	Infestations and Disease	Insect Pests	-
		Plant Diseases	-
		Animal Diseases	-
	Focal Species or Communities [b]	Marine Communities [b c]	Measures: Change in seagrass beds [b]
		Intertidal Communities	-
		Estuarine Communities	-
		Wetland Communities	-
		Riparian Communities	-
		Freshwater Communities	-

[a] Measures listed in column 4 describe general areas of study interest and include suggested measures or ones already available from existing data.

[b] Represents relevant vital signs specifically selected for Gulf Islands National Seashore (also in light-blue font).

[c] Denotes an official vital sign as identified by the GULN for GUIS by the network monitoring plan.

[d] Denotes significant natural resources mentioned elsewhere or sampled as part of network inventory and monitoring efforts.

Table 1 (continued). General Ecological Monitoring Framework used to organize and identify natural resource areas of interest at GUIS (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest [a]
Biological Integrity [b] (continued)	Focal Species or Communities [b] (continued)	Sparsely Vegetated Communities	-
		Cave Communities	-
		Desert Communities	-
		Grassland/Herbaceous Communities	-
		Shrubland Communities	-
		Forest/Woodland Communities [b, c]	Measures: Species present, community composition, sensitive species [b]
		Marine Invertebrates	-
		Freshwater Invertebrates	-
		Terrestrial Invertebrates	-
		Fishes [b d]	Measures: Species richness, diversity, observed vs. expected assemblages [b]
		Amphibians [b, c]	Measures: Species richness, observed vs. expected, marine turtle nesting trends [b]
		Birds [b, c]	Measures: Assemblage richness, indicator species/species of concern, observed vs. expected [b]
		Mammals	-
		Vegetation Complex	-
		Terrestrial Complex (use sparingly)	-
	At-risk Biota [b]	T&E Species and Communities [b, d]	Measures: Perdido Key beach mouse status (endangered), marine turtles, gopher tortoise status [b]

[a] Measures listed in column 4 describe general areas of study interest and include suggested measures or ones already available from existing data.

[b] Represents relevant vital signs specifically selected for Gulf Islands National Seashore (also in light-blue font).

[c] Denotes an official vital sign as identified by the GULN for GUIS by the network monitoring plan.

[d] Denotes significant natural resources mentioned elsewhere or sampled as part of network inventory and monitoring efforts.

Table 1 (continued). General Ecological Monitoring Framework used to organize and identify natural resource areas of interest at GUIS (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest [a]
Human Use	Point Source Human Effects	Point Source Human Effects [b, d]	Measures: Pedestrian and vehicular disturbances, increased development, and dredging (mostly in FL) (Not assigned a condition status, but rather discussed in the context of the influence on focal communities) [b].
	Non-point Source Human Effects	Non-point Source Human Effects [d]	Measures: Oil and coal spills, beach pollution, pesticide use (Not assigned a condition status, but rather discussed in the context of the influence on focal communities) [b].
	Consumptive Use	Consumptive Use	-
	Visitor and Recreation Use	Visitor Use	-
	Cultural Landscapes	Cultural Landscapes	-
Landscapes (Ecosystem Pattern and Processes) [b]	Fire and Fuel Dynamics [b]	Fire and Fuel Dynamics [d]	(Not assigned a condition status, but rather outlined separately and discussed in the context its influence on vegetation) [b].
	Landscape Dynamics [b]	Land Cover and Use [c]	Measures: NPScape measures include landcover, housing, roads, population, pattern, and conservation status [b]
	Extreme Disturbance Events [b]	Extreme Disturbance Events (Hurricanes) [b]	Measures: Hurricanes; much of the research pertains to morphology and also falls within the “Coastal Dynamics” category [b]
	Soundscape	Soundscape	-
	Viewscape	Viewscape/Dark Night Sky	-
	Nutrient Dynamics	Nutrient Dynamics	-
	Energy Flow	Primary Production	-

[a] Measures listed in column 4 describe general areas of study interest and include suggested measures or ones already available from existing data.

[b] Represents relevant vital signs specifically selected for Gulf Islands National Seashore (also in light-blue font).

[c] Denotes an official vital sign as identified by the GULN for GUIS by the network monitoring plan.

[d] Denotes significant natural resources mentioned elsewhere or sampled as part of network inventory and monitoring efforts.

Table 2. Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Gulf Islands National Seashore.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	NPS Air Resources Division (NPS ARD)	Interpolated 5-year and 10-year estimates for GUIS	Various periods between: 1996-2013
		Florida Department of Environmental Protection (FDEP); Mississippi Department of Environmental Quality (MDEQ)	Three-year averages from stations in both states	2007-2013; 2001-2013
		Portable Ozone Monitoring Station (POMS)	Annual averages from station at Fort Pickens Entrance in GUIS-FL	2004-2005
Atmospheric Deposition	Wet/Dry Deposition	National Atmospheric Deposition Program (NADP) Interpolation maps; NADP stations in AL, LA, and FL; Liberty County, FL Clean Air Status and Trends Network Stations (CASTNET)	Wet and dry deposition nitrate and sulfate concentrations	2010; Varies between 1983-2013; 1989-2012
	Mercury Deposition	National Atmospheric Deposition Program (NADP) Mercury Deposition Program (MDP) stations at Bay Minette and Mobile County, AL and Oak Grove, MS	Mercury deposition	2002-2009 (AL); 2000-Present (MS)
Weather and Climate	Temperature, precipitation, wind	Remote Automated Weather Station (RAWS) at GUIS-Naval Live Oaks and Grand Bay, MS	Wind speed/direction	2003-Present
		Cooperative Observer Program (COOP) stations in Pascagoula and Biloxi, MS and Niceville, FL	Temperature, precipitation, wind speed/direction	1913-Present, 1894-Present, 1942-Present
Coastal Dynamics	Beach erosion, shoreline movements	Morton (2007), Hapke and Christiano (2007)	Average shoreline change rates, total land area	1846-2005, late 1800s to 2005
Water Quality	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), ANC (mean)	Anderson et al. (2005) water quality assessment	Water quality summary	1994-2004
		GULN and GoMA cooperative monitoring data	Datasonde monthly observations at various locations throughout GUIS	Various periods between: 2008-Present

Table 2 (continued). Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Gulf Islands National Seashore.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Terrestrial Vegetation	Status of significant communities	Urbatsch et al. (2007)	Plant inventory and general vegetation description at GUIS	2005-2007
		MSU (2001)	Vegetation map for Davis Bayou unit of GUIS	
Exotic Vegetation	Presence, relative predominance, and invasibility of exotics	Urbatsch et al. (2007)	Plant inventory and general vegetation description at GUIS	2005-2007
		NPSpecies (2007)	List of species present at GUIS	--
		NatureServe (2009)	Invasive threat rankings	--
Seagrass	Change in coverage of seagrass, biomass, species present	Carter et al. (2011)	Seagrass coverage map for MS barrier islands	2010
		Yarbro and Carlson (2011)	Coverage maps for GUIS-FL	1992-2003
		Heck and Zande (1996)	Health as measured by biomass, mainly in GUIS-FL	1993-1996
Fish Communities	Spp. richness	Wilborn and Bennett (2006) fish inventory	Narrative report with summaries of voucher specimens and literature sources, USGS lionfish point map	Varies
Bird Communities	Conservation value index, observed vs. expected, spp. of concern	NPSpecies (2014)	List of species present in park	--
		USGS (2001)	USGS Breeding Bird Survey (BBS) data, survey data from within and around GUIS	Varies
		Granger (2013)	Breeding season point count surveys throughout park	2012
	Richness, detections per effort, Snowy Plover nesting success	NPS monitoring data	Shorebird and seabird surveys/monitoring within GUIS	2002-2012

Table 2 (continued). Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Gulf Islands National Seashore.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Rare Beach Mice	Presence and distribution	Humphrey and Barbour (1981), Holler et al. (1989), Holler and Moyers (1991), Gore and Brown (2008), Gore and Greene (2011)	Number of mice captured with Sherman live traps within GUIS on Perdido Key and Santa Rosa	Varies
		Pries (2006), Branch et al. (2011)	Number of mice detected with Sherman live traps within and outside of GUIS	Varies
Reptile and Amphibian Communities	Observed vs. expected	Mohrman and Qualls (2008)	Narrative report on herpetofauna inventory including spatial locations for detections	2004-2007
		GULN I&M – Woodman and Finney (2013, 2014)	Narrative report on monitoring data and efforts for all captures	2011 - 2013
	Marine turtle nesting trends (attempts, hatching success, number of hatchlings in water)	NPS monitoring data; Nicholas (2010)	Spreadsheets with raw and summarized annual data on nesting turtles; narrative report with 16 years of data on sea turtle nesting in GUIS-FL	1996-2012; 1992-2009
Landscape Dynamics	NPScape main categories: landcover, roads, population and housing, pattern, and conservation status	NPScape dataset	Suite of GIS layers and associated data for each of the main categories, as well as resulting spatial analysis data products	Varies
		LANDFIRE	Vegetation classification for GUIS landscape	2001-2007
		GAP	Vegetation classification for GUIS landscape	--

3.2.2 Reporting Areas

GUIS is an urban park with six sites divided between two states, the Florida (GUIS-FL) and Mississippi (GUIS-MS) districts, respectively. For the purposes of this report, the majority of data collected at GUIS were gathered at only one unit or within only one state. When data were collected throughout both districts within the greater park across multiple units, these sites were included in analyses and park-level analyses were conducted as indicated in each assessment.

3.2.3 General Approach and Methods

Condition and Trend Status Ranking Methodology

Data collected as part of the NPS I&M program typically is intended to assess the condition of the vital sign at level 3, and therefore we summarize at this level using the ranking status tables at the end of each natural resource section. These tables represent a subset of the EMF tables and show finest-scale division of the level 1 category to which the ranked attribute belongs. Individual attributes are assigned two individual rankings: condition and trend.

We used this hierarchical framework to choose assessment attributes and to organize the presentation of results. We developed a list of ecological attributes suitable for condition assessment using 1) level-three category attributes from the adapted EPA framework described above, 2) the inventory and monitoring goals for the Gulf Coast Network (Segura et al. 2007), and 3) input from NPS staff. We assessed the condition of each attribute using standard methods and reference criteria. When appropriate, we performed statistical comparisons using a = 0.05. We represented the condition of each attribute as a colored circle where color indicated condition (dark green = excellent, etc.) (Table 4). Condition rankings are comparable only within an attribute, consequently, identical rankings for different attributes may represent slightly different levels of impairment or resource integrity. We used published metrics and established reference thresholds (e.g. IBI, NAAQS) to assign rankings whenever possible. But when no quantitative metric was found, we used non-quantitative information from the scientific literature and expert opinion. Whenever possible, we also assigned a trend to each condition ranking based on time series data or data sources from multiple time periods. We represented condition trends with a directional arrow within the condition circle. Arrow orientation indicated improving condition (arrow points up), stable condition (arrow points right), or deteriorating condition (down).

Data Quality

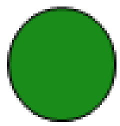
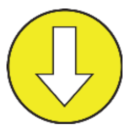
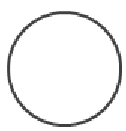
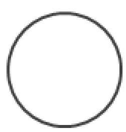
We assigned a data quality ranking to each attribute as an assessment tool for ranking reliability and to identify data gaps. This ranking is divided into three general categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al.'s (2008) NRCA report for Fort Pulaski National Monument. Each category is further subdivided into two sub-ranks, as shown in Table 3. The thematic category is divided into relevancy and sufficiency sub-ranks, answering the questions of whether the data are directly relevant to the category being assessed, and whether there is enough data or if it is sufficiently detailed. The spatial general category, which focuses on whether the data are spatially explicit, is divided into proximity and coverage sub-ranks. These sub-ranks address whether data are specific to the park and its boundaries, and whether the spatial coverage of the data includes the entire park unit. The temporal general category includes the currency and coverage sub-ranks. Respectively, these refer to whether data are recent (≤5 years) and whether they cover a sufficient breadth of time. To give an overall rank to the data quality, the number of sub-ranks fulfilled are summed and translated into a very good (6), good (5), fair (4), marginal (3), poor (2), or very poor (1) ranking and reported alongside the overall condition assessment (Table 4).

As continued monitoring adds to the available data for future condition assessments, it is likely that these data quality rankings will improve. In addition, implementation and refinement of monitoring protocols for the various natural resource categories is still underway. Data collection methods will likely also change as monitoring needs are fine-tuned to specific metrics and aspects of vital signs at each park unit.

Table 3. Data quality ranking criteria.

Data Category	Sub-Rank	Criteria
Thematic	Relevancy	Are data directly relatable to assessment?
	Sufficiency	Are data sufficient to conduct a thorough assessment?
Spatial	Proximity	Are data collected within or close to the park unit?
	Coverage	Is there sufficient areal coverage of the park unit?
Temporal	Currency	Were data sufficiently recent to reflect current conditions?
	Coverage	Do the data cover sufficient temporal breadth?

Table 4. Example condition assessments.

Attribute	Condition & Trend [a, b]	Data Quality [c] Thematic	Data Quality [c] Spatial	Data Quality [c] Temporal	Interpretation
Example 1:		Relevancy √ Sufficiency √	Proximity √ Coverage √	Currency √ Coverage √	Condition: Excellent Trend: None Assigned Data Quality: Very Good
		6 of 6: Very Good			
Example 2:		Relevancy √ Sufficiency √	Proximity √ Coverage √	Currency Coverage √	Condition: Good Trend: Stable Data Quality: Good
		5 of 6: Good			
Example 3:		Relevancy √ Sufficiency √	Proximity Coverage √	Currency √ Coverage	Condition: Fair Trend: Declining Data Quality: Fair
		4 of 6: Fair			
Example 4:		Relevancy √ Sufficiency	Proximity Coverage √	Currency √ Coverage	Condition: Poor Trend: Improving Data Quality: Marginal
		3 of 6: Marginal			
Example 5:		Relevancy Sufficiency	Proximity Coverage √	Currency √ Coverage	Condition: Not Ranked Trend: None Assigned Data Quality: Poor
		2 of 6: Poor			
Example 6:		Relevancy √ Sufficiency	Proximity Coverage	Currency Coverage	Condition: Not Ranked Trend: None Assigned Data Quality: Very Poor
		1 of 6: Very Poor			

[a] Attribute condition is as follows: dark green = excellent, light green = good, yellow = fair, red = poor, white = no condition assigned.

[b] Condition trend is indicated by the arrow within the circle. Pointing up = improving condition, pointing right = stable condition, pointing down = declining/deteriorating condition, no arrow = no trend assigned.

[c] Checkmarks indicate whether data were appropriately thematic, spatial, or temporal for assessments, as described in the text.

[d] Dark green = 6 of 6 possible checks (very good), light green = 5 of 6 possible checks (good), bright yellow = 4 of 6 possible checks (fair), light yellow = 3 of 6 possible checks (marginal), red = 2 of 6 possible checks (poor), dark red = 1 of 6 possible checks (very poor).

3.2.4 Literature Cited

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Chapter 4 Natural Resource Conditions

4.1 Ozone

4.1.1 Context and Relevance

Ozone is a major air quality consideration in the GULN. The National Ambient Air Quality Standards (NAAQS) set by the EPA include two thresholds for primary and secondary pollutant limits. Primary limits are set with human health factors in mind, while secondary standards pertain to visibility, vegetation health, and building integrity. In the case of ozone, the NAAQS primary and secondary standard concentrations were lowered starting on May 27, 2008 from 0.080 ppm to 0.075 ppm for ozone over 8-hr periods. As a result, violations of this standard are defined as 3-year averages of the 4^{th} highest daily maximum 8-hour average ozone concentration (4^{th} Hi Max 8-hr means) that exceed 0.075 ppm (EPA 2014).

4.1.2 Resource Knowledge and Data

Portable Ozone Monitoring Stations

Data on ozone concentrations was collected at one Portable Ozone Monitoring Station (POMS) at GUIS Fort Pickens Entrance Station, near Gulf Breeze, FL (Figure 8). Data at this station were available from 2004 – 2005. This station collected hourly ozone concentrations during the summer ozone season (April – September). The average 4^{th} Hi Max 8-hr over the two seasons of data at the Fort Pickens POMS was 0.076 ppm, which is just above the EPA NAAQS. However, data were only collected in 2004 for 35 days of the season, thus this average may be biased. The average 4^{th} Hi Max 8-hr for 2005 summer season was below the EPA NAAQS at 0.074 ppm (NPS 2006). The goal of these stations was to determine whether there was a need to monitor on the park between the larger metropolitan areas, and to determine whether existing stations near Pensacola adequately reflected on-park conditions. After the initial monitoring periods, the NPS Air Resources Division (ARD) determined there was no reason to continue monitoring (M. Segura personal communication).

NPS Air Resources Division Assessments

Ozone concentrations were monitored by the ARD, which produces interpolated estimates of ozone metrics for individual park units, averaged over five year periods. Estimates are available for GUIS (Table 5).

Table 5. Five-year 4th Hi Max 8-hr annual mean estimates from POMS monitoring by the NPS ARD (NPS 2014).

Period of Estimate	GUIS 4^{th} Hi Max 8-hr mean (ppm)
1999-2003	0.081
2003-2007	0.078
2008-2012	0.070

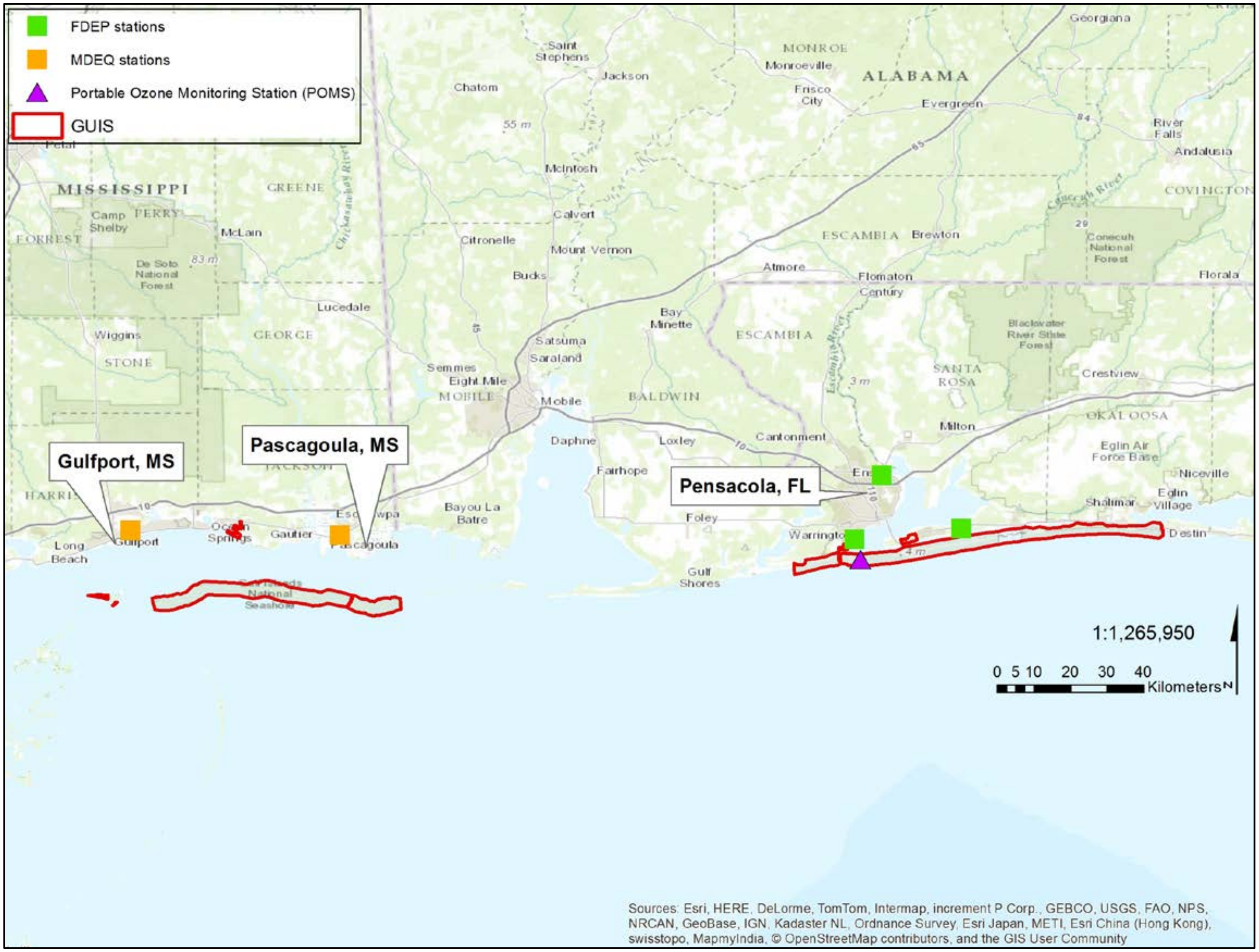

Figure 8. The Portable Ozone Monitoring Station (POMS) at GUIS represents data from 2004 to 2005. The Florida Department of Environmental Protection collects ozone data at three locations in the Pensacola area. The Mississippi Department of Environmental Quality collects ozone data at Gulfport and Pascagoula.

The NPS ARD also assesses overall trends based on 10 year periods (NPS 2013). According to Air Quality Reports by the ARD in 2013, nearly statistically significant decreases ($P \leq 0.15$) in 4th Hi max 8-hr metrics were observed at GUIS over the period 2000-2009, indicating an improving trend. Statistically significant decreases for the period 1998-2007 were also observed (NPS 2009). The 2009 report observed no trend in GUIS ozone metrics over the period 1999-2008 (NPS 2010).

<u>MS Department of Environmental Quality and FL Department of Environmental Protection</u>
The Mississippi Department of Environmental Quality (MDEQ) and Florida Department of Environmental Protection (FDEP) collect ozone data at several locations throughout their states, many of which are in metropolitan areas. Relevant to GUIS are three stations in the Pensacola, FL area and one each in Pascagoula and Gulfport, MS, respectively (Figure 8). Three-year averages of the 4th Hi Max 8-hr metrics are available at the two MS stations for the period 2001 to 2013 (1999-2001, 2000-2002, etc.), during which both stations showed a steady decrease (MDEQ 2014). The same data are available for the three FL stations for the period 2007 to 2013 and also exhibit a steady decline (FDEP 2014). In 2013, the average 3-yr mean among all stations was 0.066 ppm.

4.1.3 Condition and Trend

Overall, the POMS measurements for ozone at GUIS are reasonably low. The 3-yr 4th Hi Max 8-hr mean from the Fort Pickens station falls within the range of significant concern ($\geq$0.076 ppm) for ozone condition, according to the ARD, but the single year metric from 2005 falls within the moderate condition category (0.061 – 0.075 ppm, NPS 2013). Moreover, the short period of time for which this station was active, likely biases the three-year estimates. The MDEQ and FDEP stations also averaged metrics in the range for moderate concern. ARD five-year estimates were in the moderate condition category for GUIS for the latest prediction period of 2008-2013. As a result of these findings, the condition status for ozone for GUIS receives a rating of fair (Table 6). Ten-year data periods assessed by NPS ARD (1999-2008 and 1998-2007) and all MDEQ and FDEP stations (2007-2013) showed significantly decreasing three-year mean metrics. As a result a trend of improving is also assigned for this condition status (Table 6). The quality of the data used to make the assessment was very good (Table 6).

Table 6. The condition of ozone concentration was fair. An improving trend was assigned to ozone condition. The quality of the data used for the assessment was very good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Ozone		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage √
		6 of 6: Very Good		

4.1.4 Literature Cited

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4.2 Atmospheric Deposition

Atmospheric deposition is an issue at GUIS due to the proximity of air pollution sources near the park units. Airborne constituents can affect ecological systems through acidification, soil fertilization, and surface water loading. Deposition resulting from the production of nitrogen oxides (NO_x) and sulfur dioxides (SO_2) are particular issues. These pollutants are typically divided into wet (e.g. precipitation, condensation) and dry (e.g. adsorption, particulate, direct contact) sources, which can debilitate growing conditions for biota, among other effects.

Anthropogenic sources of sulfur dioxides typically include power plants, vehicle emissions, and other industrial sources, while natural sources may include volcanoes, organism emissions, and decaying organic material. The U.S. Clean Air Act, originally passed in 1970, was amended in 1990 to include further controls on atmospheric deposition rates. As a result, during the 18 years from 1990 to 2007, total nitrogen and sulfur deposition in the U.S. decreased by 17 and 34 percent, respectively (MACTEC 2008). Sulfur dioxide can react in the atmosphere to form sulfuric acid (H_2SO_4) and ammonium sulfate [$(NH_4)_2SO_4$], the latter of which is a significant constituent of potentially harmful fine particulate matter ($PM_{2.5}$).

Particulate sulfate (SO_4^{2-}) is a resultant product of sulfur dioxide that often takes the form of ammonium sulfate [$(NH_4)_2SO_4$]. Sulfate deposition is greatest in the Ohio River Valley region around the Great Lakes (Figure 9). Concentrations of sulfate at eastern U.S. reference sites show a 26% decline during the period from 1990 to 2007 (MACTEC 2008).

In addition to sulfur dioxide, nitrogen oxides also react in the atmosphere to produce other pollutants. Nitric acid (HNO_3), for example, is a contributing factor to acid rain while particulate nitrate (NO_3^-) can take the form of ammonium nitrate (NH_4NO_3), a fine particulate matter. Farm production of ammonia (NH_3) can also react with sulfate and nitrate particles to produce particulate ammonium (NH_4^+). Ammonium deposition is highest in the Upper Midwest region of the U.S., while nitrate deposition closely follows the distribution of sulfate (Figure 9). Figure 10 shows a hierarchical format of atmospheric deposition and its constituents.

4.2.1 Context and Relevance

The NPS ARD outlined an approach for assessing deposition values, noting that background wet deposition in the eastern U.S. is roughly 0.25 kg ha^{-1} yr^{-1} for both nitrogen (N) and sulfur (S) (NPS 2013). To gauge condition, the ARD stipulates a threshold of 3 kg ha^{-1} yr^{-1} for total deposition, or about 1.5 kg ha^{-1} yr^{-1} for wet deposition. The ARD primarily concentrates on wet deposition data rather than dry deposition to establish thresholds, mainly because dry deposition data is not as readily available. In the east, dry deposition is usually a smaller proportion than wet deposition of total deposition. Between 2003 and 2006, sulfur dry deposition averaged between 11% and 60% of total deposition in the eastern U.S. (EPA 2007). Below 1 kg ha^{-1} yr^{-1}, wet deposition is not generally considered harmful to ecosystem function, while wet levels above 3 kg ha^{-1} yr^{-1} are considered a significant threat.

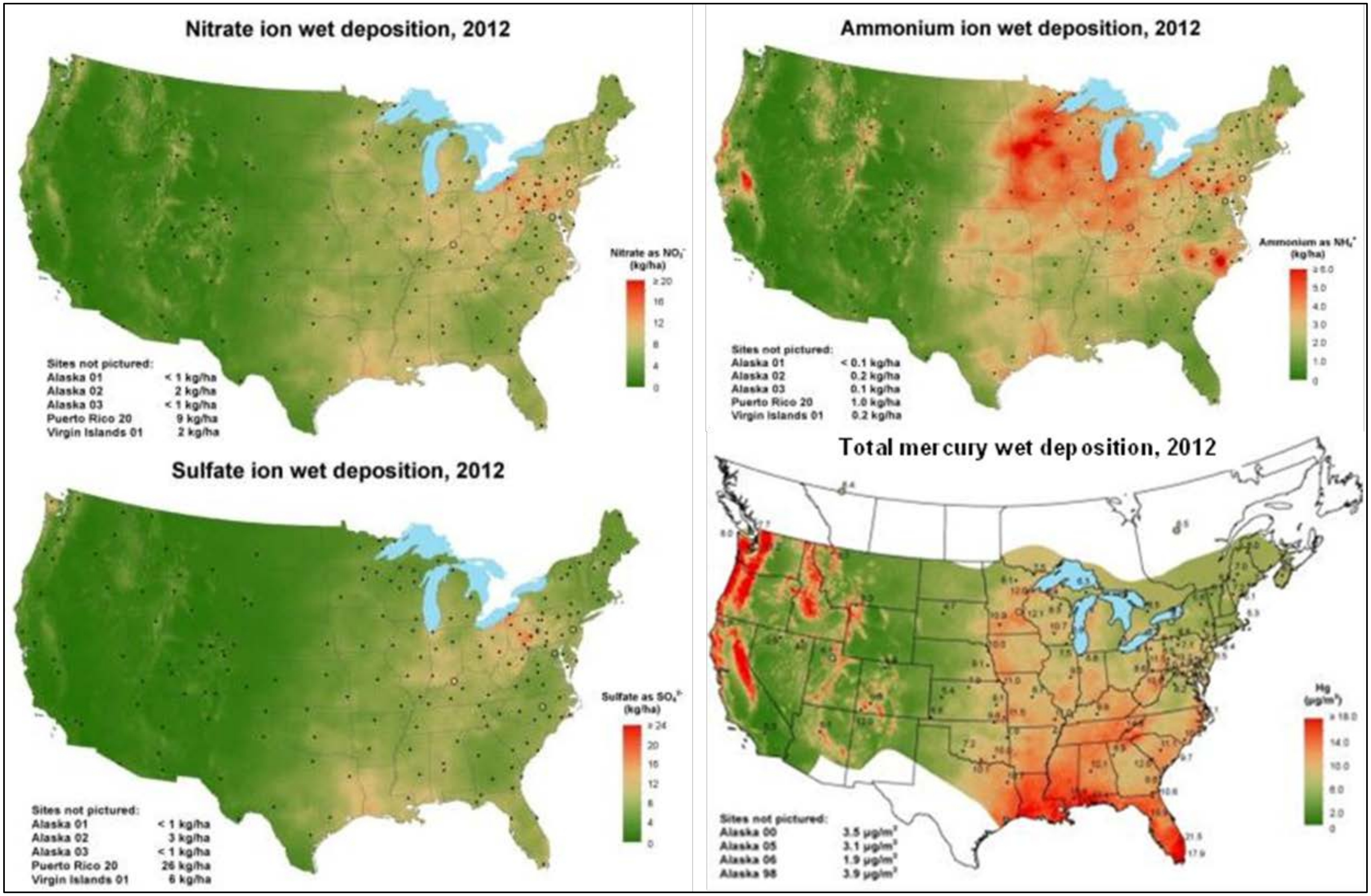

Figure 9. Atmospheric wet deposition maps interpolated for U.S. in 2012. Clockwise from top left: nitrate (NO_3^-), ammonium (NH_4^+), mercury (Hg^+), and sulfate (Eastern U.S. nitrate (left) and sulfate (SO_4^{2-})) [Source: http://nadp.sws.uiuc.edu/].

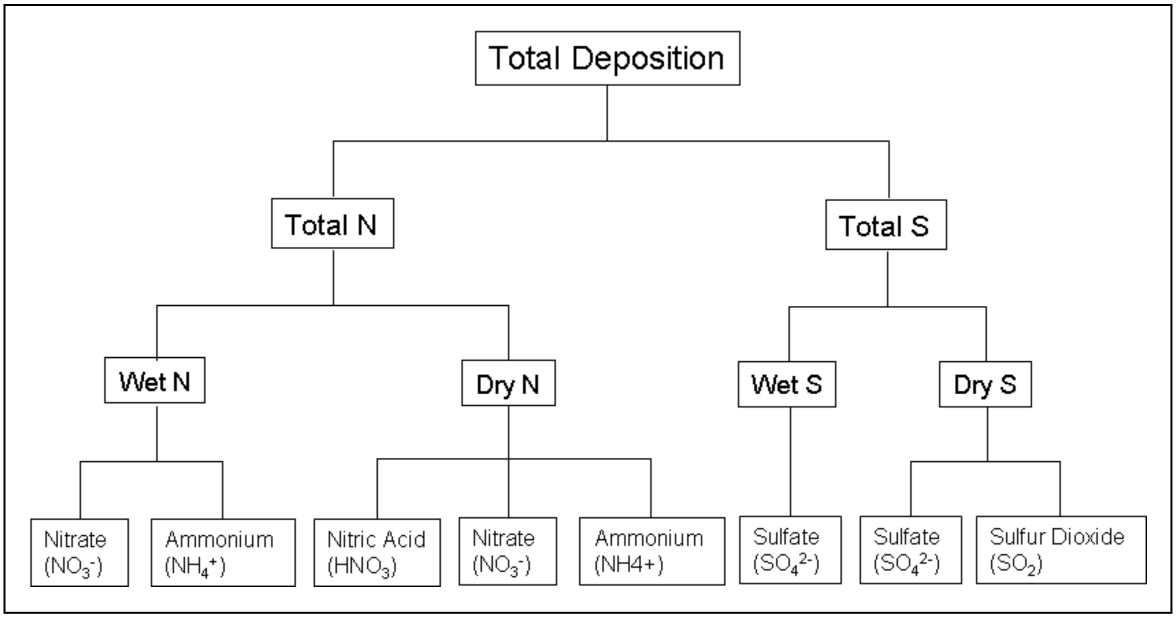

Figure 10. Total atmospheric deposition is typically divided into nitrogen (N) and sulfur (S) portions, each with wet and dry means of deposition.

4.2.2 Resource Knowledge

Other sources concentrating solely on N deposition suggest more lenient thresholds, such as Fenn et al.'s (2003) assessment that the lower limit of ecosystem effects from total N deposition ranges from 3 to 8 kg ha^{-1} yr^{-1} for sensitive species such as lichens and phytoplankton. Krupa (2003), on the other hand, suggests 5 to 10 kg ha^{-1} yr^{-1} total N as the critical range for sensitive terrestrial systems such as heaths and bogs, and values of up to 10 to 20 kg ha^{-1} yr^{-1} for forests. A USFS report by Pardo and Duarte (2007) examined deposition effects on forest types in GRSM, and generally found an acceptable limit of 3 kg ha^{-1} yr^{-1} for N deposition in low elevation mixed hardwood forests and 7 kg ha^{-1} yr^{-1} for higher elevation spruce-fir types.

While there are several references discussing critical thresholds for N deposition, less are available concerning rates of S deposition. In a description of developing critical loads for deposition, Porter et al. (2005) notes that S deposition has altered the acid neutralizing capacity (ANC) of aquatic resources in Shenandoah National Park in Virginia. Based on modeling, a reduced range of S deposition rates between 0 and 4 kg ha^{-1} yr^{-1}would be necessary to even begin to restore ANC values to pre-industrial levels.

4.2.3 Data and Methods

Nitrogen and Sulfur Deposition

There are five sites around GUIS that collect wet deposition data either as part of the EPA Clean Air Status and Trends Network (CASTNET) or the National Atmospheric Deposition Program (NADP, Figure 11). The CASTNET station is located in Liberty County, FL (SUM156, ~150 km ESE of GUIS-FL). The closest NADP station to GUIS-FL is located in Pensacola (FL96, ~25 km N), while the closest station to GUIS-MS is in Jackson County, MS (MS12, ~20 km N). Two other NADP stations, the Southeast Research Station (SRS) in Washington Parish, LA (LA30, ~120 km NW) and

Sumatra (FL23, ~180km NW) in Liberty County, FL also provide reference for wet deposition data. The Sumatra CASTNET station collected wet and dry deposition data over the period 1989 to present, while the Jackson County NADP station recorded data from 2010 to present. At the time of this analysis, data were only available at the CASTNET station through 2012 and at Jackson County through 2013. Because the Jackson County station only had three years of data and the Pensacola NADP station only began data collection in 2013, data from both stations were deemed insufficient to examine trends in deposition. To examine trends relevant to the park units, data from two stations that were active from 2001 to 2010 were used (AL02, ~65 km NNW from GUIS-FL and AL24, ~35 km NE from GUIS-MS). Data from the SRS and Sumatra stations are available over the periods 1983 to 2013 and 1999 to 2013, respectively. All sites except AL24 showed significant decreases in S wet deposition over the period of monitoring, while the CASTNET station also showed a decrease in S dry deposition. Only the LA30 and FL23 stations showed a significant decreasing trend for N wet deposition, and SUM156 also showed a decreasing trend for N dry deposition (Table 7).

Mean deposition values for all years of monitoring and for the final five years of monitoring are shown in Table 8. Annual deposition values for N and S are shown for the CASTNET station in Liberty County, FL in Figure 12. Annual deposition values are also shown for NADP stations in Bay Minette, AL, Mobile County, AL, Liberty County, FL, and Washington Parish, LA, respectively in Figures 13, 14, 15, and 16. Mean annual deposition values for N at the Alabama stations (AL02 and AL24) closest to GUIS, fall within the overall range of values for both averaging periods among stations. However, mean annual deposition for S at the Alabama stations was considerably higher, although a reduction over the period of monitoring is apparent (Table 8).

Table 7. Slopes and p-values for sulfur and nitrogen deposition trends at Liberty County, FL (SUM156 and FL23), Bay Minette, AL (AL02), Mobile County, AL (AL24), and Washington Parish, LA (LA30).

Station Type	Station Name	S (Wet) $^{-}$ kg ha^{-1} yr^{-1}	S (Dry) kg ha^{-1} yr^{-1}	N (Wet) kg ha^{-1} yr^{-1}	N (Dry) kg ha^{-1} yr^{-1}	n yrs
CASTNET	SUM156	**-0.118 ($p < 0.01$)** [a]	**-0.047 ($p < 0.01$)** [a]	**-0.052 ($p < 0.01$)** [a]	**-0.034 ($p < 0.01$)** [a]	23
NADP	AL02	**-0.316 ($p = 0.046$)** [a b]	--	-0.189 ($p = 0.20$) [b]	--	8
	AL24	-0.164 ($p = 0.25$) [b]	--	0.032 ($p = 0.82$) [b]	--	8
	FL23	**-0.183 ($p < 0.01$)** [a]	**--**	**-0.095 ($p = 0.015$)** [a]	--	14
	LA30	**-0.105 ($p<0.0001$)** [a]	**--**	**-0.057 ($p < 0.01$)** [a]	--	30

[a] Trends show significance (α = 0.05, also shown using bold font)

[b] Outliers removed

Table 8. Mean annual wet deposition values for all sites for all years and the last five years of data.

Station	S (last 5 years) kg ha^{-1}	N (last 5 years) kg ha^{-1}
SUM156	4.19 (2.86)	3.19 (2.56)
AL02	5.68 (5.19)	3.92 (3.61)
AL24	5.62 (5.39)	4.32 (4.36)
FL23	3.74 (2.81)	3.01 (2.67)
LA30	4.99 (3.45)	4.62 (3.99)

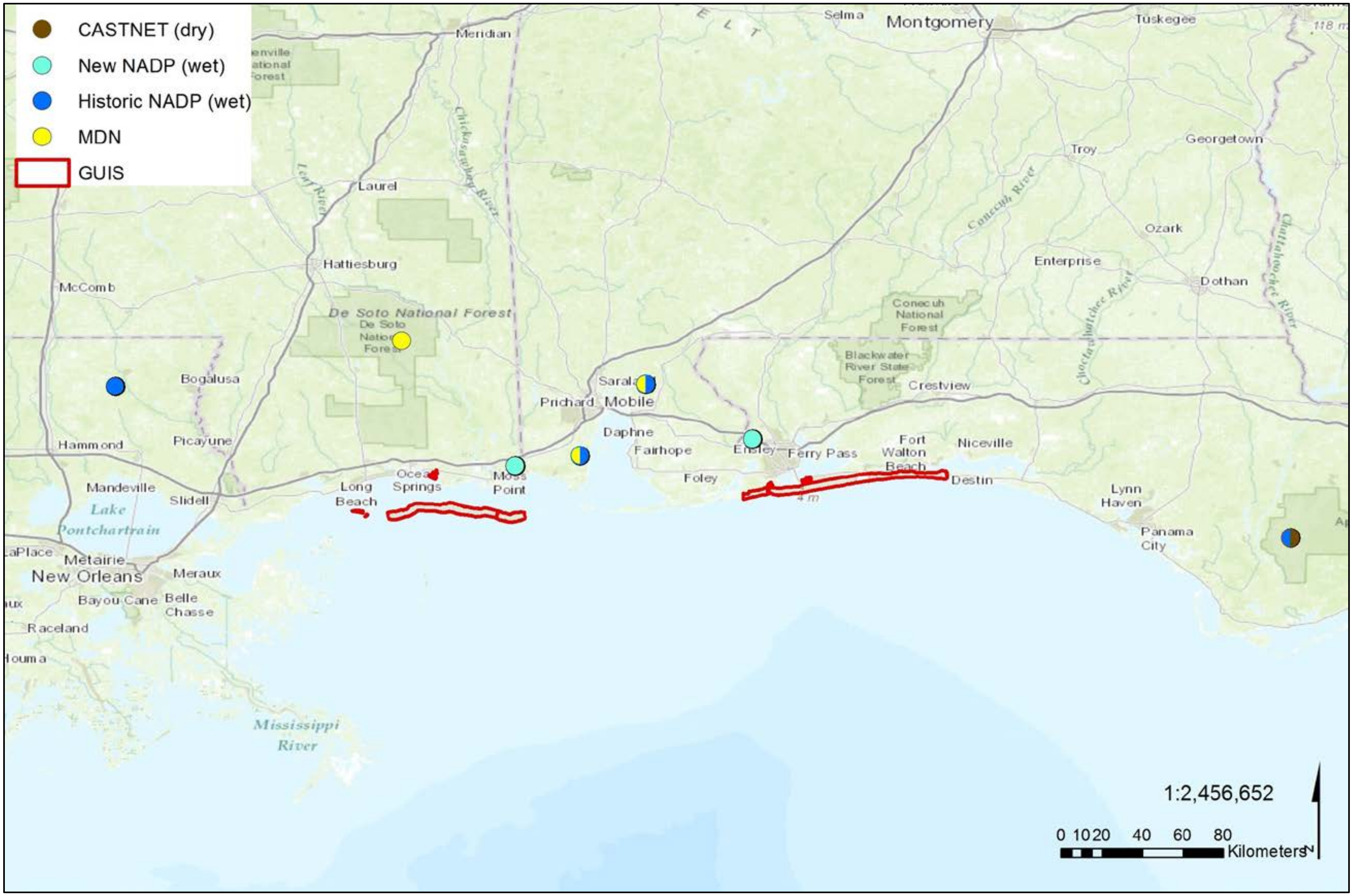

Figure 11. Six NADP stations, one CASTNET station, and three MDN stations monitor atmospheric deposition near GUIS.

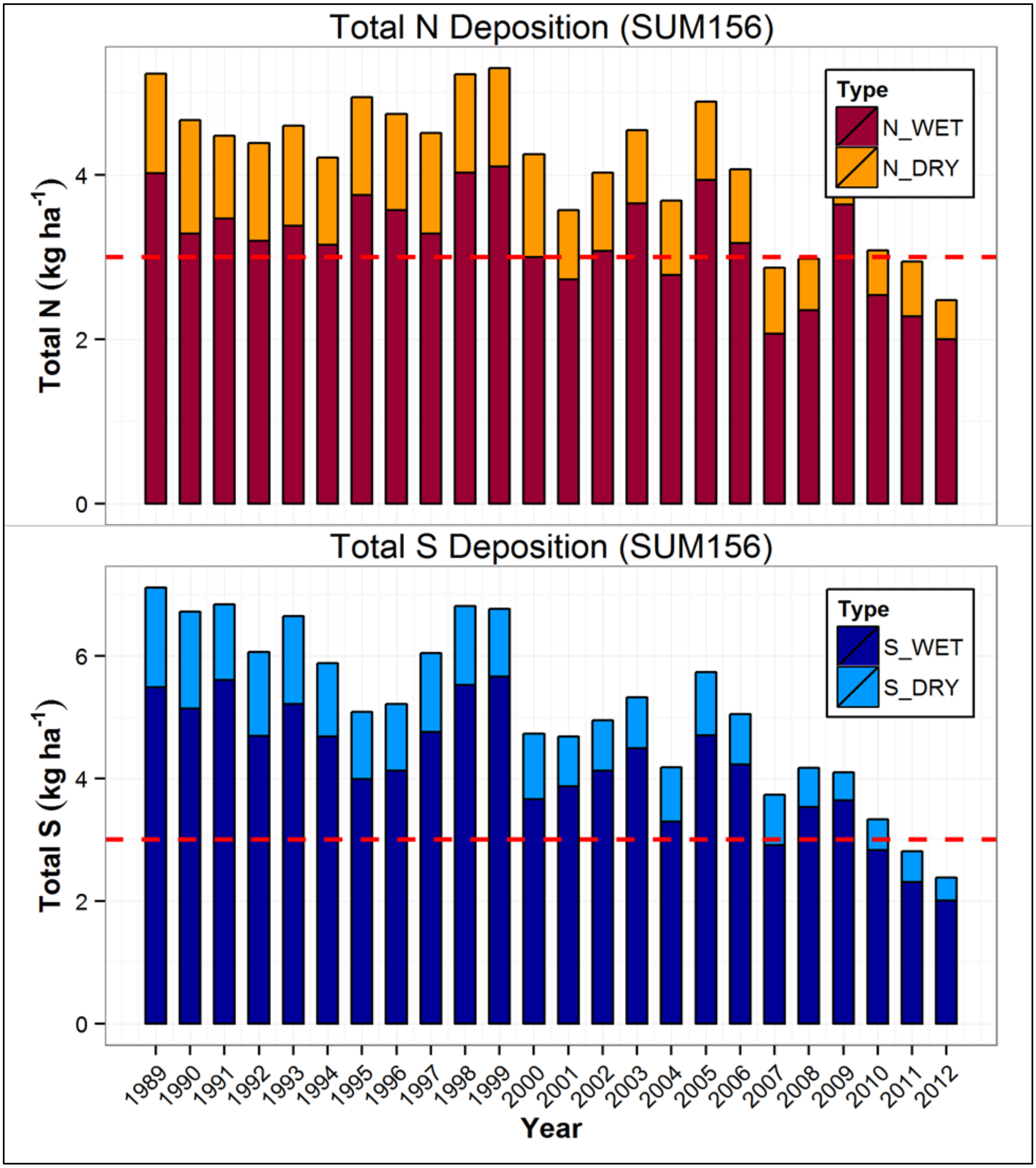

Figure 12. Wet and dry N and S deposition measured at the EPA CASTNET station in Liberty County, FL over the period 1989 to 2012. Values above the dashed red line indicate NPS ARD-specified levels that warrant significant concern (NPS 2013).

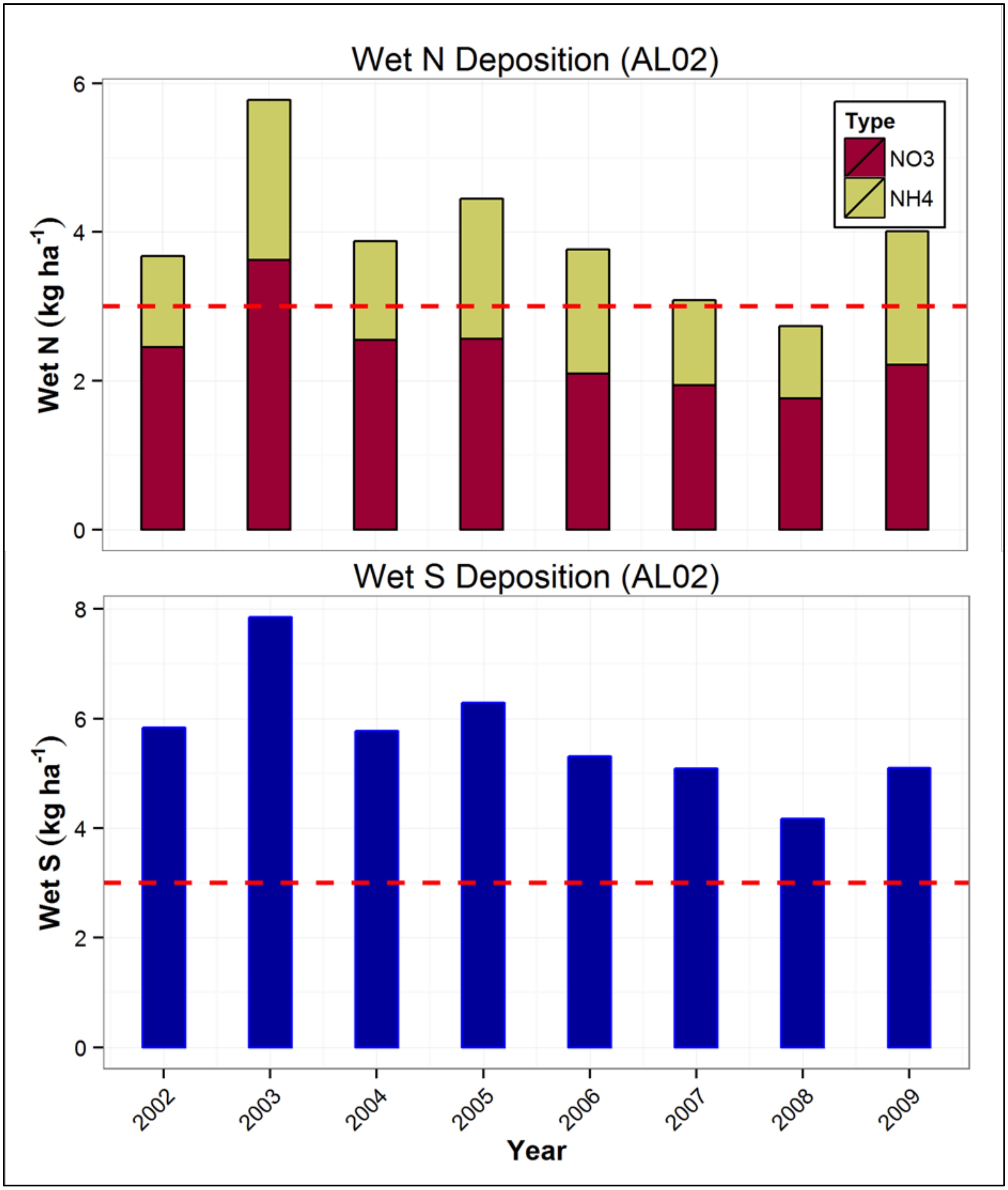

Figure 13. Annual wet N (top) and S (bottom) deposition values measured at the Bay Minette, AL NADP station (AL02) over the period 2002 to 2009. Values above the dashed red line indicate NPS ARD-specified levels that warrant significant concern (NPS 2013).

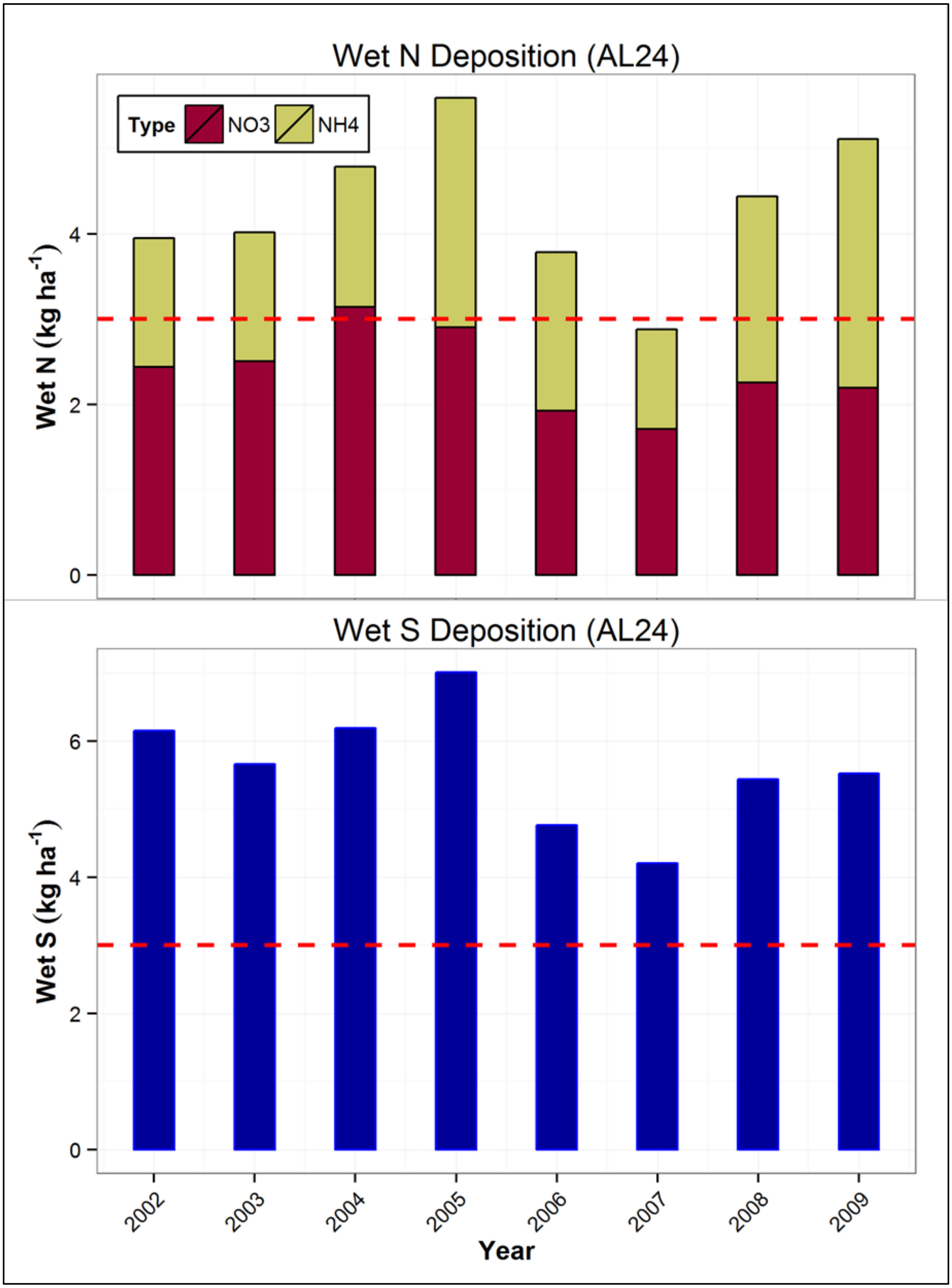

Figure 14. Annual wet N (top) and S (bottom) deposition values measured at the Mobile Bay, AL NADP station (AL24) over the period 2002 to 2009. Values above the dashed red line indicate NPS ARD-specified levels that warrant significant concern (NPS 2013).

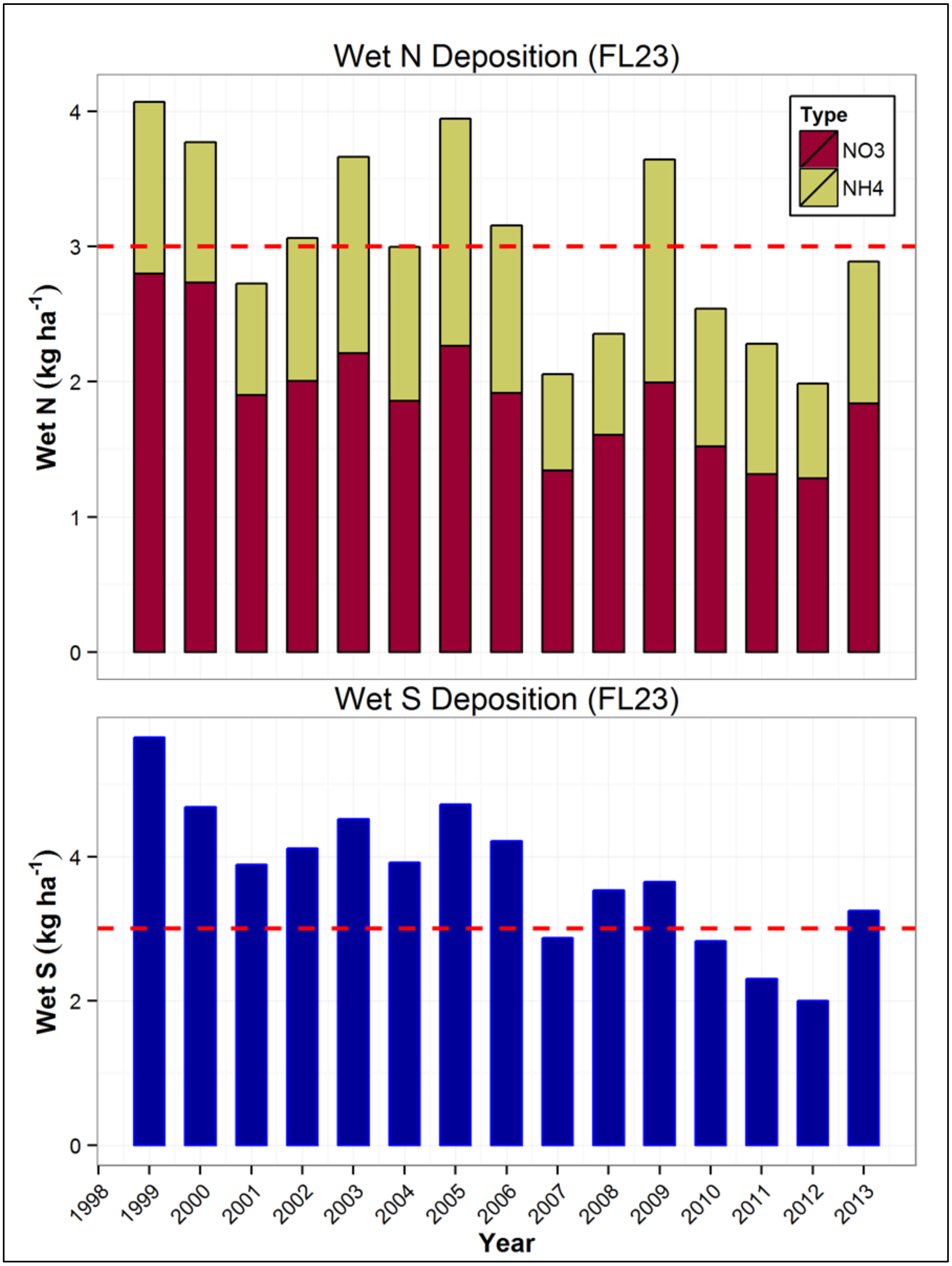

Figure 15. Annual wet N (top) and S (bottom) deposition values at the Liberty County, FL NADP monitoring station (FL23) over the period 1998 to 2013. Values above the dashed red line indicate NPS ARD-specified levels that warrant significant concern (NPS 2013).

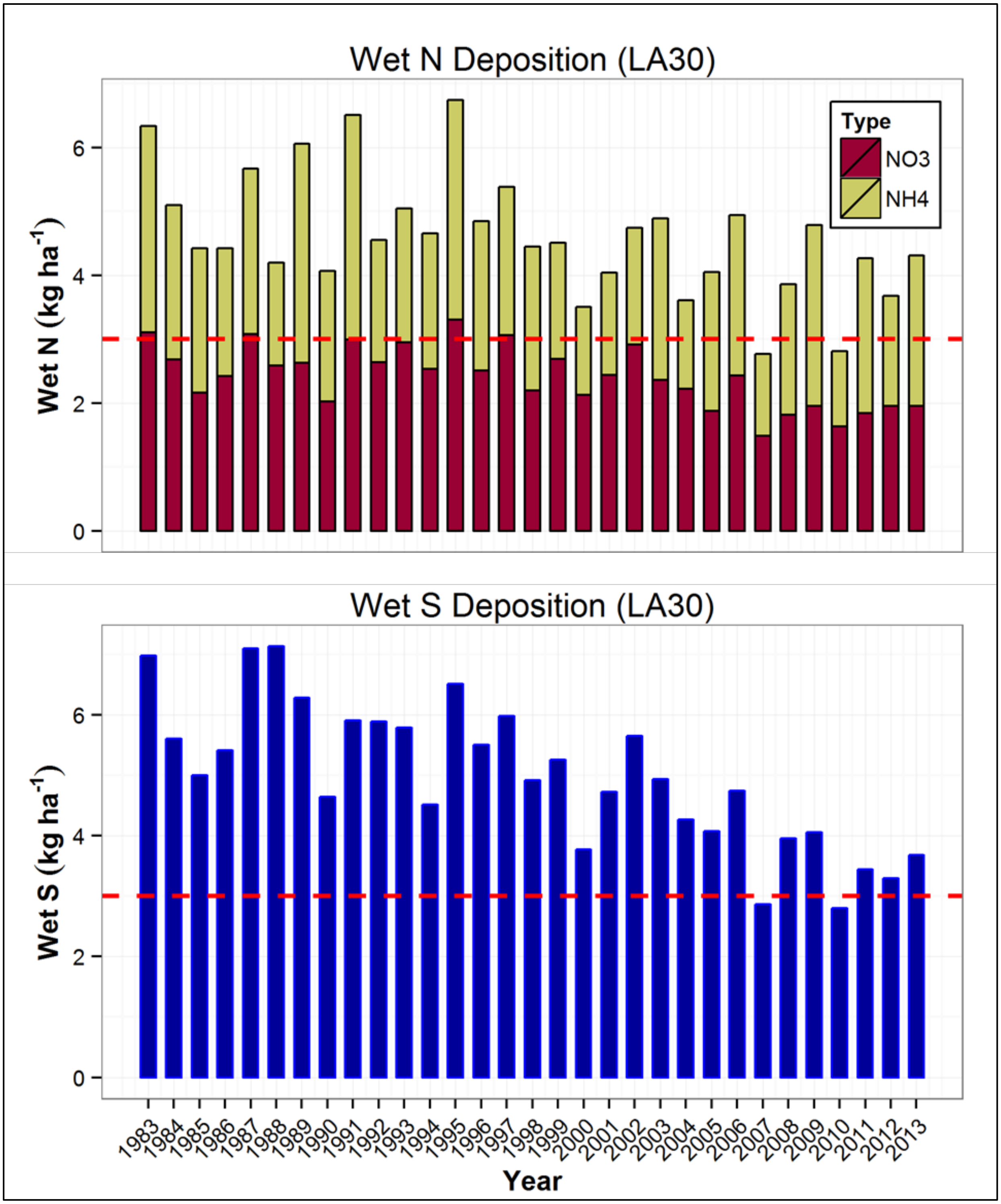

Figure 16. Annual wet N (top) and S (bottom) deposition values at the Southeastern Research Station NADP monitoring station (LA30) over the period 1983 to 2013. Values above the dashed red line indicate NPS ARD-specified levels that warrant significant concern (NPS 2013).

Mercury Deposition

Mercury (Hg) finds its way into ecosystems via similar vectors as N and S. Concentrations of Hg may be transferred long distances in the atmosphere before deposition occurs. Like N and S, Hg may be deposited as either wet or dry mostly in elemental (Hg) or ionic (Hg^{2+}) versions (NADP 2012). Deposition of Hg is particularly a problem in forested areas, because forest canopies can act as a filter that traps dry particles, which are in turn either re-emitted or transported to the ground as throughfall. Terrestrial transport can also lead to contamination of aquatic systems, which can result in human health issues, though generally amounts of mercury transported as runoff are considered to be far less than those which are retained in the soil (EPA 1997a). Once Hg reaches aquatic environments, it can persist in the water column, be carried away, revolatize into the atmosphere, enter the sediment, or be taken up by biota, where it is converted to a different form known as methyl-mercury ($[CH_3Hg]^+$). The accumulation of methyl-mercury in organisms, known as bioaccumulation, is particularly evident in aquatic ecosystems, where organisms higher in the food chain (e.g. fish) can build up relatively high concentrations of mercury (NADP 2012). Fortunately, effects of Hg deposition on vegetation are minimal because most plants do not uptake Hg, thereby limiting a similar bio-accumulative terrestrial pathway (EPA 1997). In 2010, mercury deposition rates were highest in the Pacific Northwest and Gulf Coast regions (Figure 9). There are no federal or state standards for mercury deposition, but there are defined thresholds for different organisms that indicate mercury contamination risk from consumption (Landers et al. 2008). The mercury toxicity threshold for humans, for example, is 185 ng g^{-1}, while for kingfishers (*Megaceryle alcyon*) it is 30 ng g^{-1} (Landers et al. 2008).

The NADP Mercury Deposition Network (MDN) monitors stations throughout the U.S. that collect weekly measurements of total mercury deposition. Five MDN stations collect measurements near GUIS (Figure 11). Two of these stations (FL96 and MS12) began collecting measurements in 2010, and thus those data were not temporally sufficient to be examined in this analysis. These stations are also the closest to both the FL and MS districts of GUIS. Of the three remaining stations, AL02 (in Bay Minette, AL) and AL24 (located in Mobile County, AL) only collected measurements from 2002 to 2009. The closest station that still collects measurements is in Oak Grove, MS, about 65 km north, which began collecting data in 2000. Because of their proximity, the stations in Alabama are likely more representative of mercury deposition at GUIS. Figures 17 and 18 depict weekly measurements at all three sites. No significant trends were found for any of the station data, however, AL02 indicated a nearly significant decreasing trend in deposition ($\beta = -0.042$, $P = 0.082$). Mean deposition rates were 362 ng*m^{-2}, 311 ng*m^{-2}, and 310 ng*m^{-2} at AL02, AL24, and MS 22, respectively.

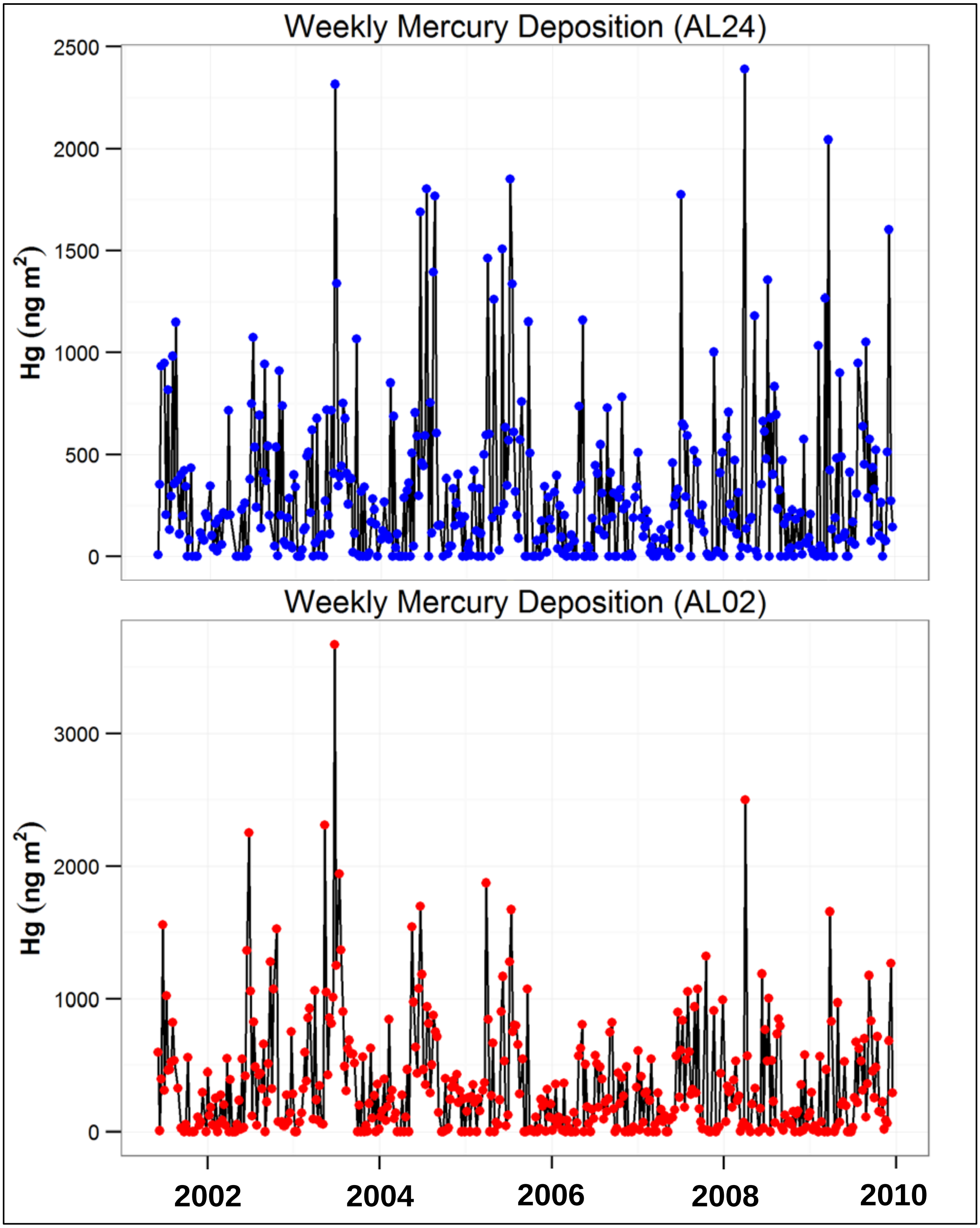

Figure 17. Total mercury weekly deposition measurements (ng m^{-2}) collected at Mobile County (top) and Bay Minette, AL (bottom) from 2001 to 2009.

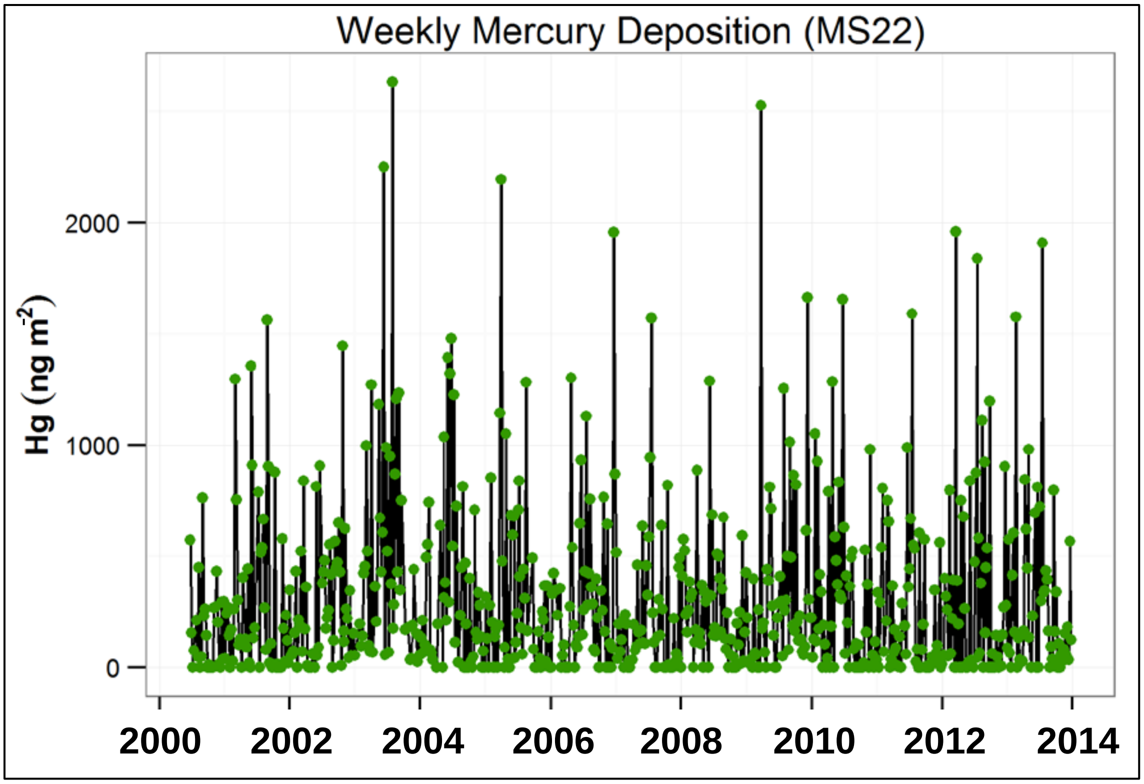

Figure 18. Total mercury weekly deposition measurements (ng m^{-2}) collected at Oak Grove, MS from 2000 to 2013.

4.2.4 Condition and Trend

Overall, the EPA CASTNET and NADP stations provide a continuous and relatively complete data source for deposition throughout the region. Both wet and dry N and S deposition shows significantly decreasing trends over monitoring periods, though mercury deposition demonstrated no trends. According to the NPS ARD wet deposition threshold of 3 kg ha^{-1} yr^{-1}, most (86%) of the annual observations for N and S from the NADP and CASTNET stations near GUIS represent a significant threat to ecosystem health. Because of these factors, GUIS is assigned a condition status of poor for atmospheric deposition (Table 9). All deposition measurements were decreasing over monitoring periods, though mercury did not demonstrate a significant trend. As a result, deposition is assigned a status of improving. A spatial proximity data quality check was not awarded because monitoring locations are located from 35 km to 115 km beyond the park boundary, and thus actual deposition patterns at GUIS may be different. Ideally, monitoring would take place in the park. With time, the addition of two new NADP stations in close proximity to GUIS will likely improve the spatial quality of the data relevant to the park.

Table 9. The condition status for atmospheric deposition at GUIS was poor with an improving trend. Data quality was fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Atmospheric Deposition		Relevancy √	Proximity	Currency √
		Sufficiency √	Coverage	Coverage √
		4 of 6: Fair		

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4.3 Weather and Climate

4.3.1 Context and Relevance

Climate patterns can provide insight into other processes and natural resource conditions such as water quality, vegetation dynamics, and animal communities. For the purposes of monitoring, “weather” generally refers to present and short-term conditions, whereas “climate” is the long-term trend, or norm, representing the entire distribution of atmospheric activity and its associated set of statistical descriptors. Associating weather monitoring datasets with biological data is the primary method for detecting how meteorology affects ecosystem processes. The behavior of many natural resource systems (e.g. groundwater, species patterns, pollutant loads, and plant productivity across the landscape) fluctuates as a consequence of weather events in the short-term. If the frequency or intensity of weather events changes over a longer-term (decades to centuries), this can alter the essential properties of natural resource systems. For this reason, the analysis of long-term records can reveal gradual and more permanent changes in climate, which may in turn cause fundamental alterations in the environment of the GULN region. Sea-level rise and increased storm frequency and intensity are two ways that GUIS habitats may be directly affected by a warming climate (IPCC 2007).

4.3.2 Resource Knowledge and Data

One significant factor affecting short-term weather variation in the Gulf region is the El Niño Southern Oscillation (ENSO), which alternates between periods of warmer temperatures with intense thunderstorms and cooler periods that are overall wetter. Severe weather disturbances such as tropical storms and hurricanes also tend to be less frequent during the warm ENSO cycle (Davey et al. 2007). There are several weather monitoring stations in the vicinity of GUIS that provide observations of temperature, precipitation, wind, and humidity, among other observations. Three of the closest stations with long monitoring periods include two Cooperative Observer Program (COOP) stations in Pascagoula and Biloxi, MS, and one in Niceville, FL (NWS 2014). Collectively, these stations began collecting data in 1913, 1894, and 1942, and all are still currently active as of this writing.

<u>Precipitation</u>

Precipitation is one of the most influential drivers for many ecosystem processes. Precipitation patterns affect fire regimes, primary production by plants, stream flow, and pollutant deposition. The latest Weather and Climate Inventory Report for the GULN (Davey et al. 2007) points out that precipitation has increased in some places in the GULN over the last century (Figure 19). Figure 20 shows annual precipitation levels at the three COOP stations near GUIS from as early as 1894. Linear regression shows significantly increasing trends for each of the stations. Table 10 shows minimums, maximums, means, and years of data for each station.

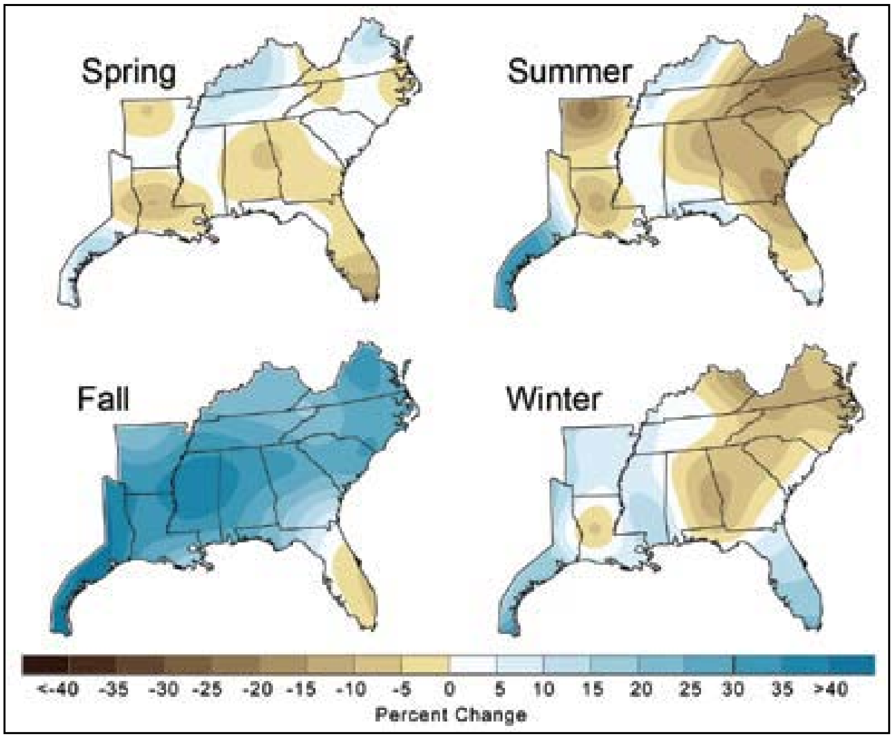

Figure 19. Changes in precipitation in the southeastern U.S. observed from 1901 to 2007 [Source: Karl et al. 2009].

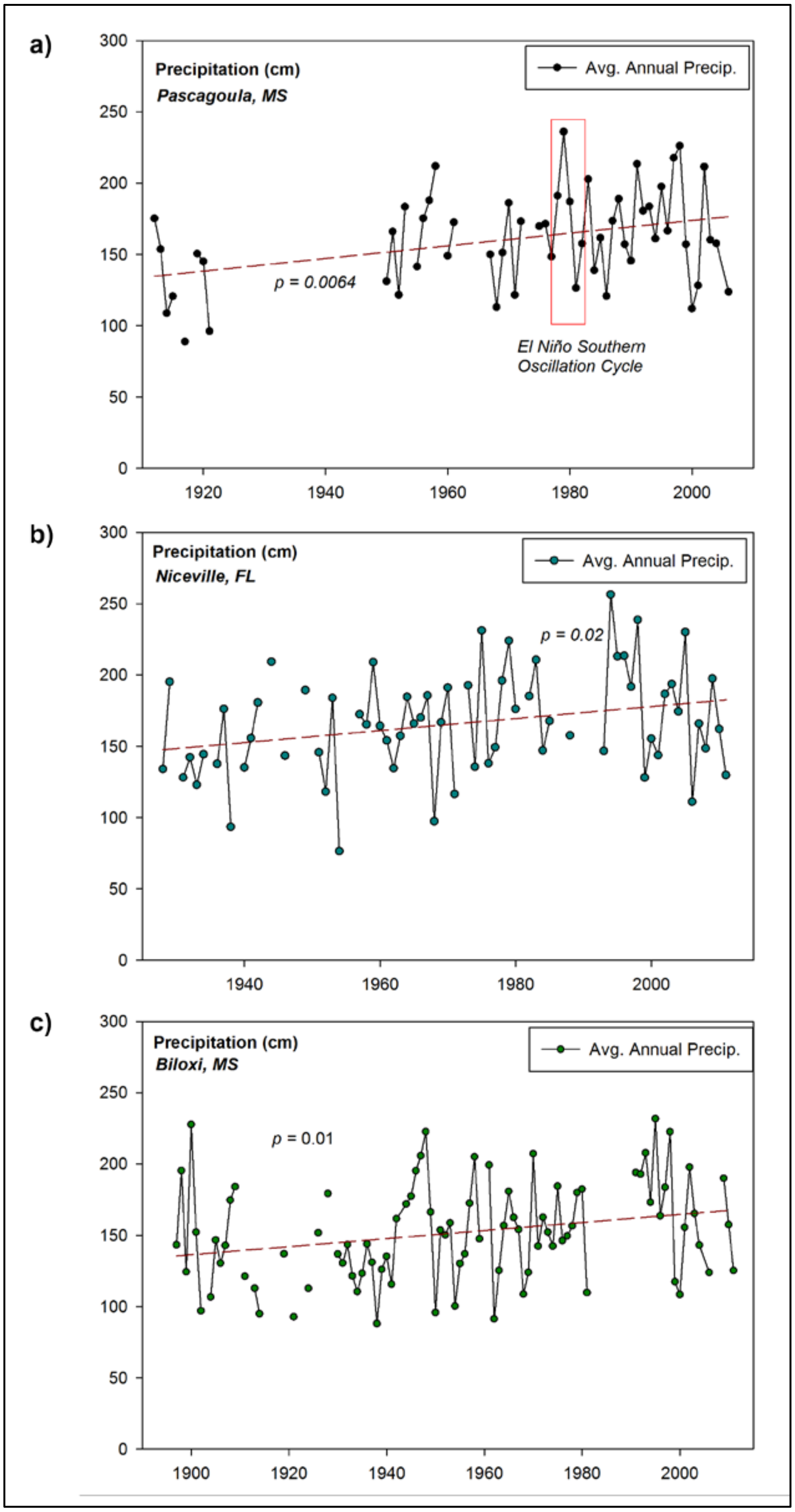

Figure 20. Precipitation data near GUIS from COOP stations in a) Pascagoula, MS, b) Niceville, FL, and c) Biloxi, MS. Monitoring for precipitation began as early as 1894 at Biloxi, MS. As of this writing, all stations are still collecting data. Stations missing one entire month of data or three months with at least three days of data are not plotted for that year.

Table 10. Precipitation statistics for each of the COOP stations near GUIS.

Precipitation	Pascagoula	Biloxi	Niceville
Min (cm)	89	88	76
Max (cm)	236	231	256
Mean (cm)	161	152	166
# Years with data	64	101	79

Temperature

Long-term temperature monitoring in the GULN has also shown noticeable patterns over the past decades. Large-scale changes in temperature could be the result of climate change, as are changes in frequency of extreme weather events such as storms and droughts. These changes can also lead to ecosystem effects such as disease spread and susceptibility to invasive species (Davey et al. 2007). The GULN Weather and Climate Monitoring Plan indicated that temperatures cooled throughout the region during the 1960s and 1970s, but warmed after that period in the central and western portions of the network.

Figure 21 shows average daily, maximum, and minimum annual temperatures at the COOP stations near GUIS, while Table 11 shows minimums and maximums. Years with insufficient data were not included in the plot. Linear regression shows significantly decreasing values for two temperature records at each of two stations, though the majority showed no trend.

Table 11. Temperature statistics for each of the COOP stations near GUIS.

Temperature	Pascagoula	Biloxi	Niceville
Min (cm)	12	14	11
Max (cm)	27	22	28
Mean (ºC)	20	20	19
# Years with data	62	104	58

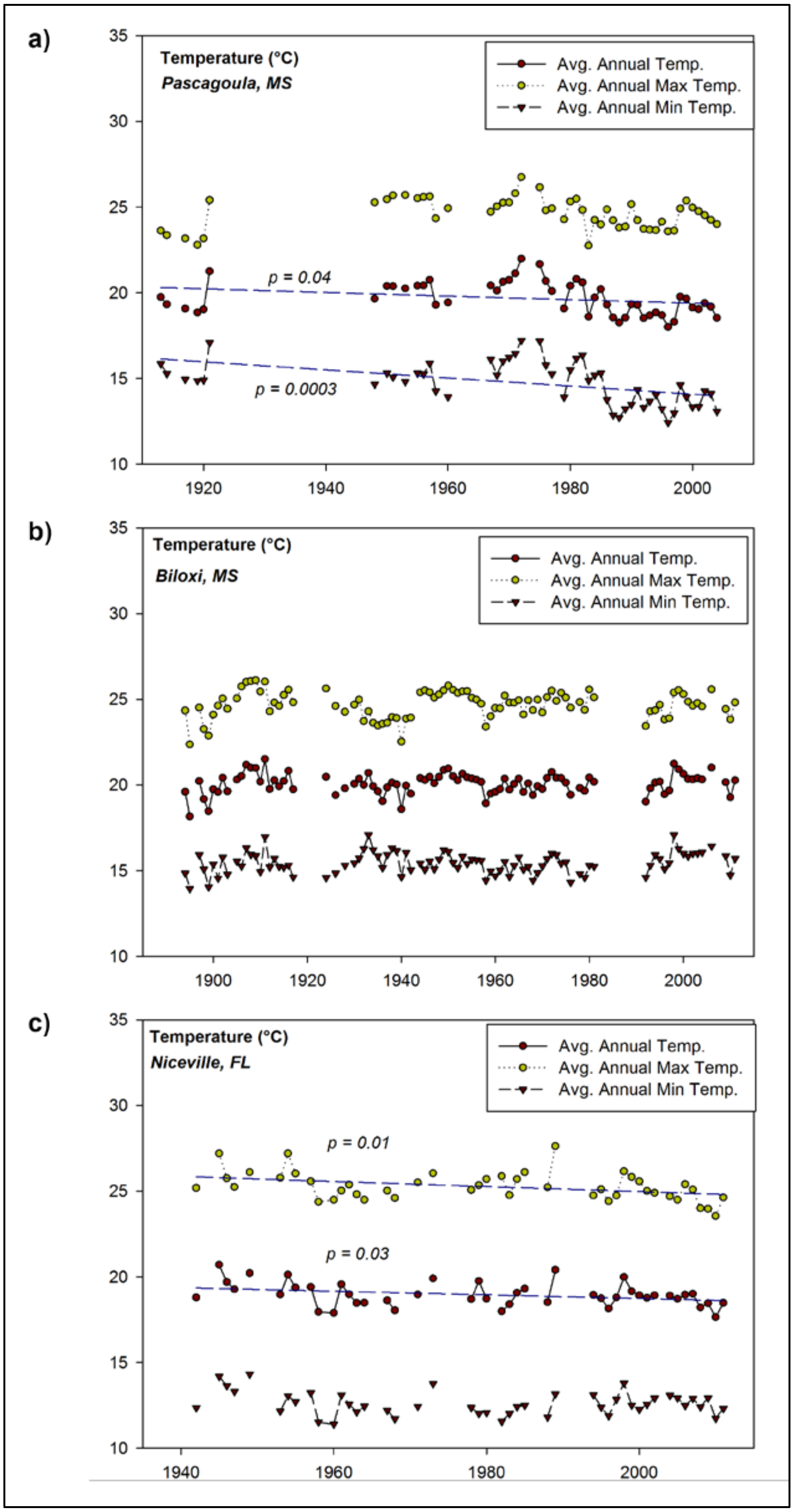

Figure 21. Average daily, maximum, and minimum annual temperatures at COOP stations in a) Pascagoula, MS, b) Biloxi, MS, and c) Niceville, FL. Monitoring for temperature began as early as 1894 at Biloxi, MS. As of this writing, all stations are still collecting data. Stations missing one entire month of data or three months with at least three days of data are not plotted for that year.

Wind Speed and Direction

Two Remote Automated Weather Stations (RAWS) are located in Grand Bay, MS and at the Naval Live Oaks unit at GUIS that monitor wind speed and direction. Figures 22 a and 22b show a 16-point wind rose depicting cumulative wind speed and direction over the history of both stations, which began collecting in 2003. At the Grand Bay station, winds were calm (<1.3 m s^{-1}) approximately 37% of the time, and the direction of wind origin with the highest proportion is from the southeast, though directions were mainly spread between NNW and SSE. At the Naval Live Oaks station, winds were calm around 13% of the time, though directionally was much more variable. The most frequent direction of wind origin was the north.

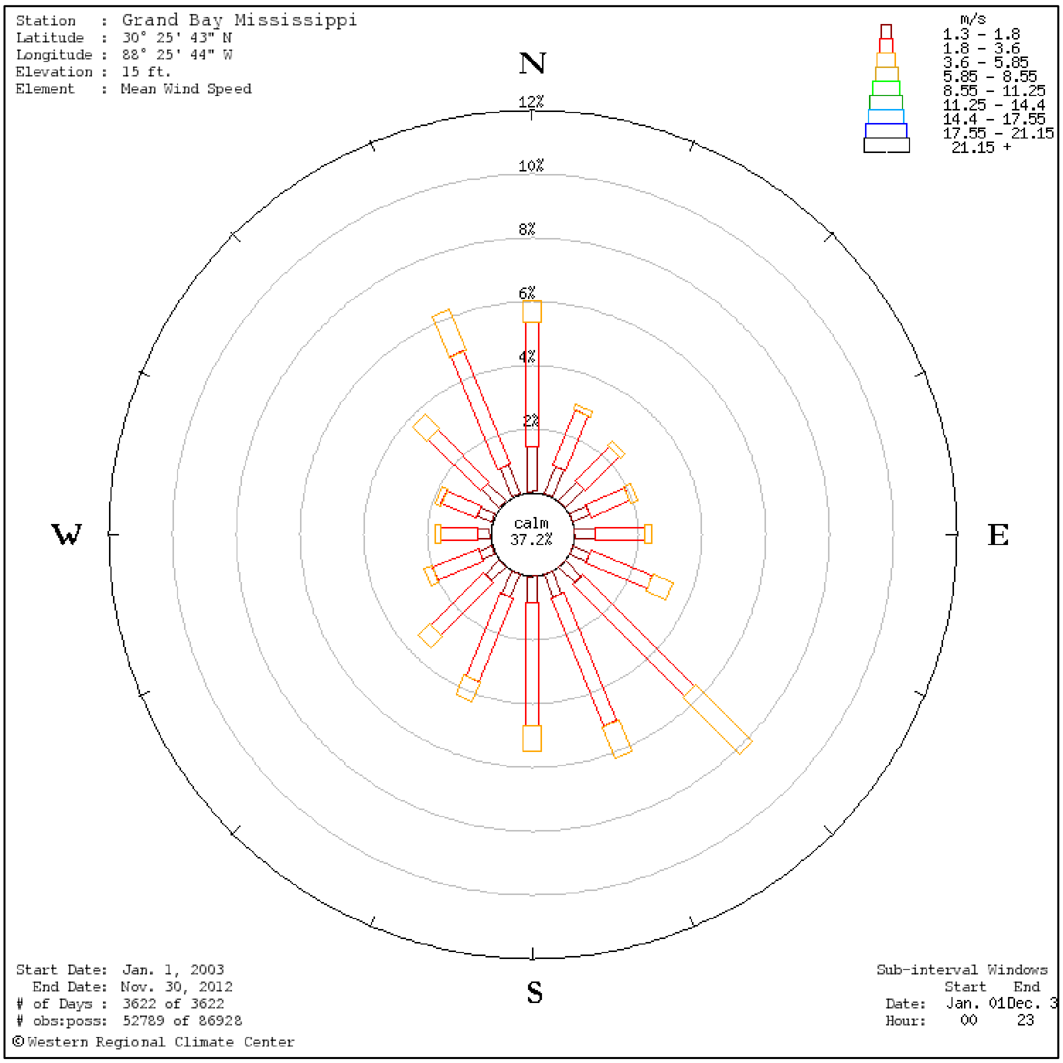

Figure 22a. Directional wind rose for the Grand Bay, MS, RAWS monitors over the period 2003-2012. Colors represent wind speed classes, and length of individual colored bars represent proportion of wind in a given direction.

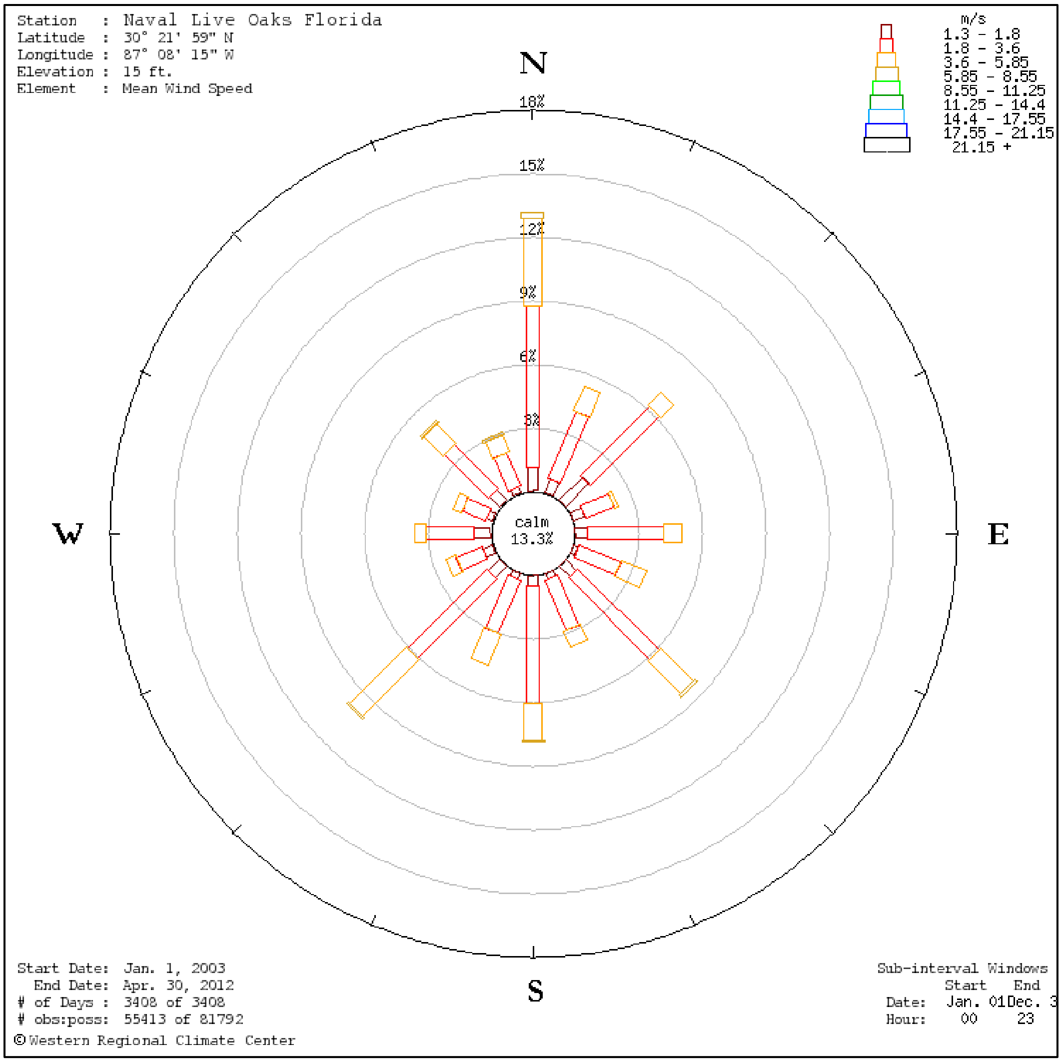

Figure 22b. Directional wind rose for the Naval Live Oaks, FL, RAWS monitors over the period 2003-2012. Colors represent wind speed classes, and length of individual colored bars represent proportion of wind in a given direction.

4.3.3 Condition and Trend

Overall, the two data sources near GUIS provide a reliable history of weather and climate monitoring. Each of the three COOP stations continue to collect data as of this writing, as do the RAWS, which began collecting much more recently in 2003.

Each of the three precipitation records showed an overall increasing trend along, while some of the temperature records showed decreasing trends. Most temperature records showed no trend. Continued monitoring by the COOP stations, RAWS, and potentially other nearby stations is essential to ensure longer-term climate patterns do not go undetected. It is important to note, however, that these datasets, despite being extensive, are still insufficient and inappropriate to conduct an assessment of climate change. An overall condition assessment for weather and climate is untenable, and so this attribute is left without a rank or trend (Table 12).

Table 12. The condition status for weather and climate at GUIS was not assigned a rank or trend. The data quality for this attribute was very good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Weather and Climate		Relevancy √	Proximity	Currency √
		Sufficiency √	Coverage	Coverage √
		6 of 6: Very Good		

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4.4 Coastal Dynamics

4.4.1 Context and Relevance

GUIS consists of seven barrier islands, five in Mississippi (Cat Island, Sand Island, Ship Island, Horn Island, and Petit Bois Island) and two in Florida (Perdido Key and Santa Rosa Island). Mississippi islands are 7 to 15 miles from the mainland, whereas Florida islands are no more than 2 miles from the mainland. These islands also differ in their geomorphological stability (Pendleton et al. 2004), with Mississippi islands historically experiencing greater instability regarding shoreline change. However, all of these barrier islands are undergoing constant change due to coastal processes and are especially vulnerable to storm events. In 2005, the storm surge from Hurricane Katrina temporarily submerged all of the MS barrier islands (Figure 5; NPS 2007). During the past century and a half, combined land area of Ship, Horn, and Petit Bois islands has been reduced by roughly a quarter (Figure 6, NPS 2007). Santa Rosa Island was nearly completely overwashed by multiple hurricane events, including Hurricane Frederic in 1979, Hurricane Opal in 1995, and Hurricane Ivan in 2004 (Pendleton et al. 2004, Hapke and Christiano 2007).

Shifting coastal dynamics are a priority vital sign for the GULN at two parks, GUIS and Padre Islands National Seashore (PAIS; GULN 2009). With the geographic position of these parks to surrounding water bodies, relative sea level rise is a serious concern. Average sea levels rose globally 1.5 mm yr^{-1} over the past century (IPCC 2013). There are many ways sea level rise may affect GUIS including increased rates of shoreline erosion, saltwater intrusion in freshwater bodies, and possible damage to park infrastructure (Pendleton et al. 2004). In addition to sea level rise, sediment transport, dredging and placement of dredge materials on park property (Perdido Key), and active restoration projects all influence the coastal dynamics of GUIS. Finally, the Mississippi Coastal Improvement Program (MsCIP), via efforts by the U.S. Corps of Engineers, is a project to restore Ship Island by filling in the gap between East and West Ship with about 19 million cubic yards of sand. The main goal of this project is to mitigate hurricane/storm damage, control erosion, and prevent salt water intrusion (U.S. Army Corps of Engineers 2009). Coastal dynamics at GUIS are shaped by all of these ongoing natural and anthropogenic processes.

Sea-level rise is a critical management issue for GUIS, especially because of its influence on the park's geomorphology and habitat composition. The nearest long-term monitoring stations for sea-level rise are the Pensacola, FL and Dauphin Island, AL stations, which are part of the NOAA's National Water Level Observation Network (NWLON; NOAA 2013). Data from these stations indicate a rate of sea-level rise at 2.19 (+/- 0.23) mm yr^{-1} and 3.19 (+/- 0.65) mm yr^{-1}, respectively. While the magnitude of these trends does not seem great when compared to data collected at other stations, sea-level trends assessed at nearby Louisiana stations have recorded some of the highest increases globally (9.24 mm yr^{-1}, NOAA 2013).

In order to assess GUIS's coastal vulnerability to sea-level rise, USGS collected data on a variety of factors expected to be most vulnerable to changes in sea level (Pendleton et al. 2004). A relative vulnerability index was generated based on the expected magnitude of contribution to physical changes of the coast with predicted sea-level increases. Results of this assessment indicated that GUIS-MS may be more vulnerable to predicted sea-level rise than GUIS-FL. Geologic variables were responsible for the majority of difference in vulnerability between the two park districts. GUIS-MS experiences very high erosion rates on the eastern end of the barrier islands, at rates greater than experienced in GUIS-FL. Beach nourishment projects for Perdido Key likely influenced the assessment results, and similar projects begun in MS, such as MsCIP, will likely alter the shoreline.

4.4.2 Threats and Stressors

In light of anthropogenic climate change and resulting sea-level rise, there is an ever-pressing need to quantify possible impacts to coastal areas. Yet, accurate prediction of the effects of sea level rise on shorelines is challenging because of the many uncertainties around the magnitude of change and how sea level rise may interact with any other ongoing coastal pressures. Given this knowledge gap, Pendleton et al. (2004) sought to identify the variables that contribute to coastal dynamics and thereafter areas that may be most vulnerable to sea-level rise. GUIS is especially vulnerable to climate change through both sea-level rise and increased storm frequency. Shoreline conditions of GUIS-FL have been historically more stable than in GUIS-MS (Pendleton et al. 2004), but both Perdido Key and Santa Rosa have succumbed to overwash and inundation from storm surges in the last four decades (Doyle et al. 1984).

In addition to threats incurred by sea-level rise, barrier islands can be affected by other factors that are influenced by climate change. Drought can play a major role in loss of vegetation communities in these fragile dune ecosystems and can potentially spur land loss via increased erosion in storms or breaching by heavy winds (Amberg et al. 2014). Wind action in combination with high tides can rapidly accelerate erosion and deposition rates, thereby altering the geomorphology of coastal beaches and dunes and potentially increasing vulnerability to future storm events. Increasing hurricane frequency, as predicted to result from climate change (IPCC 2013), may exacerbate existing threats of relative sea-level rise to the geomorphology of GUIS.

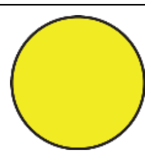
Finally, direct human alterations of the landscape have the potential to negatively interact with any of the preceding threats to GUIS coastal stability. Dredging and disposal of dredge materials has been shown to have a negative effect on grassbeds on the sound side of Horn Island (Barrineau and James 1983) and affect shoreline position and change rate on Perdido Key (L. York personal communication). Dredging of navigation channels has trapped large volumes of sand typically in transport along the MS barrier islands of the Gulf shore, resulting in reduction of sediment supply and therefore loss of land on these islands (Morton 2007). Human use of beaches is a management concern for GUIS. Damage to dunes and dune flora by off-road vehicles in the past has been demonstrated on Perdido Key (Shabica et al. 1979), and loss of dune vegetation could result in increased erosion and sand displacement during high winds and storms (Baccus et al. 1977). Lastly, oil and gas development in near the park has the potential to significantly disrupt the geology, groundwater, and sensitive habitats at GUIS with lasting effects, as was demonstrated during the 2010 British Petroleum oil spill. These threats are not a comprehensive list of all impacts to coastal dynamics at the park, but are meant to provide a general background of the stressors to this resource that could potentially interact with outcomes of a changing climate.

4.4.3 Condition and Trend

Following Pendleton et al.'s (2004) assessment, GULN identified both GUIS and PAIS as parks requiring monitoring of coastal dynamics. The GULN approach to monitoring geomorphology of these parks is largely based on employing Light Detection and Ranging (LiDAR) technology to collect fine-resolution elevation data (NPS 2009). Elevation data for the coast will be used to determine shoreline position change, collected on a 3–5 year timespan. These data have not been formally summarized or analyzed as of the writing of this report. Analyses of shoreline change at GUIS-FL by Hapke and Christano (2007) allow for an assessment for the FL district (Fort Pickens and Santa Rosa Island), and likewise analyses by Morton (2007) examined the long-term changes in barrier island shape, size and position for islands of the MS district (Petit Bois, Horn, Ship, and Cat Islands). Thus, the condition assessments and data quality for GUIS coastal dynamics are ranked separately for each district (Tables 13 and 14). Implementation of GULN monitoring protocols will undoubtedly help with future assessments of this resource for the entire park.

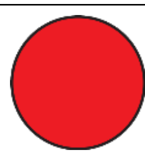
Shoreline change as analyzed by Hapke and Christiano (2007) from 1800s - 2005 indicated that Santa Rosa and Fort Pickens maintain long-term erosion rates of 0.4 (+/-0.1) m yr^{-1} and 0.9 (+/-0.1) m yr^{-1}, respectively. This rate of shoreline erosion increased for both park units following the hurricanes of 2004 and 2005, and much of the previously stable accretional portions of the beach became erosional. Generally, GUIS-FL islands are still more stable than GUIS-MS islands, and while shoreline position change is a natural process in barrier islands, the many extrinsic factors that influence this resource raise concern that the more stable beaches are exhibiting increased erosion. Data quality for coastal dynamics at GUIS-FL was ranked fair (Table 13). While there was information to describe long-term shoreline change at GUIS-FL, it was neither temporally current nor sufficient to conduct a thorough assessment and assign a trend.

Table 13. The condition status for shoreline change at GUIS-FL was ranked fair, but not assigned a trend. The data quality for this attribute was fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Shoreline Change (GUIS-FL)		Relevancy √	Proximity √	Currency
		Sufficiency	Coverage √	Coverage √
		4 of 6: Fair		

Generally, all of the GUIS-MS barrier islands evaluated by Morton (2007) were experiencing loss of land area. Of the GUIS-MS islands, loss of land area at Ship Island has been most dramatic, with 64% of land area lost since 1848 (Morton 2007). Petit Bois experienced similar land erosion in the same timeframe, with 54% land area lost. The eastern portion of Horn Island eroded substantially since the mid 1800's, although some of this sediment transferred to the western tip of the island via lateral spit accretion. However, overall losses of sediment were greater than accretional gains, with 24% land area lost in the almost 160-year time period. Finally, although the general position of the island remains largely unchanged, Cat Island lost 39% of its original land area and was showing increasing rates of loss over time. Morton (2007) found that the average rates of land loss for these barrier islands have been temporally consistent and increasing since 1917; therefore the smallest islands have seen the greatest reduction in land area. Primary causes of land area loss to these islands as detailed by Morton (2007) include: increased frequency of intense storms, relative sea-level rise, and reductions in sediment inputs (mainly from dredging practices). Given these findings and that these pressures on shoreline change for GUIS-MS islands will persist, the condition of the resource is considered poor (Table 14). Data quality for coastal dynamics at GUIS-MS was also ranked fair (Table 14), primarily lacking current information on the condition of the resource. Rates of land loss in the past century are accelerated when compared to long-term geologic rates (Morton 2007), thought the data available were not sufficient to assess a trend. Future monitoring by GULN will help to determine if this resource is truly at risk.

Table 14. The condition status for shoreline change at GUIS-MS was ranked poor and a trend was not assigned. The data quality for this attribute was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Shoreline Change (GUIS-MS)		Relevancy √	Proximity √	Currency
		Sufficiency	Coverage √	Coverage √
		4 of 6: Fair		

4.4.4 Literature Cited

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4.5 Surface Water Quality

4.5.1 Context and Relevance

Gulf Islands National Seashore is a water-based park unit, stretching some 260 km from Cat Island off the coast of MS to Santa Rosa Island in FL. GUIS-MS consists almost entirely of barrier islands with the exception Davis Bayou on the mainland. GUIS-FL consists of the 84-km long Santa Rosa Island, also a barrier island, and three mainland units, Perdido Key, Naval Live Oaks, and Fort Barrancas and Advanced Redoubt (NPS 2012). However, around 80% of the park area is underwater, and as a result is particularly vulnerable to influences from the surrounding landscape. Flow from nearby river outlets can impact water quality variably, and cycling of the Gulf of Mexico loop current can also affect hydrology (Anderson et al. 2005). In addition to the Gulf waters, other upland water features exist, including pools, inlets, and small flows that provide essential habitat for wildlife throughout the region.

4.5.2 Resource Knowledge

<u>Hydrologic Units</u>

The mainland adjacent to GUIS contains 10 major watersheds (Figure 7). In FL, the Pensacola Bay watershed (HUC-0314010505) drains three major rivers: Blackwater, Escambia, and Yellow (Anderson et al. 2005). The Blackwater and Yellow Rivers flow directly into Blackwater Bay, whereas the Escambia River flows into Escambia Bay. These bays, along with the East Bay and Santa Rosa Sound, comprise the Pensacola Bay watershed (NPS). One of the largest anthropogenic influences on this watershed is the city of Pensacola, located across the bay from the Naval Live Oaks unit. Blackwater Bay is minimally impacted; the Blackwater River flows mainly through protected state land, while the Yellow River flows adjacent to Eglin Air Force Base.

To the east of Pensacola Bay is Choctawhatchee Bay, which is fed primarily by the Choctawhatchee River. Waters from this bay are connected to Santa Rosa Sound below Ft. Walton Beach and to the Gulf via the East Pass between Santa Rosa Island and Destin, FL. Much like the Blackwater River, the Choctawhatchee River flows primarily through protected area before reaching the bay.

In MS, the Mississippi Sound is divided into five watersheds that include portions of GUIS. Four of these are subdivisions of the sound representing the main drainage areas and are bounded by the MS barrier islands to the south, while the fifth which includes the Davis Bayou unit is mostly land-based. The eastern most subdivision is Grand Bay (HUC 0317000902), which is contiguous with Mobile Bay to the east. Immediately to the west is Pt. Aux Chenes Bay (HUC 0317000903), followed by Biloxi Bay (HUC 0317000907), which drains the Back Bay of Biloxi watershed (HUC 0317000906). The Back Bay of Biloxi is roughly parallel to the MS coastline and contains several marsh islands. The top of the bay is isolated by one of these islands, forming Big Lake, which is fed primarily by the Tchoutacabouffa and Biloxi Rivers. The east side of the bay is fed by the Old Fort Bayou drainage just north of where the entire bay flows into Biloxi Bay between Biloxi and Ocean Springs, MS. Ship Island Pass (HUC 0317000908) is the westernmost watershed in the park based on the division of the Mississippi Sound and represents coastal drainage along Gulfport and from Cat and Ship Islands.

303(d) Impaired Waters

As of 2010, there are only two waterbodies at GUIS included on the 303(d) list of impaired waters. One is Pensacola Bay, which forms the northern shoreline of the Naval Live Oaks unit. Also listed in 1998 and 2002, the current listing cites depleted oxygen levels, coliform contamination, and mercury contamination as impairments for the shellfish propagation use classification of the bay. The other impaired water is a portion of Big Lagoon, the shoreline opposite Perdido Key of which was listed in 2010 for mercury contamination and in 1998 and 2002 for organic enrichment and oxygen depletion. This listed portion of shoreline begins at the mouth of Big Lagoon and extends westward to Perdido Bay (EPA 2012).

Use Classification

Water quality standards are dictated by both MS and FL. Streams are classified according to use, each of which carries a suite of specific water quality standards. In MS, classifications include Public Water Supply, Recreation, Shellfish Harvesting, and Fish and Wildlife; all waters without a specific classification are classified by default as Fish and Wildlife (MDEQ 2012). Figure 23 shows water use classifications in the MS Coastal cataloging unit. The default classification in FL is Class III – Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife (Anderson et al. 2005, FDEP 2006). Possible FL classifications are as follows:

Class 1) Potable Water Supplies

Class 2) Shellfish Propagation or Harvesting

Class 3) Fish Consumption; Recreation or Limited Recreation; and/or Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife

Class 3-Limited) Fish Consumption; Recreation or Limited Recreation; and/or Propagation and Maintenance of a Limited Population of Fish and Wildlife

Class 4) Agricultural Water Supplies

Class 5) Navigation, Utility, and Industrial Use

For each of these uses in both states, available water quality criteria are shown in Table 15.

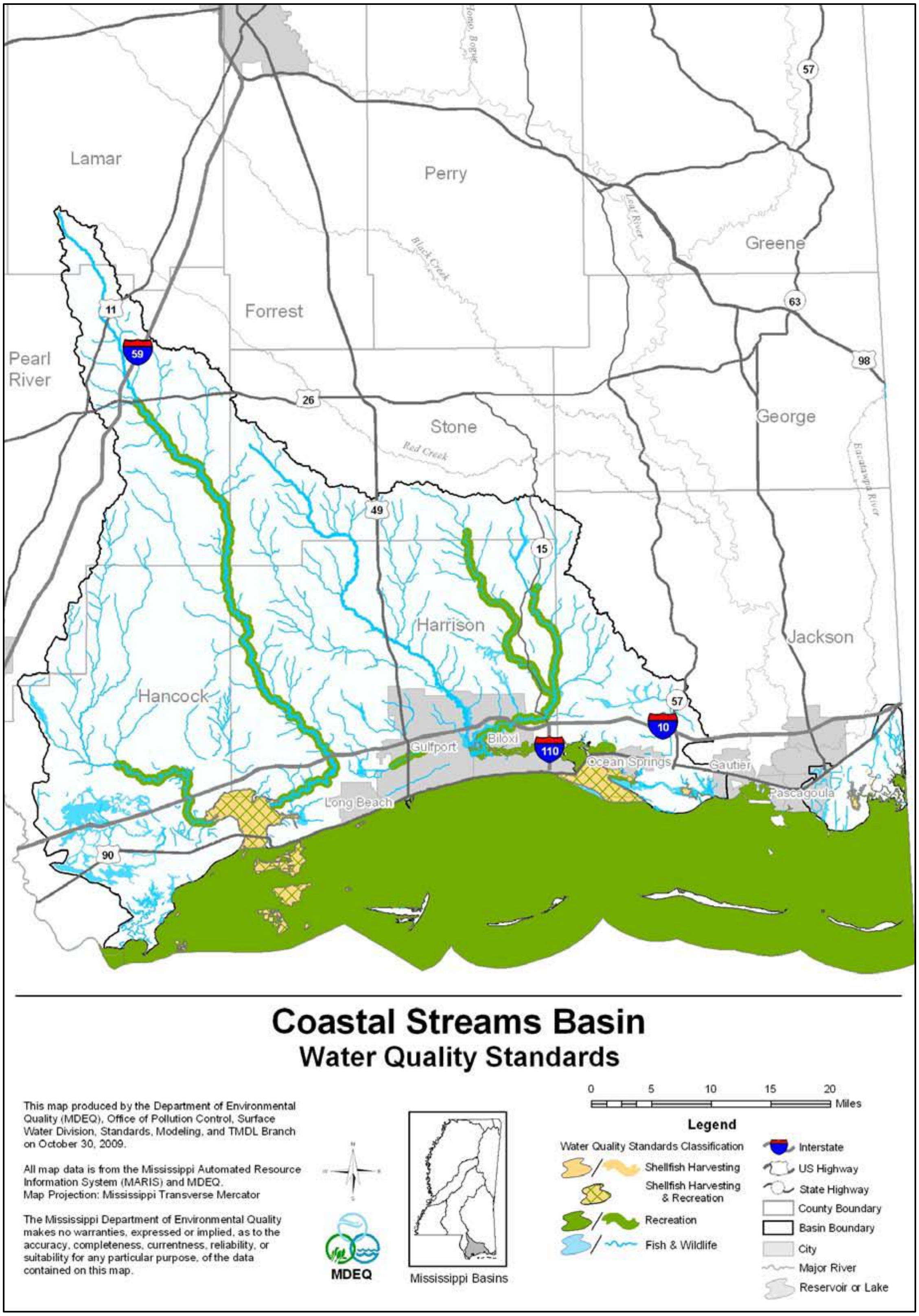


Figure 23. MS Coastal Streams Basin water use classification according to MDEQ (2012).

Table 15. Water quality standards for each use classification in MS (MDEQ 2012) and FL (FDEP 2006).

State	Classifi-cation	Dissolved Oxygen (mg/L)	Fecal Coliform (number per 100mL)	pH (SU)	Turbidity (NTU)	Specific Conductance (µmho/cm)	Temperature (°C)
FL	Class 1	≥5.0	≤200 monthly geo. Mean; ≤400 10% samples; ≤800 daily	6.0 ≤ pH ≤ 8.5 with ≤ 1.0 variance	≤ 29 above background	limit greater of 50% > background or 1275	--
	Class 2	≥5.0 24-hr; ≥4.0 instan.	≤14 median; ≤43 10% samples; ≤800 daily	6.5 ≤ pH ≤ 8.5 with ≤ 1.0 variance coastal waters, 0.2 open waters	≤ 29 above background		--
	Class 3	≥5.0	≤200 monthly geo. Mean; ≤400 10% samples; ≤800 daily	same as Class 2 except min 6.0 for fresh waters	≤ 29 above background	limit greater of 50% > background or 1275	--
	Class 3 - Limited	≥5.0 24-hr; ≥4.0 instan.	≤200 monthly geo. Mean; ≤400 10% samples; ≤800 daily		≤ 29 above background		--
	Class 4	≥4.0 24-hr; ≥3.0 instan.	--	6.0 ≤ pH ≤ 8.5 with ≤ 1.0 variance	≤ 29 above background	limit greater of 50% > background or 1275	--
	Class 5	≥0.3 50% annually; ≥0.1 instan.	--	5.0 ≤ pH ≤ 9.5; min 4.5	≤ 29 above background	< 4,000	--
MS	Public Water Supply	≥5.0 24-hr; ≥4.0 instan.	≤200 monthly geo. Mean; ≤400 10% samples	6.0 ≤ pH ≤ 9.0 with ≤ 1.0 variance	--	< 500 for freshwater	< 2.8°C exceedance above natural conditions; max 32.2°C
	Shellfish Harvesting	≥5.0 24-hr; ≥4.0 instan.	median ≤14; ≤10% ≤43	6.0 ≤ pH ≤ 9.0 with ≤ 1.0 variance	--	≤1000 for freshwater	< 2.8°C exceedance above natural conditions; max 32.2°C
	Recreation	≥5.0 24-hr; ≥4.0 instan.	≤200 monthly geo. Mean; ≤400 10% samples; estuarine/marine geo. Mean max 35 with ≥ 20 samples	6.0 ≤ pH ≤ 9.0 with ≤ 1.0 variance	--	≤1000 for freshwater	< 2.8°C exceedance above natural conditions; max 32.2°C
	Fish and Wildlife	≥5.0 24-hr; ≥4.0 instan.	≤200 monthly geo. Mean; ≤400 10% samples (2000 and 4000 during Nov. - April)	6.0 ≤ pH ≤ 9.0 with ≤ 1.0 variance	--	≤1000 for freshwater	< 2.8°C exceedance above natural conditions; max 32.2°C

4.5.3 Threats and Stressors

Anthropogenic activities around GUIS have contributed to major problems for water quality from both point and non-point sources. These hazards related to water quality in the park include: nutrient loading from stormwater runoff, oil and gas discharges (emissions from watercraft and spills), sewage effluent dumping, and alterations to rates of groundwater recharge, among others (Anderson et al. 2005). Point source pollution threats to water quality at GUIS are primarily because of the park's position in an urban, industrial landscape. There are multiple Superfund sites that are listed for remediation on the National Priorities List within the same counties as the GUIS-FL district. At least 45 industrial or municipal facilities within surrounding watersheds are registered as part of the Clean Water Act to be regularly monitored for point-source discharges.

In addition, the high proportion of land use in petroleum refining and chemical industries along the Gulf Coast likely makes GUIS much more vulnerable to non-point source pollution than many other parks. Over 40 percent of U.S. petroleum refining capacity is located along the Gulf Coast, in addition to 30 percent of the U.S. natural gas processing plant capacity (EIA 2014). Other threats from non-point sources of pollution to water quality at GUIS include: urban stormwater runoff (particularly in urbanized areas adjacent to GUIS-MS), sedimentation via agricultural runoff, and toxicity from golf courses (Thorpe et al. 1997, Thorpe and Ryan 1996, Lewis et al. 2001). Combined, these potential pollution sources have the potential to seriously alter hydrology and water quality at GUIS, as well as the biology, chemistry, and ecology of the park.

4.5.4 Data and Methods

As part of an assessment of water resources at GUIS, Anderson et al. (2005) retrieved water quality data from the EPA STORET website representing the period 1999 to 2004, with limited nutrient data from 1996 to 1999. Data represented collections by various organizations and were retrieved for a 3.2 km buffer around the GUIS boundary. Certain subgroups of stations were selected to be representative for certain parameters based on length of record. Since this analysis was initially conducted, additional data have been collected for dissolved oxygen and nutrients which were not included in this report.

Dissolved Oxygen

Dissolved oxygen (DO) is typically measured in situ using a sensor that adjusts for temperature and which is calibrated for atmospheric pressure at each site. Concentrations of DO are also important to the survival of essentially all aquatic species (Palmer et al. 1997). Several sources of runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (EPA 1997).

Dissolved oxygen was available at a handful of stations in the FL unit, none of which fell below the 4.0 mg/L standard between the period 1996 and 2003; few were additionally below the 5.0 mg/L level. Lowest values were associated with warmer months. In the Mississippi Sound, adjacent to the Davis Bayou, two sampling locations recorded occasional low DO values in 2002 and 2003. Samples were also mostly above 4.0 mg/L for several stations surrounding the barrier islands. Due to the frequency of low DO around Davis Bayou, Anderson et al. (2005) recommended continued sampling in these areas.

Bacterial Monitoring

Contamination by certain types of bacteria may result in health risks for recreational users. Coliform bacteria live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated viruses and pathogens. Total coliform counts themselves, however, do not necessarily represent a health risk, as many types of coliform bacteria are harmless. Fecal coliform are a subset of total coliform bacteria that exist only in warm-blooded organisms, and may often be introduced to waters via wildlife feces. Because *Escherichia coli* is a type of fecal coliform that is relatively easy to measure, it is commonly used to indicate fecal contamination.

For bacterial monitoring, seven stations in GUIS-FL within the 3.2 km park buffer recorded usable data from 1993 to 2004, during which no observations exceeded Class II thresholds for shellfish harvesting. One station was located in Pensacola Bay at Naval Live Oaks, while the remaining six were in Choctawhatchee Bay on the eastern end of the Okaloosa unit. In MS, waters surrounding Davis Bayou and Cat Island are classified as restricted, according to the U.S. Food and Drug Administration's (FDA) National Shellfish Sanitation Program (NSSP), meaning they must undergo an additional sanitation process called depuration to remove pathogens before harvests are safe for consumption. Instead of the regular limit of ≤14 most probable number (MPN) per 100 mL median with 43 MPN/100 mL 10% maximum, these respective values for restricted harvesting areas are 88 and 260 (Anderson et al. 2005, U.S. FDA 2009).

Additional monitoring occurred at several beaches in FL and MS to ensure that bacteria concentrations were at levels safe for swimming. Both states measured concentrations of fecal coliform and enterococci. In FL, during the period 2000 to 2003, only four observations out of over a thousand at 14 stations exceeded the FL daily maximum of 800 CFU/100 mL. During the same period a total of 13 observations exceeded the threshold of 400 CFU/100mL, which is the threshold at which a health warning would be issued to swimmers (Anderson et al. 2005). Most of these exceedances occurred during the warmer summer months, when recreational activity is higher. In MS, a series of bacterial samples between 2001 and 2005 revealed few concerns on West Ship Island, while a few samples along the mainland coast showed coliform spikes (Anderson et al. 2005).

Metals

Anderson et al. (2005) analyzed data in FL for various metal contaminants collected during the period 1999 to 2003 including cadmium, chromium, copper, iron, lead, nickel, and zinc, though none were collected within the 3.2 km park unit buffer. Most measurements fell below detection limits with the exception of iron, which exceeded state standards for 28 out of 29 observations. In MS, several samples for metal concentrations were collected in the Biloxi Bay region, though only single instances of copper and arsenic exceeded state standards.

Nutrients

Enrichment by nitrogen and phosphorus can have major impacts on aquatic biota. Natural levels of these nutrients encourage a healthy balance of aquatic plants and microbes, though once unbalanced, they can promote overgrowth of primary producers that can disrupt biological pathways. High levels of microbial activity often result in hypoxic waters, which directly affect aquatic biota, and nutrients can also result in increased photosynthesis, which is associated with algal blooms, increased turbidity, and elevated water pH (EPA 2012).

Anderson et al. (2005) analyzed several types of nutrient data collected between 1994 and 2003, including nitrate (NO_3^-) + nitrite (NO_2^-), ammonia (NO_3), total Kjeldahl nitrogen (TKN), and total phosphorus (TP). In FL, state standards specify simply that nutrients should be limited such that they do not “cause an imbalance in natural populations of aquatic flora or fauna” (FDEP 2006). MS standards include a direct reference to EPA guidelines for ammonia, and a maximum concentration of 10.0 mg/L nitrate as N for public water supply waters. In FL, data from approximately 60 stations showed average values for derivations of N, whereas TP concentrations were below what might present a concern for enrichment (Anderson et al. 2005). At 20 stations within the 3.2 km buffer in GUIS-MS, values for each source of N were somewhat higher than for FL, though concentrations were extremely variable. Based on comparisons with historical data, the average TKN and nitrate + nitrite sources of N represented moderately enriched waters. Most stations were near the Davis Bayou unit, and Anderson et al. (2005) recommended additional monitoring to determine if ammonia toxicity may be impacting biota. Data for TP in GUIS-MS represented highly enriched waters, though this was generally only in the area of Davis Bayou; the barrier islands were relatively unaffected.

Current Monitoring

As part of the current monitoring system, the GULN cooperates with the Gulf of Mexico Alliance (GoMA) to ensure that water quality data collected at GUIS is comparable to what other Gulf States are collecting. The GoMA, in turn, works through the EPA and National Oceanic and Atmospheric Association (NOAA) to monitor Gulf waters and estuarine systems. For GUIS-MS, a USGS monitor has collected continuous data since 2008 along the eastern portion of East Ship Island. The GULN, in cooperation, added additional parameter collections in 2009. In FL, GULN rotates two continuous monitoring datasondes among three locations with permanent sub-surface mounts: Santa Rosa Sound adjacent to Naval Live Oaks (NLO), Big Lagoon adjacent to Perdido Key (SCBL), and in the Santa Rosa Sound at Big Sabine Point adjacent to the Opal Beach area (BISA, Figure 24). Along with core physical parameters, grab samples are analyzed for nutrient data (NPS 2010). Data are presented for each station below.

Figure 24. Currently, GULN collects water quality data for GUIS from one site in Mississippi and three sites in Florida.

East Ship Island

Data are collected continuously at East Ship Island by a USGS monitor, which measures water temperature, specific conductance, turbidity, and dissolved oxygen (Figure 25). Median daily values for specific conductance fluctuate seasonally between a low of 30,000 microsiemens per cm (µS/cm) and a high of 50,000 µS/cm. MS standards for specific conductance do not specify limits for marine waters. Turbidity limits, similarly, are only narrative, though FL specifies <29 NTU above background values (Table 15). The background value appears low, between 0 and 50 formazin nephelometric units (FNU), with periodic spikes as high as 100 to 300 FNU. Formazin nephelometric units are similar to NTU but use a slightly different method of measurement.

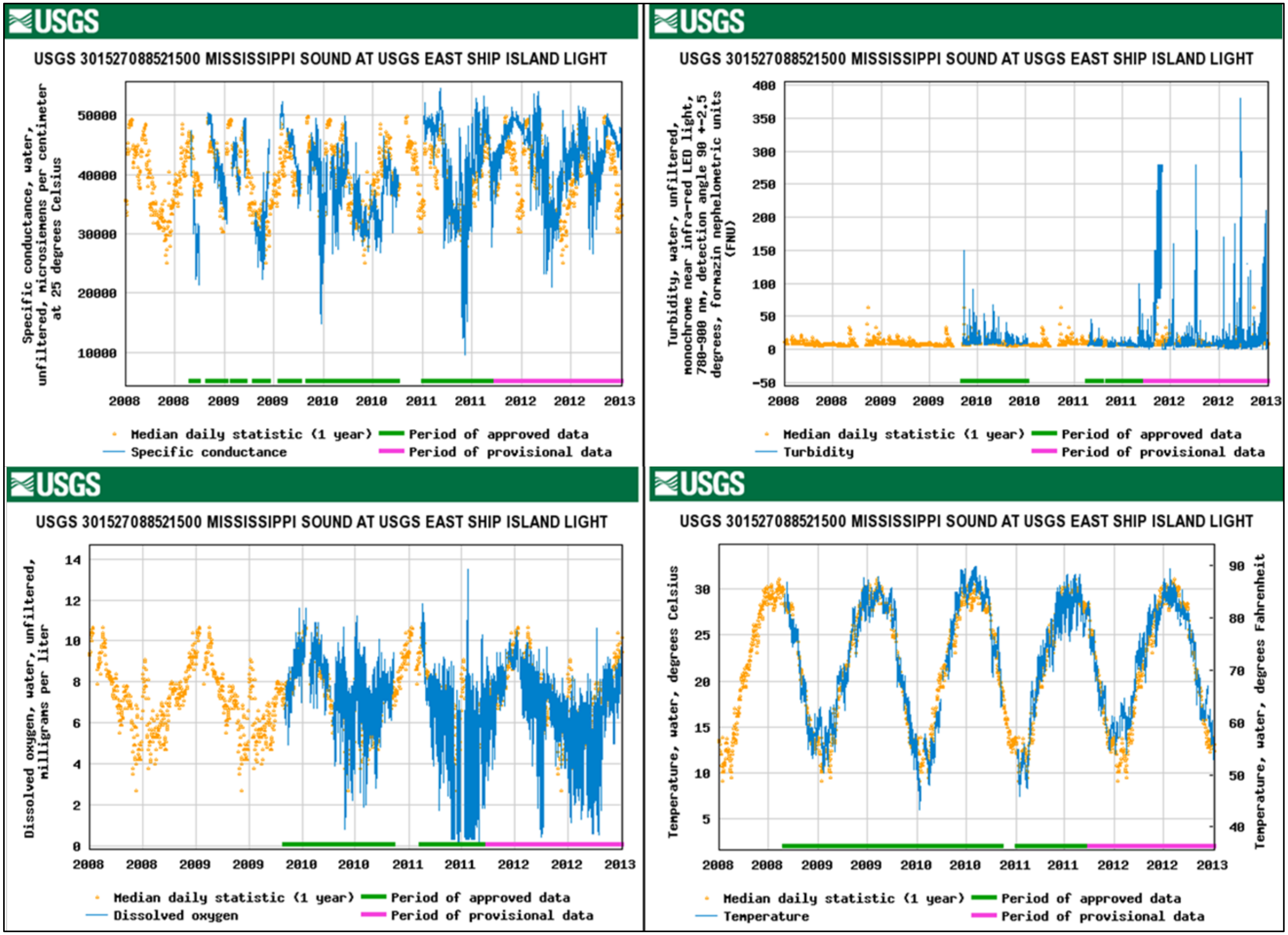


Figure 25. Monitoring at the USGS Ship Island monitor for specific conductance, turbidity, dissolved oxygen, and temperature (USGS 2013).

For dissolved oxygen at the time of analysis, data were available from November 2009 through September 2011, and values fell below the instantaneous state standard of 4.0 mg/L 46 times during the warmer months of 2011. For temperature, data was available from October 2008 through the same date, during which temperatures approached but did not exceed the state standard. Temperature is an important factor for water quality because it interacts with other parameters. As temperature increases, breakdown of organic material generally accelerates, which can lead to elevated oxygen demand through microbial activity. This, combined with lower solubility of oxygen at warmer temperatures, can quickly lead to oxygen depleted water and reduced survival of sensitive organisms. Higher temperatures also correspond to greater toxicity rates of certain substances (EPA 1986).

Naval Live Oaks

Temperature observations were recorded once a month from March through May 2010 at NLO. Turbidity during a single visit in February 2011 was low, while specific conductance averaged 34,155 µS cm^{-1} from a single visit in September 2010. Several measures for nutrients were sampled as averages of several grab samples on one or two dates during 2011-12, including total phosphorous, orthophosphate, ammonia as N, TKN, nitrate as N, nitrate + nitrate as N, and nitrite as N. For each measure, the majority of observations fell below the detection limit at LO. Dissolved oxygen averaged 7.9 mg/L based on three days of sampling in 2010.

Big Lagoon

For Big Lagoon, observations collected in 2010-11 were also within expected ranges for temperature and turbidity. Specific conductance values averaged 42,394 µS/cm based on two occasions. Nutrient measurements were similarly undetectable as those at the Naval Live Oaks station. Dissolved oxygen values averaged 6.69 mg/L based on two sample occasions.

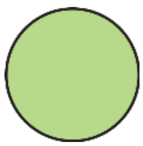
Big Sabine

Values for turbidity and temperature were within expected ranges for Big Sabine, while specific conductance averaged 40,995 µS/cm. Nutrient measurements were mostly undetectable, with the exception of TKN. Of the total eight samples on two separate occasions, four were undetectable, while the other half averaged 1.4 mg/L, resulting in an overall average of 0.7 mg/L. This value is slightly higher than the overall value of 0.41 mg/L reported by Anderson et al. (2005) for all stations within the GUIS study area during the period 1999 to 2003. Although no standards are available for nutrient concentration, these values might be the result of patchy nutrient concentrations in Santa Rosa Sound. Dissolved oxygen values averaged 7.05 mg/L during one sampling occasion.

4.5.5 Condition and Trend

Overall, collected samples at the USGS East Ship Island location and the monitoring sites in GUIS-FL tell somewhat different stories, which may be in part due to the separate sampling regimes. As a result, condition rankings for this section are divided by unit. Despite the fact that GUIS-FL potentially faces more threats to water quality than GUIS-MS, values for temperature and dissolved oxygen do not fall outside of state standards for available data at each of the stations. Values for turbidity were also consistently low. The majority of nutrient measurements were also below detectable limits, with the exception of TKN at Big Sabine. According to Anderson et al. (2005), total N values, defined as the sum of nitrate + nitrite and TKN, are considered highly enriched at levels greater than 1.29 mg/L, and moderately enriched between 0.95 and 1.29 mg/L. All samples at each of the FL locations fell below detectable limits for nitrate + nitrite, and as a result overall averages for TKN for NLO, SCBL, and BISA were respectively 0.66, 0.43, and 0.72 mg/L. Based on recent GULN sampling within GUIS-FL, water quality in this district receives a condition status ranking of good (Table 16). Data quality is also good, lacking only the temporal coverage quality check, which reflects the recent inception of the GULN monitoring program in the Florida district. At the creation of this report, these data were not readily available for analysis. Analysis of the resource using the more recently collected data will improve this aspect of the data quality.

Table 16. Water quality within GUIS-FL is assigned a condition ranking of good, with no trend. Data quality for this attribute is also good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Water Quality (GUIS-FL)		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage
		5 of 6: Good		

At the MS USGS gauge, temperatures never exceeded the state standard, although dissolved oxygen levels during 2011 were repeatedly well below the state limit, including ten days when mean daily values were hypoxic (<2.0 mg/L). Turbidity values were also periodically high, varying from a baseline that appears between 10 and 50 FNU, but with spikes as high as 250 FNU. The high rates of detection of problematic dissolved oxygen and turbidity values at East Ship Island may be due in part to the continuous monitoring schedule, as compared to the static sampling regime in GUIS-FL. Additional nutrient sampling conducted by USGS will help link the hypoxia to sources of eutrophication, although this may have limited usefulness due to the broad-scale causes of this issue. Instead, nutrient sampling could further elucidate effects on important ecosystems such as seagrass beds surrounding the MS barrier islands. Based on available data at the East Ship Island USGS gauge, water quality within the MS district receives a condition ranking of poor (Table 17). Data quality is fair and lacks the thematic sufficiency and spatial coverage checks. Spatial coverage was withheld due to the presence of only a single monitoring location. Since this analysis of water quality was conducted, USGS has begun collecting nutrient data as part of routine grab samples (M. Segura personal communication). Thus, though thematic sufficiency was withheld due to the lack of available nutrient data at the time of this analysis, future studies incorporating the available data as of the writing of this report will certainly improve assessments of water quality for GUIS-MS.

Table 17. Water quality within GUIS-MS is assigned a condition ranking of poor, with no trend. Data quality for this attribute is fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Water Quality (GUIS-MS)		Relevancy √	Proximity √	Currency √
		Sufficiency	Coverage	Coverage √
		4 of 6: Fair		

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4.6 Terrestrial Vegetation

4.6.1 Vegetation Communities

Resource Knowledge

Although most of GUIS protects marine habitat, a wide variety of natural communities are found on the mainland and barrier island portions of the park unit. Broadly, these include upland coastal forests, palustrine wetlands, estuarine tidal marshes, and dune communities. Detailed divisions outlined in the GUIS fire management plan are shown in Table 18 (NPS 2009). A wetland and vegetation community survey was conducted by Mississippi State University in 2002 for the Davis Bayou unit, which classified the area into three main portions consisting of 58 ha of wetland, 213 ha of upland area, and 49 ha of bayou (MSU 2001). Vegetation communities were divided into two main upland and five wetland types, and are shown in Figure 26 with the addition of a small pine hammock community, a few coastal shrub islands, and an unidentified upland forest type.

Table 18. Twelve main vegetation communities exist at GUIS, hosting a wide variety of plant species.

Community Type	Description
Pine flatwoods	Slash pine (*Pinus elliottii*) overstory with understory including wax myrtle, oaks, and heaths
Sand pine-scrub	Sand pine (*Pinus clausa*) overstory with varying understory depending on fire regime
Scrub	No overstory with varying shrub species depending on fire regime
Xeric Sandhills	Longleaf pine (*Pinus palustris*) overstory, with understory including oaks, saw palmetto (*Serenoa repens*), ground cover including grasses and other herbs
Live oak hammock	Live oak (*Quercus virginiana*) overstory with persimmon (*Diospyros virginiana*), southern magnolia (*Magnolia grandiflora*), and holly (*Ilex* spp.) understory
Coastal Grassland	Open grassland including herbaceous covering
Wet pine savanna	Slash pine or longleaf pine overstory, bay, and baldcypress (*Taxodium distichum*) in overstory, with diverse understory including many heaths
Palustrine marsh	Open grassland under periodic standing water with herbaceous cover
Palustrine shrub	Similar to palustrine marsh plus thicket of shrubs and overstory trees such as red maple (*Acer rubrum*), sweetbay (*Magnolia virginiana*), and bays (*Persea* spp.)
Estuarine marsh	Tidally influenced grasslands with a sparse overstory including cabbage palms (*Sabal palmetto*), and midstory including amaranth (*Amaranthus* spp.), and saltbush (*Atriplex* spp.)
Estuarine shrub	Similar to estuarine marsh with occasional cabbage palm, but often occurring at higher elevations with less frequent tidal influence, as well as developed midstory containing falsewillow (*Baccharis neglecta*), marshelder (*Iva annua*), and wax myrtle, as well as a developed understory
Beach Dune	Sparsely vegetated; occurring on beach foredunes; occasional species include redcedar (*Juniperus virginiana*), slash pine, and cabbage palm, undeveloped midstory and understory with mostly unvegetated groundcover

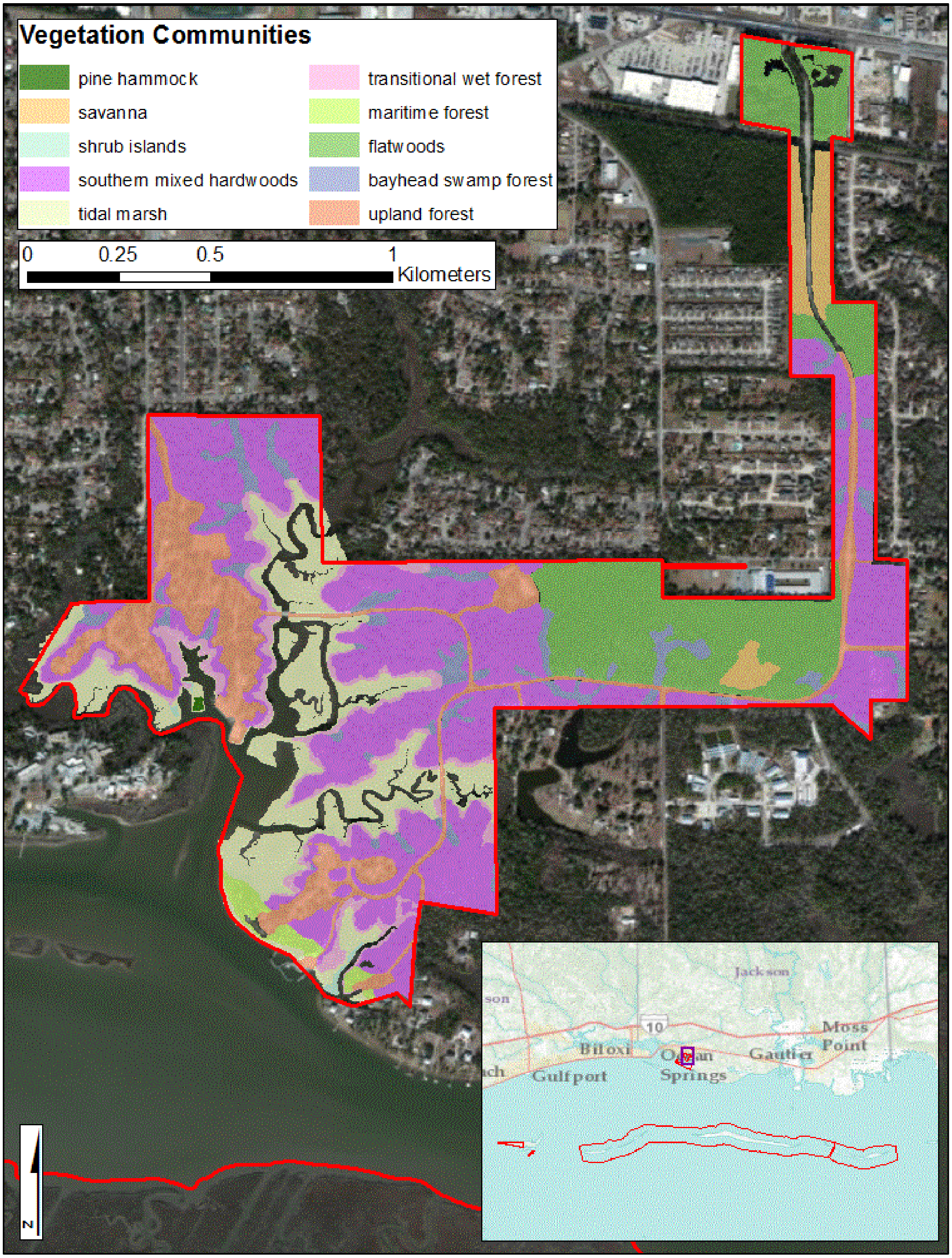


Figure 26. MSU (2001) classified the Davis Bayou unit at GUIS into seven main vegetation types. Three additional classifications are shown here.

Sensitive Species

According to the combined efforts of Urbatsch et al. (2007) and Gunn (2005), 18 species occurring in at GUIS are of state special concern in either MS or FL. These species are shown with state conservation rankings in Table 19.

Table 19. Eighteen species state-listed plant species were identified by Urbatsch et al. (2007) and Gunn (2005).

		State Ranking [a]		
Scientific Name	**Common Name**	**MS**	**FL**	**Habitat/Location**
Andropogon virginicus var. *glaucus*	Chalky bluestem	S1		Wet flatwoods of Davis Bayou
Calamovilfa curtissii	Florida sandreed		S3	Wet pine flatwoods of Naval Live Oaks
Chrysopsis gossypina ssp. *Cruiseana*	Cottony goldenaster		S2	Relic dunes on Okaloosa and Santa Rosa
Chrysposis godfreyi	Godfrey's goldenaster		S2	Coastal grasslands of Ft. Pickens
Cleistes bifaria	Spreading pogonia	S3	S3	Bayheads and wet forest of Davis Bayou
Dichanthelium wrightianum	Wright's rosette grass	S1		Wet flatwoods of Davis Bayou
Helianthemum arenicola	Coastal sand frostweed	S1	S3	Relic dunes on E. Ship, Horn, and Petit Bois
Ipomoea pes-caprae	Bay hops	S2		Beach dunes on Horn and E. Ship
Lycium carolinianum	Carolina desert-thorn	S1		Horn Island
Paronychia erecta	Squareflower	S1		Horn, Petit Bois, E. Ship, W. Ship
Paspalum monostachyum	Gulfdune paspalum			Interdune swales of W. Ship
Polanisia tenuifolia	Slenderleaf clammyweed	S1		Mesic slash pine forest on Horn and E. Ship
Polygonella macrophylla	Largeleaf jointweed		S3	Relic dunes on Okaloosa, Ft. Pickens, and Naval Live Oaks
Quercus macrocarpa	Bur oak	S2		S. mixed hardwood forest at Davis Bayou
Cleistes divaricata	Spreading pogonia		S1	Davis Bayou in wet longleaf flatwoods
Platanthera cristata	Yellow-crested orchid		S3	Davis Bayou in wet longleaf flatwoods
Physalis angustifolia	Coast ground-cherry		S3	Relic dunes and coastal grassland on Horn Island
Quercus minima	Dwarf live oak	S1		Relic dunes and coastal grassland on E. Ship Island

[a] Rounded NatureServe conservation status of a species from a state/province perspective, characterizing the relative imperilment of the species. S1=Critically Imperiled, S2=Imperiled, S3=Vulnerable, S4=Apparently Secure, S5=Secure; Refer to <http://www.natureserve.org/explorer/nsranks.htm> for additional information on ranks.

A recent status report on large-leaved jointweed (*Polygonella macrophylla*), listed with a state conservation ranking of vulnerable in FL, estimated the population size at close to 9,500 individuals.

Main threats to the species include fire suppression and the resulting encroachment of woody species. Prescribed burns at GUIS-Naval Live Oaks unit have helped populations. Loss of habitat from development also plays a role in rapidly changing coastal areas.

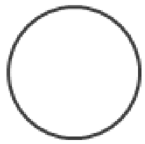
Invasive and exotic animals also pose a threat to sensitive plant species, as well as complete vegetative communities. Nutria have altered dune plant community structure via foraging preferences on more palatable plants, leading to encroachment of non-native plant competitors and a decline in species that provide structure and maintain the dune habitat (Hester et al. 1994). Wetland habitats are typically the most susceptible to nutria damage. Species richness, biomass, and seedling recruitment have all displayed severe declines after nutria grazing in controlled field studies in coastal wetlands (Holm et al. 2011). Despite their native status, the high abundance of eastern cottontail (*Sylvilagus floridanus*) on GUIS-MS barrier islands, in combination with their generalist foraging habits, was considered to pose the greatest risk to the vegetation (Esher et al. 1988). Future monitoring efforts at GUIS should consider evaluating the role of non-native and invasive animal populations on the health of their native plant communities.

Condition and Trend

GUIS contains a wide variety of plant community types in a relatively small area, in addition to providing habitat for several rare plant species. Surveys of the park’s vegetation communities have identified a diverse assemblage of species and recognize the resources as being some of the better preserved examples of threatened habitats in the region, including relic dunes and scrub (Urbatsch et al. 2007). These communities and others are in decline because of human development and fire suppression. Furthermore, future projections indicated that these coastal vegetation communities will likely be affected by increased storm intensity and saltwater intrusion, as well as establishment of invasive species. Recent implementation of a fire management plan at GUIS will help restore these threatened communities, and restore fire-adapted species, including longleaf pine.

Because this section is intended mainly as an overview of vegetation communities at GUIS rather than an assessment, no condition status is assigned (Table 20). Data quality was assessed as fair, however, lacking thematic sufficiency and a temporal currency check because of the time since available inventories classifying terrestrial vegetation at GUIS. Continued monitoring of both rare plant species and natural plant communities throughout the park unit would help efforts to ensure their persistence. As the data quality was ranked ‘fair’, we did not feel that there were sufficient data to inform the assignment of a trend. Trends for invasive, non-native species were more difficult to address with existing data and more detailed monitoring on the extent and distribution of these species within the park would be valuable.

Table 20. No condition status or trend was assigned to terrestrial vegetation communities at GUIS. The data quality for this attribute was fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Terrestrial Vegetation Communities		Relevancy √	Proximity √	Currency
		Sufficiency	Coverage √	Coverage √
		4 of 6: Fair		

4.6.2 Exotic Vegetation

Context and Relevance

Exotic species can impact functioning of native ecosystems at small to very large scales (Vitousek et al. 1997). In the case of exotic plants, these impacts may result from any number of factors resulting from invasion, including altered nutrient cycling, allelopathy, or changes in hydrology or fire regime (Levine et al. 2003).

Data and Methods

Despite the predominance of natural landscapes throughout GUIS, exotic plant species also pose a resource management concern. The 2007 NPSpecies list identifies 107 exotic plant species present at GUIS, representing roughly 13% of the 795 species listed as present in the park. Urbatsch et al. (2007) performed a vascular plant inventory from 2005 to 2007 and documented 93 exotics, representing 12% of the taxa. This survey included all GUIS units except Perdido Key and Cat Island. Table 21 shows numbers of exotics and total species present at each surveyed unit. Fort Pickens and Fort Barrancas/Advanced Redoubt contained the highest proportion of exotic species (13% and 15%, respectively) while the Davis Bayou and Naval Live Oaks units contained the greatest species richness (407 and 436, respectively).

Table 21. Summary of exotics predominance at each GUIS unit (Urbatsch et al. 2007).

State	Unit	Exotics	Total
Mississippi	Davis Bayou	47 (12%)	407
	East Ship Island	7 (6%)	118
	West Ship Island	12 (9%)	140
	Horn Island	11 (6%)	199
	Petit Bois	5 (4%)	136
Florida	Naval Live Oaks	53 (12%)	436
	Ft. Pickens	37 (13%)	285
	Ft. Barrancas and Advanced Redoubt	31 (15%)	203
	Santa Rosa Island	7 (5%)	137
	Okaloosa	13 (10%)	134
Overall GUIS		93 (12%)	807

Some of the highest priority species in the park include Chinese privet, Chinese tallow, cogongrass, Japanese honeysuckle, torpedo grass, common reed, and most recently, Cuban bulrush (C. Bromley personal communication). According to a 2000 report by the Exotic Plants Management Team, torpedo grass covered the most area, approximately 2000 ha, most of which was on Horn Island. Also extensive were infestations of Chinese tallow, Chinese privet, and Japanese honeysuckle, each of which covered 160 ha in the Davis Bayou unit. Chinese privet competes with wax myrtle (*Myrica cerifera*) and yaupon (*Ilex vomitoria*), both of which are important forage species for migrant birds.

Tallow tree (Figure 27) is a particular problem because it has the ability to invade natural areas and outcompete other understory trees, at which point it becomes very difficult to eliminate (USDA 2013). This species is also adaptable to a wide variety of light conditions but does best in full sunlight; it can also change soil chemistry such that it facilitates its own spread (NatureServe 2013). Eradication efforts require long-term commitment, including cut-stump herbicide application and seed collection. In drier areas, fire may also help control trees (USDA 2013). Tallow tree has posed a particular problem on Horn Island, where it threatens to invade a freshwater marsh (Fraley 2004).

Figure 27. Chinese tallow tree (*Sapium sebiferum*) is a high priority invasive at GUIS. [Source: C. Evans, IL Wildlife Action Plan, Bugwood.org]

Figure 28. Cogongrass (*Imperata cylindrica*) is an exotic species mainly distributed in the Davis Bayou unit at GUIS. [Source: L.M. Marsh, FL Dept. Agriculture and Consumer Services, Bugwood.org]

Cogongrass (Figure 28) was reported on 6 ha in the Davis Bayou unit, where it invades roadsides and disturbed areas. It also threatens less disturbed areas such as pine savanna wetlands, pine flatwoods, swamps, and upland forest (EPMT 2000). This species also threatens wetland species such as the yellow pitcher plant (*Sarracenia alata*) and threadleaf sundew (*Dorsera filiformis*, Figure 29), the latter of which has a state conservation ranking of S1, meaning critically imperiled (NatureServe 2013).

As of 2000, much of the infested area had been treated, though a new and smaller infestation had been discovered on Horn Island with immediate plans for treatment. Also of note is the effect of the cogongrass on the ability to conduct prescribed burns. Cogongrass infestations contribute to hotter, more intense fires that kill native species, though favoring the cogongrass.

Torpedo grass (Figure 30) is a problem in the Gulf Coast region, where it infests wetland habitats and coastal marshes. It can spread quickly via rhizomes, and as a result may require repeat herbicide treatments to control. According to NPSpecies, torpedo grass is the most abundant exotic plant species at GUIS.

Figure 29. Threadleaf sundew (*Drosera filiformis*) is a sensitive species at GUIS threatened by the growth of the exotic cogongrass in wetland areas. [Source: E. Grunwald, Native Plant Society of NJ]

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics to native species and ecosystems, called the I-rank. The overall I-rank consists of 20 questions that cover four main subranks: ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty. To offer a further quantitative assessment of exotic species present at GUIS, each I-rank has been recalculated excluding consideration of current distribution and abundance, which considers the overall distribution of the species at large rather than just within the park unit. These rankings are shown in Table 22 and are expressed on a scale of zero to three, with three representing the greatest threat to park resources. Species included in the table are those mentioned by the Exotic Pest Management Team (2000), and those listed as common in the latest NPSpecies list at GUIS (NPSpecies 2014).

Figure 30. Torpedo grass (*Panicum repens*) threatens wetland areas at GUIS. [Source: A. Murray, University of Florida, Bugwood.org]

Condition and Trend

Overall, the threat of exotic species at GUIS remains an ongoing problem. Based on the combination of I-Rank and abundance shown in Table 22, torpedo grass may represent a primary target for management efforts. Treatments are also underway to remove many of these exotics. As a result, exotic vegetation at GUIS receives a condition status of fair (Table 23), since removal is ongoing but many exotic plants remain common. Several data quality gaps exist for this assessment, however, namely the lack of a recent update for GUIS-MS by the Exotic Pest Management Team, and for the NPSpecies vascular plant list, which may now include additional species. Furthermore, observations by park personnel indicate that cogongrass has increased in abundance in both districts (C. Bromley personal communication), and data on the current distribution would be useful for accurate assessments of this resource. No exotic plant report is available for GUIS-FL. Also of note is the lack of availability of spatial information on exotic species locations, which may aid in targeting of eradication efforts.

Table 22. I-Ranks and abundance of exotic plant species at GUIS. Species include those mentioned specifically by the Exotic Plant Management Team (2000), or those classified as common within the park. Abundance rankings are taken from NPSpecies (2014).

Scientific name	Common name	I-Rank [a]	Abundance
Imperata cylindrical	Cogongrass	2.83 [c]	Rare
Sapium sebiferum	Chinese tallow tree	2.67 [c]	Rare
Lonicera japonica	Japanese honeysuckle	2.33 [c]	Rare
Panicum repens	Torpedo grass	2.00 [c]	Abundant
Alternanthera philoxeroides	Alligatorweed	2.00 [c]	Common
Cynodon dactylon	Bermudagrass	1.83 [b]	Common
Ligustrum sinense	Chinese privet	1.67 [b]	Rare
Poa annua	Annual bluegrass	1.50 [b]	Common
Medicago lupulina	Hop clover	1.00 [b]	Common
Sonchus asper	Spiny sowthistle	Not Ranked	Common
Medicago polymorpha	Burclover	Not Ranked	Common
Medicago minima	Burr medick	Not Ranked	Common
Hypericum reductum	Atlantic St. Johnswort	Not Ranked	Rare
Bidens pilosa	Beggar's ticks	Not Ranked	Common

[a] I-Rank is calculated as a mean of ecological impact, trend in distribution and abundance, and general management difficulty, each of which is assigned a value of 1 to 3 (Morse et al. 2004).

[b] Medium I-Rank value (1-1.99 - also highlighted in light orange).

[c] High I-Rank value (2+ - also highlighted in light red).

Table 23. The condition status for exotic plants was fair, with no trend assigned. The data quality for this attribute was poor.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Exotic Plants	Fair (yellow circle), no trend	Relevancy √	Proximity	Currency √
		Sufficiency	Coverage	Coverage
		2 of 6: Poor		

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4.7 Seagrass

4.7.1 Context and Relevance

Seagrass beds are found throughout the US, although the majority of them are located in the Gulf of Mexico, where one of the highest concentrations exists along the MS barrier islands. Seagrass species comprising these beds at one time included shoalweed (*Halodule wrightii*), Engelmann's seagrass (*Halophila engelmannii*), manatee grass (*Syringodium filiforme*), and turtlegrass (*Thalassia testudinum*, Moncreiff et al. 1998). These beds serve many essential roles in these shallow aquatic ecosystems, where they stabilize sediment, reduce turbulence and currents, improve nutrient flow, as well as provide habitat for many aquatic species (Carter et al. 2011). Many anthropogenic effects associated with coastal activities are detrimental to the health and persistence of seagrass beds, including direct impacts such as dredging, boat scarring, and fishing, as well as indirect impacts such as degraded water quality and sediment flow alteration. Seagrass beds also experience natural variation in distribution from hurricanes (Carter et al. 2011).

4.7.2 Resource Knowledge

Various surveys have determined that seagrass habitat along the MS barrier islands has declined in the past decades, but recovered in recent years (Moncreiff et al. 1998, Lores et al. 2003, Carter et al. 2011). Figure 31 shows changes in seagrass coverage as reported by Carter et al. (2011), based on aerial image interpretation. Carter et al. (2011) also point out that different assessment techniques have resulted in widely variable estimates of past seagrass coverage. In addition, differences in coverage on Cat Island and Horn Island are notable between 2006 and 2007, though the factors involved are not clear. Hurricanes Camille (1969) and Katrina (2005) appeared to have no lasting effects on the persistence of seagrass along the MS barrier islands.

Heck and Zande (1997) monitored seagrass health from 1993 to 1996 with an emphasis on GUIS-FL units, where seagrass is mainly found at Big Lagoon and Santa Rosa Sound. They predicted that Hurricane Opal (1995) may have had a detrimental impact on FL seagrass because of reduced biomass the following year. Overall, they assessed that seagrass health appeared to be declining in FL, while holding steady in MS.

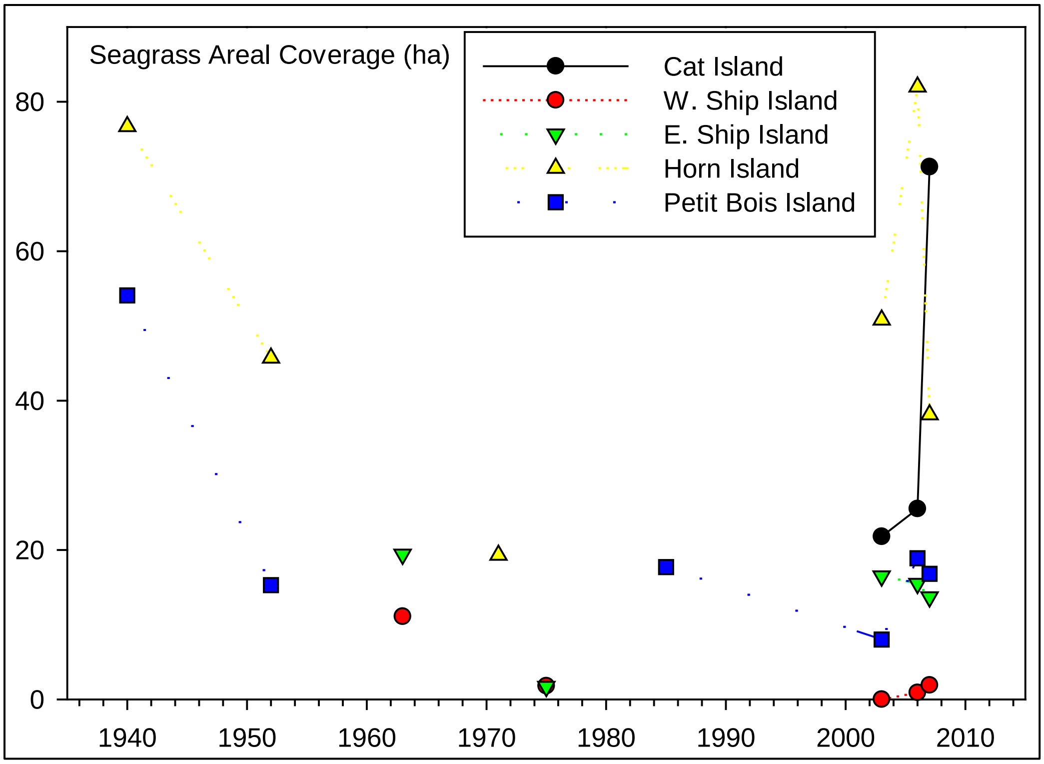


Figure 31. Carter et al. (2011) reports that seagrass on MS barrier islands are recovering from declines observed in recent decades.

<u>Habitat Mapping</u>

Moncreiff et al. (1998) predicted seagrass covering 533 ha on the MS GUIS barrier islands as recently as 1992, with up to 5,200 ha of potential habitat, which Carter et al. (2011) attributes to a broad definition of habitat mainly pertaining to water depth. Two later assessments conducted by the Gulf Coast Geospatial Center (GCGC) mapped existing habitat in 2003 and 2006 based on aerial photography, as well as mapped potential restoration areas based on water depth, shore distance, and proximity to current and historical areas of seagrass coverage (Foster 2005). Total area reported in 2002 was 365 ha. These two existing coverages are shown for each of the MS islands in Figure 32a, b, c, and d.

The most recent assessment for seagrass coverage on the MS barrier islands was conducted by Vittor and Associates, Inc. (2011), who used 2010 aerial imagery. Shoal grass was the only species of seagrass observed by Vittor and Associates, Inc. (2011), who overall reported a total of 1,463 ha of seagrass present throughout the islands (Table 24). They also created several polygons showing areas of patchy vegetation, though maps by the GCGC provide much greater detail. However, both mapping efforts outlined essentially the same area of seagrass habitat.

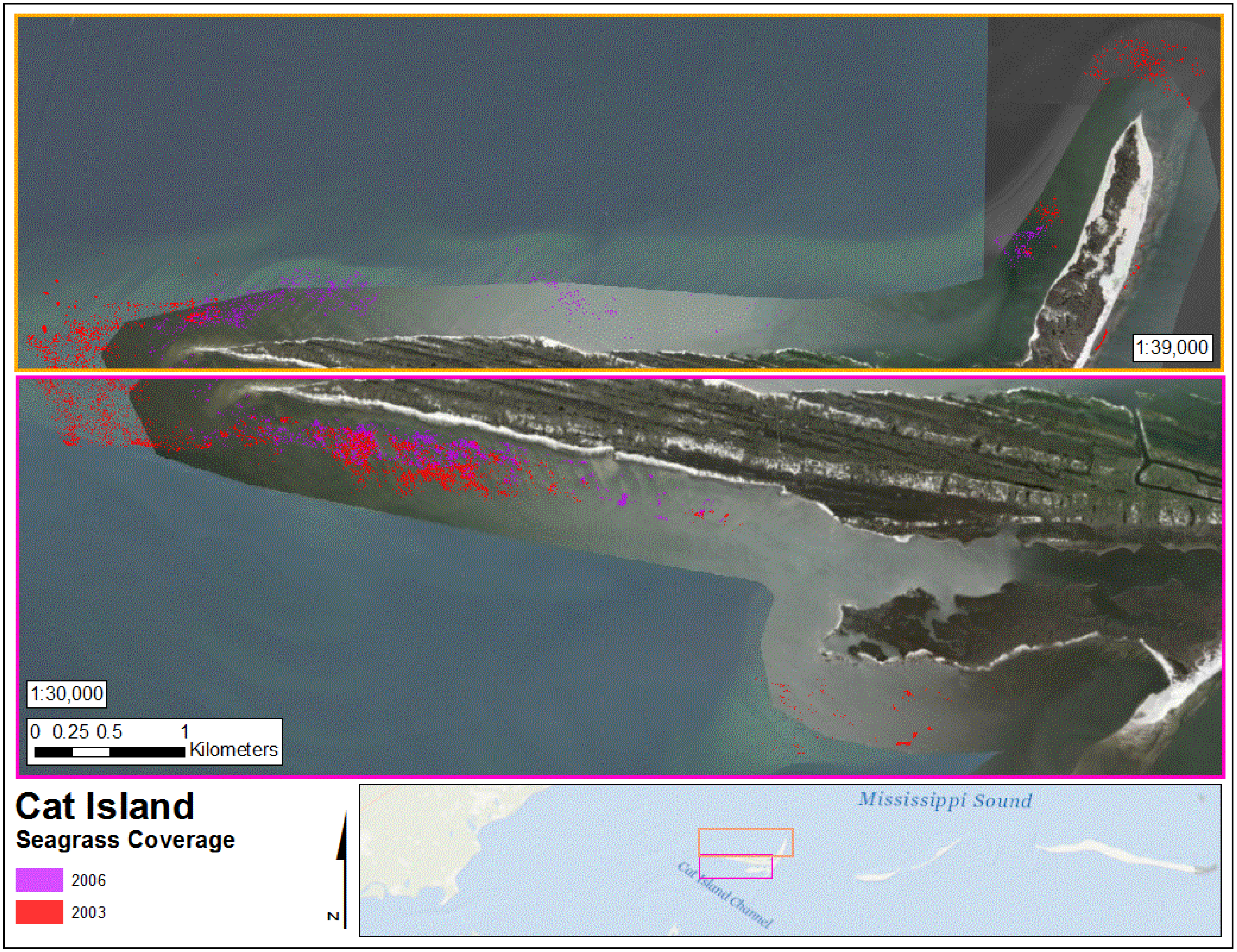


Figure 32a. Cat Island seagrass coverage. The Gulf Coast Geospatial Center (GCGC) conducted detailed mapping of seagrass area on the MS barrier islands in 2003 and 2006.

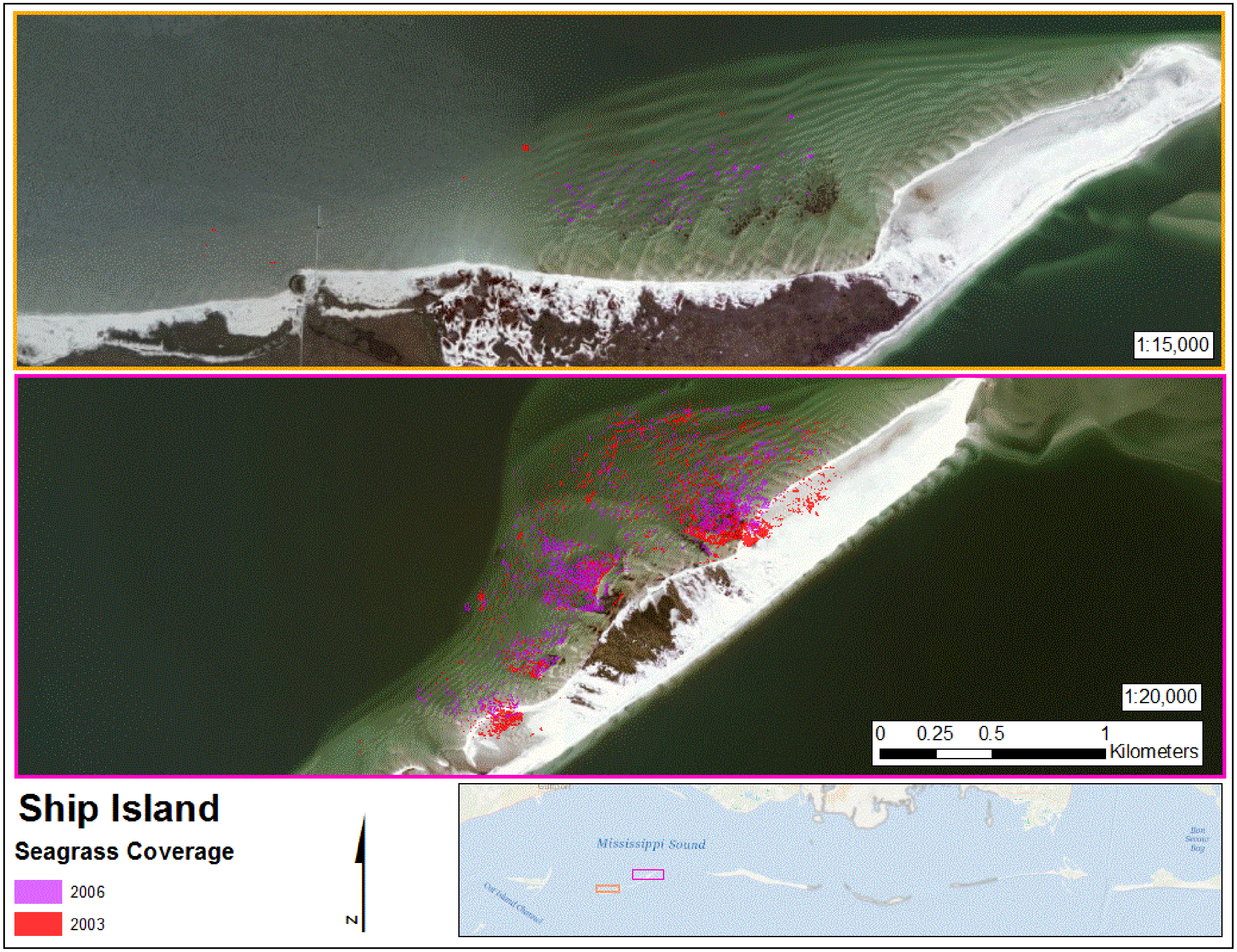


Figure 32b. Ship Island seagrass coverage. The Gulf Coast Geospatial Center (GCGC) conducted detailed mapping of seagrass area on the MS barrier islands in 2003 and 2006.

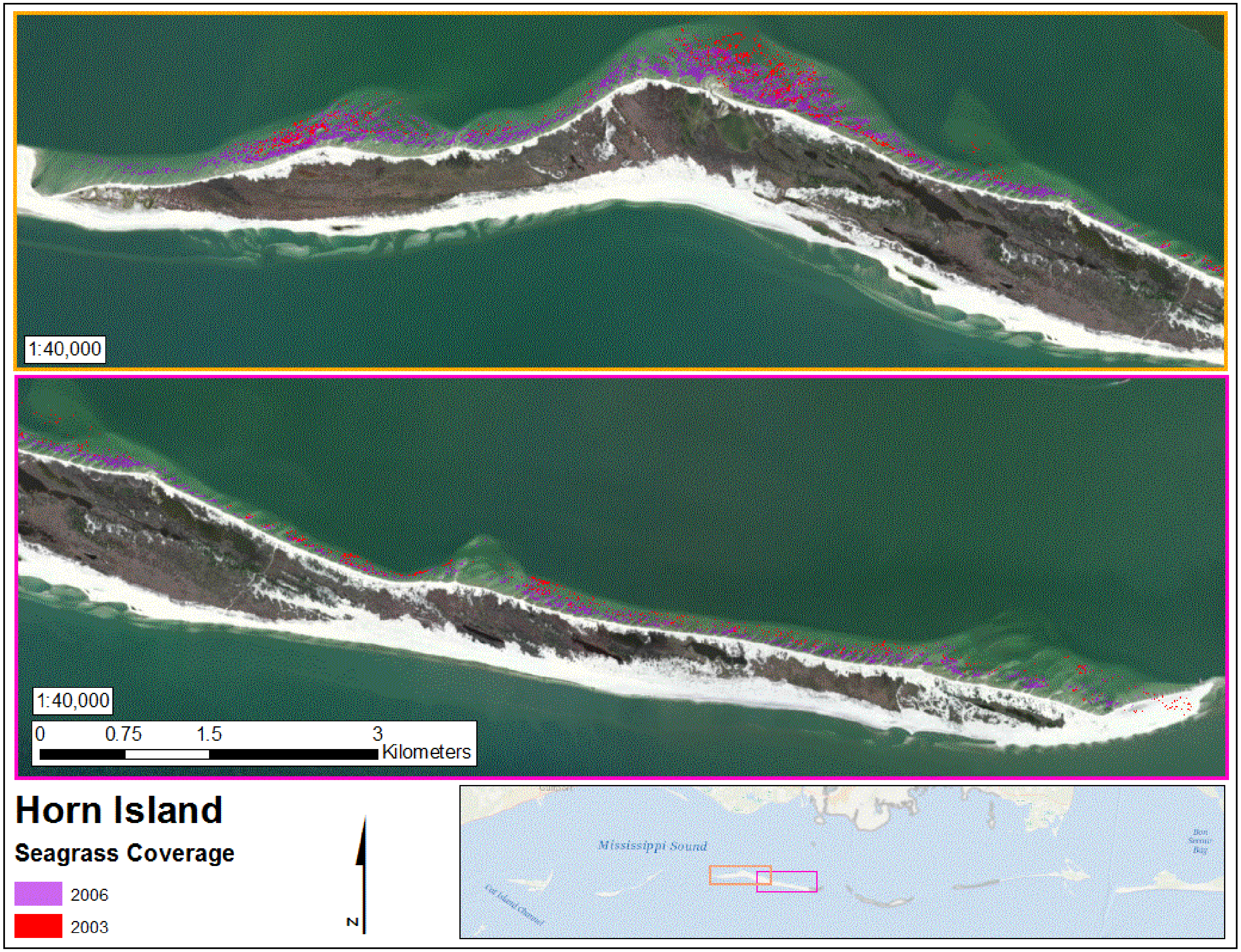


Figure 32c. Horn Island seagrass coverage. The Gulf Coast Geospatial Center (GCGC) conducted detailed mapping of seagrass area on the MS barrier islands in 2003 and 2006.

Figure 32d. Petit Bois Island seagrass coverage. The Gulf Coast Geospatial Center (GCGC) conducted detailed mapping of seagrass area on the MS barrier islands in 2003 and 2006.

Table 24. Seagrass total area mapped by Vittor (2011) for the MS barrier islands based on 2010 imagery.

Location	Density	Area (ha)
Cat Island	Continuous (>50% coverage)	72
Cat Island	Patchy (<50% coverage)	621
E. Ship Island	Patchy	106
W. Ship Island	Patchy	51
Horn Island	Patchy	394
Petit Bois Island	Patchy	219
Total		**1,463**

The most recent assessment for seagrass coverage for waters adjacent to GUIS-FL (to include Pensacola Bay System, Choctawhatchee Bay, Big Lagoon, and Santa Rosa Sound) was conducted by Yarbro and Carlson (2011) using aerial imagery from 1992-2003. Field sampling in Big Lagoon and Santa Rosa Sound reported both shoal and turtle grasses. Overall, Yarbro and Carlson (2011) reported a total of 2,715 ha of seagrass present in the waters adjacent to the barrier islands of GUIS-FL (Table 25). Recent monitoring of seagrass condition by GULN in both FL and MS will help to inform future assessments of this resource (M. Segura personal communication).

Table 25. Seagrass total area and percent change per year mapped by Yarbro and Carlson (2011) for water sources adjacent to GUIS-FL based on 2003 imagery. Percent changes denoted with an asterisk represent statistically significant changes in area from 1992-2003.

Location	Area (ha)	% Change / Year
Big Lagoon	220	+0.1
Choctawhatchee Bay	1,061	-3.5*
Pensacola Bay System	207	-3.9*
Santa Rosa Sound	1,227	+0.9*
Total	**2,715**	

4.7.3 Threats and Stressors

Increased turbidity (from dredging and boat traffic), modification to shorelines, nutrient loading, and hurricanes have all been implicated for substantial losses to seagrass at GUIS (Handley 1995, Moncreiff et al. 1998). In FL, some point source pollution discharges has been eliminated in the Pensacola Bay area in recent years, but stormwater runoff and subsequent eutrophication still poses a great risk to the health of the seagrass community (Schwenning 2001). Lewis et al. (2007) documented non-nutrient chemical concentrations of multiple contaminants (e.g., DDT, DDE, arsenic, copper, nickel) that exceeded sediment quality guidelines in seagrass beds in Santa Rosa Sound, Little Sabine, and Choctawhatchee Bay adjacent to GUIS-FL. Direct damage to beds from boating can have long-lasting effects (Figure 33). FDEP (2013) notes a minimum of 8-10 year repair time, with some areas that never recover depending on the severity of the propeller scarring.

Response to the 2010 Deepwater Horizon oil spill resulted in increased scarring, in addition to die-offs related to oil exposure (NOAA 2011). Seagrass declines have been marked since the 1950s (FDEP 2013), and the combined effects of any of the aforementioned pressures seriously threaten the persistence of this important habitat.

Figure 33. Boat scarring is a major threat to seagrass ecosystems throughout GUIS. [Source: FL Dept. of Environmental Protection]

4.7.4 Condition and Trend

Overall, much attention has been paid to the mapping and monitoring of seagrass beds around the MS barrier islands, while fewer efforts have focused on seagrass distribution within the FL district in recent years. Since GUIS-FL and GUIS-MS varied in available and current data on the status of their seabed resources, they were ranked separately. Monitoring of seagrass condition as begun by GULN in both FL and MS will help to inform future assessments of this resource (M. Segura personal communication).

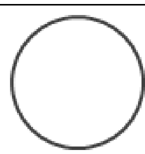
Extensive analysis by Carter et al. (2011) in MS showed a considerable decline between the period 1960 and 1990, though more recent analysis indicated signs of recovery. In 2007, Carter et al. (2011) reported 142 ha of seagrass; Vittor (2011) mapped 1463 ha in 2010, though this disparity is likely due to different mapping resolutions, wherein Vittor (2011) mapped seagrass at a broader scale. The condition status for seagrass at GUIS-MS was assigned a rating of fair (Table 26), with an improving trend, to reflect the current recovering state of the resource, but also to indicate the ongoing threats to its persistence, such as recreational boating and coastal renourishment. The data quality for this attribute was very good.

Table 26. The condition status for seagrass at GUIS-MS was ranked fair with an improving trend. The data quality for this attribute was very good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Seagrass (GUIS-MS)		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage √
		6 of 6: Very Good		

The condition status for seagrass at GUIS-FL was not ranked (Table 27). We did not feel the data were sufficiently recent or proximal to evaluate the current state of the resource. The data quality for seagrass at GUIS-FL was rated fair. Checks for spatial proximity and temporal currency were withheld because information for this assessment was primarily derived from data on seagrass coverage outside of park boundaries from over ten years ago (Table 27). Recent efforts from the Florida Fish and Wildlife Commission (FWC) to develop a Seagrass Integrated Monitoring and Mapping (SIMM) program will likely prove useful in monitoring and assessing the health of Florida's seagrass communities (FWC 2013).

Table 27. The condition status and trend for seagrass at GUIS-FL was not ranked. The data quality for this attribute was fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Seagrass (GUIS-FL)		Relevancy √	Proximity	Currency
		Sufficiency √	Coverage √	Coverage √
		4 of 6: Very Fair		

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4.8 Fish Assemblages

4.8.1 Context and Resource Knowledge

As a barrier island complex, GUIS offers a variety of potential fish habitats across a gradient of salinity and productivity (Wilborn and Bennett 2006). GUIS supports seasonal reproduction, critical nursery habitat, and a shifting mosaic of adult fish year-round. Most of the historical work on fish in and around GUIS has been in the marine environment and ecological in nature, primarily investigating habitat, behavior and interactions. Only a small amount of work has been conducted on inland freshwater areas, primarily in the freshwater lakes of Horn Island. A good review of this work is available in Cooper et al. (2005). While no single broad-scale fish survey has been conducted by GUIS, the large number of studies over the years has led to a comprehensive species list compiled most recently by Wilborn and Bennett (2006), and updated by NPS staff (NPSpecies 2014).

4.8.2 Threats and Stressors

Few studies have addressed actual effects of various stressors on fish communities in and around GUIS (Cooper et al. 2005); yet extensive toxicological work has been conducted in the northern Gulf of Mexico since the 2010 British Petroleum oil spill (FDA 2014). Fitzgeral & Gohlke (2014) reported on an extensive voluntary testing program with Gulf of Mexico commercial fishers to ensure the safety of their catch. Seven species of reef fish were tested for polycyclic aromatic hydrocarbons, several metals, and for constituents of the dispersants used during oil spill clean-up. Just two of 92 samples had detectable levels benzo(a)-pyrene-equivalents (measure of carcinogenic potency), and these were still below federal safety thresholds. Further, evidence suggested this contamination was from a source other than Deepwater Horizon. Mercury and arsenic were detected at levels previously reported, and other metals (cadmium and lead) were largely absent from the samples. This study suggested minimal public health risk, however, they acknowledge that due to where the fishers were active, the most contaminated areas were not sampled. Several other acute toxicity studies find specific effects of crude oil-derived polycyclic aromatic hydrocarbons (PAHs), such as potential cardiac arrhythmias (Block et al. 2014) and modest levels of mortality (Echols et al. 2014). However, it is too early to tell what long term effects may exist because of bioaccumulation and the movement of fish, other nekton, and contaminants throughout the Gulf. Finally, the recent expansion of lionfish (*Pterois volitans* and *Pterois miles*) into park waters presents a major hazard to the natural fish communities (USGS 2014). Lionfish possess a number of qualities that make them successful invaders and as a predatory fish have been documented to outcompete native predators and consume large numbers of small fishes and crustaceans (Albins and Hixon 2013). Without any natural predators, lionfish have the potential to cause major declines to GUIS species that are important commercially, recreationally, and ecologically.

4.8.3 Condition and Trend

The condition of the fish community in GUIS is not formally ranked in this report (Table 28). While there is fairly good documentation of the diverse fish community, there was no single survey with sufficient detail to perform a meaningful analysis, such as creating an index to allow comparisons to either expected communities or the relative health of the community. For example, both the Fish Community Index (FCI) proposed by Jordan et al. (2010) and the Benthic Index of Biotic Integrity (Tetra Tech 2011) require consistent, catch-level data sufficient to calculate relative abundance across different taxa. As a result of this scarcity of data, the data quality for fish assemblages at GUIS was ranked marginal (Table 28). While there were lists to inform species present within multiple units of GUIS, the data were neither temporally current nor sufficient to conduct a true assessment.

However, the brief assessment by Wilborn and Bennett (2006) found that 271 species were confirmed present within park boundaries and an additional 110 species were considered probably present. Based on these numbers, compared to comprehensive species lists for the northern Gulf of Mexico, they determined that nearly 75% of species known in the northern Gulf of Mexico are likely to occur within GUIS boundaries at some stage of their life. Park-specific surveys of the fish community would be useful in informing future assessments of the resource.

Table 28. The condition of GUIS fish assemblages was not ranked. No trend was assigned. The data used to make the assessment were marginal.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Fish Assemblages		Relevancy √	Proximity √	Currency
		Sufficiency	Coverage √	Coverage
		3 of 6: Marginal		

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4.9 Bird Assemblages

4.9.1 Context and Relevance

Birds specialize in a variety of habitats and are relatively easy to monitor, making them valuable indicators of terrestrial ecosystem quality and function (Maurer 1993). Key species of eastern U.S. obligate forest birds have shown a steady decline in abundance for over 40 years, causing concern for managers (NABCI 2009). GUIS's position on the Gulf Coast makes it a potential critical stopover site for many species of migratory birds. The Gulf Coast is also generally recognized to provide breeding and over-wintering areas for many migratory species (Granger 2012).

GUIS is located within the East Gulf Coastal Plain (EGCP) which is characterized by a diversity of bird habitats including floodplain forests, coastal uplands, and pine flatwoods and savannas (ABC 2001). Additionally, the EGCP supports over 300 species with over 180 breeding in the region, as well as a number of breeding birds of conservation concern. GUIS itself is designated as an Important Bird Area by the National Audubon Society (National Audubon Society 2013). The park is primarily composed of barrier islands and the associated vegetation communities, and much of this habitat is critical for migrating avifauna and could be suitable for nesting landbirds as well (Watson 2005).

4.9.2 Resource Knowledge

GUIS contains a variety of potential avian habitats, including maritime forest, beaches and dunes, fresh and salt marshes, and open water. All of these habitats are necessary for the known breeding, migratory, and wintering bird assemblages of GUIS. At least 345 bird species have been historically reported from GUIS (NPS 2012, NPSpecies 2014). Of these 345 listed species, 322 species of birds are listed as "present" in the park and one is "probably present", according to NPSpecies (2014). Information on breeding bird populations in GUIS were collected via the Breeding Bird Survey, a long-term monitoring program (USGS 2001) and via GULN monitoring protocols (Twedt 2010), in addition to systematic surveys for Osprey (*Pandion haliaetus*), Least Tern, Piping Plover, Snowy Plover, and Black Skimmer (*Rynchops niger*).

Of the 321 species known to inhabit GUIS, many species are residents of high abundance (NPSpecies 2014). Abundant resident songbird species include: Northern Cardinal (*Cardinalis cardinalis*), Red-winged Blackbird (*Agelaius phoeniceus*), Boat-tailed Grackle (*Quiscalus major*), and Carolina Wren (*Thryothorus ludovicianus*). Perhaps most importantly, the extent of the barrier islands of GUIS constitutes critical stopover habitat for Neotropical migrants (Cooper et al. 2005). Wetland habitats of GUIS also provide foraging and breeding opportunities for a number of wading birds. Those species most commonly observed and breeding within GUIS marshes and wetlands are: Great Blue Heron (*Ardea herodias*), Green Heron (*Butorides virescens*), Yellow-crowned Night-Heron (*Nyctanassa violacea*), and a number of passerine species including Red-winged Blackbird, Prothonotary Warbler (*Protonotaria citrea*), Marsh Wren (*Cistothorus palustris),* and Eastern Kingbird (*Tyrannus tyrannus*).

Finally, GUIS supports the highest number of breeding Southeastern Snowy Plovers, a state-threatened species on the Gulf Coast (Watson 2005), as well as breeding populations of Osprey, FL state-listed Least Tern, and the MS and FL listed Brown Pelican. While not all of these above species are of special conservation concern, their combined presence reveals the importance of GUIS in supporting a diverse group of avian species with differing habitat requirements. Since shorebirds and seabirds are a high priority for GUIS, the condition of this resource is discussed separately in section 4.9.7 below.

The establishment of the I&M Program in 1992 motivated the first complete inventories of several taxonomic groups in GUIS. However, since the bird list for the park was deemed complete, no additional inventories were conducted in association with GULN. Since this decision, the park has begun monitoring of the avian community via the establishment of breeding landbird monitoring protocols in association with the GULN Avian Monitoring Plan (Twedt 2010). These monitoring protocols use standardized bird surveys conducted at 48 randomly selected point locations within the GUIS-FL and GUIS-MS districts, omitting beach/dune, emergent marsh, or water habitats (Granger 2012). Survey points were divided into eight panels (four for each district) and two panels are selected to be sampled each year from May 15 – June 15 (within breeding season).

Species lists from GUIS reported a number of species of conservation concern according to Partners in Flight (PIF) criteria (Tables 29 and 30). PIF, a bird conservation organization including federal, state, academic, and NGO partners, assigns a variety of conservation scores to North American birds (Panjabi et al. 2012). These scores are designed to summarize the level of threat to birds within specific Bird Conservation Regions (BCRs). Because GUIS is located within the Southeastern Coastal Plain (SCP) BCR, we used scores from this region to determine a list of species of concern. Again, seabirds and shorebirds are treated in section 4.9.7 below, and thus they were omitted from this list. From the collective data on landbirds observed at GUIS, 25 species of concern were reported (Tables 29 and 30). In addition, the Mississippi Natural Heritage Program (MNHP) and FWC have identified species of conservation concern in the states (MDFWP 2014, FWC 2014). Those species identified and present in GUIS are: Little Blue Heron (*Egretta caerulea*), Osprey, Reddish Egret (*Egretta rufescens*), Roseate Spoonbill (*Platalea ajaja*), Tricolored Heron (*Egretta tricolor*), Snowy Egret (*Egretta thula*), and White Ibis (*Eudocimus albus*).

Table 29. Breeding season bird species of conservation concern reported from Gulf Islands National Seashore. Conservation concern species were those defined by Partners in Flight as of continental concern (CC) or regional concern (RC) in the Southeastern Coastal Plain (SCP) Bird Conservation Region. Also shown are values for "Percent of Population" (%Pop), which indicates the proportion of the global population contained within the BCR during the breeding season (Panjabi et al. 2012).

Scientific Name	Common Name	CC	RC	%Pop
Falco sparverius	American Kestrel		x	
Columbina passerina	Common Ground-dove		x	
Chaetura pelagica	Chimney Swift		x	19.7
Colaptes auratus	Northern Flicker		x	3.6
Melanerpes erythrocephalus	Red-headed Woodpecker	x		14.9
Lanius ludovicianus	Loggerhead Shrike		x	4.8
Contopus virens	Eastern Wood-Pewee		x	12.7
Tyrannus tyrannus	Eastern Kingbird		x	9.6
Sturnella magna	Eastern Meadowlark		x	7.6
Caprimulgus carolinensis	Chuck-will's-widow		x	37.1
Setophaga dominica	Yellow-throated Warbler		x	21.3
Protonotaria citrea	Prothonotary Warbler	x	x	52.9
Pipilo erythrophthalmus	Eastern Towhee		x	43.4
Spizella pusilla	Field Sparrow		x	7.8
Passerina ciris	Painted Bunting		x	2
Hylocichla mustelina	Wood Thrush	x	x	18

Table 30. Non-breeding season and migratory bird species of conservation concern reported from Gulf Islands National Seashore. Conservation concern species were those defined by Partners in Flight as of continental concern (CC) or regional concern (RC) in the Southeastern Coastal Plain (SCP) Bird Conservation Region. Species receiving a TN4 are expected to have severe deterioration in the future suitability of their non-breeding environment.

Scientific Name	Common Name	CC	RC	TN4
Elanoides forficatus	Swallow-tailed Kite [a]	x	x	
Buteo platypterus	Broad-winged Hawk		x	
Caprimulgus vociferus	Eastern Whip-poor-will	x		
Coccyzus americanus	Yellow-billed Cuckoo		x	
Limnothlypis swainsonii	Swainson's Warbler		x	x
Geothlypis formosa	Kentucky Warbler	x		x
Setophaga cerulea	Cerulean Warbler	x	x	x
Setophaga discolor	Prairie Warbler	x	x	
Setophaga virens	Black-throated Green Warbler		x	

[a] Designates species that are only known to migrate through the park. Also shown are birds receiving a "Threat to Non-breeding" score of 4 (TN4), which indicates the vulnerability of the continental population to survive over the non-breeding season (Panjabi et al. 2012).

4.9.3 Threats and Stressors

North American birds face a number of general threats including land conversion, development, exotic species, forest pests, and poor land management (NABCI 2009). There are many factors specific to GUIS that could have a negative effect on bird populations. For example, the location of GUIS within an urban environment and adjacent to marsh habitat which has historically been in decline, could make habitat unsuitable for many of the birds present. Birds nesting in fragmented habitat are subjected to high level of nest parasitism and nest predation, relative to birds nesting in undisturbed forest habitats (Robinson et al. 1995). In such cases, even apparently diverse assemblages containing native species of concern could be population sinks at the meta-population level (Robinson et al. 1995). Brown-headed Cowbirds are commonly noted in GUIS during the breeding season (NPS 2014) suggesting that cowbird brood parasitism may be a threat faced by birds nesting in GUIS.

Non-native species can have both indirect and direct effects on native bird communities at GUIS. Feral or free-roaming domestic cats occur at GUIS. In urban and suburban environments, feral and free-roaming cats can pose a threat to nesting songbirds (Watson 2005). Invasive plants, especially those plants that change the vegetation structure of the forest such as shrubs, may have negative effects on GUIS birds as well (Schmidt and Whelan 1999, Watson 2005).

Finally, birds confined to the shoreline and marsh habitats of GUIS may be affected by factors outside of the park's jurisdiction. Climate change has the potential to affect park bird communities, as sea-level rise threatens to increase flooding pressure for breeding birds (Bayard and Elphick 2011), and increased severity of storm events will likely alter the vegetation structure of foraging habitats (Scavia et al. 2002) which may be critical for birds migrating over the Gulf of Mexico. Oil spills, most notably the 2010 British Petroleum Deepwater Horizon spill, can alter suitable habitat for birds with long-lasting effects on survival and demography. While GUIS may not be able to manage for some of these extrinsic effects on park habitat, managing the resources with these threats in mind is critical to maintaining bird assemblages.

4.9.4 Data

For the analyses in this report, we used data from NPSpecies on birds residing in GUIS to create a reference list of breeding birds in the park (NPSpecies 2014). We also verified species present on NPSpecies and their breeding status using a bird check list for GUIS (NPS 2014). We then acquired data from the USGS Breeding Bird Survey (BBS) database (USGS 2001) to compare expected avian species richness during the breeding season to detected species richness in the park. BBS data have been collected annually since the 1960's along pre-established routes and using specific standardized protocols. Since one of the nearby BBS routes fell within park boundaries (Santa Rosa), this route was used only in creating the reference list of birds breeding at GUIS. The analysis dataset included data from surveys conducted during primarily spring, early summer, and winter. Data included records of 321 species known to be present in the park, with at least 81 breeding at GUIS (NPS 2014, NPSpecies 2014). Breeding season observations were collected as early as April and as late as July and therefore could have included some spring migration data. Since populations of waterfowl are not typically adequately assessed using BBS methods, these species have been omitted from the analyses. In addition, the coverage of shorebirds and seabirds in section 4.9.7 below was sufficient to omit these groups from the bird community analysis. Thus, the dataset is largely comprised of passerines, wading birds, and raptors, as are sufficiently captured in this type of survey.

4.9.5 Methods

We used an index of similarity (Jaccard's similarity coefficient) to assist us in evaluating GUIS bird communities. The Jaccard's similarity coefficient is a method used to compare species diversity between two different communities when only presence/absence data are available (Krebs 1999). BBS routes selected for the reference list were chosen because they were within a similar ecoregion and exhibited similar land cover to GUIS (Figure 34). Six routes were selected for creating the reference list. The total number of species was compiled for each route. Those species seen on at least three out of six routes were included in the reference list for the region.

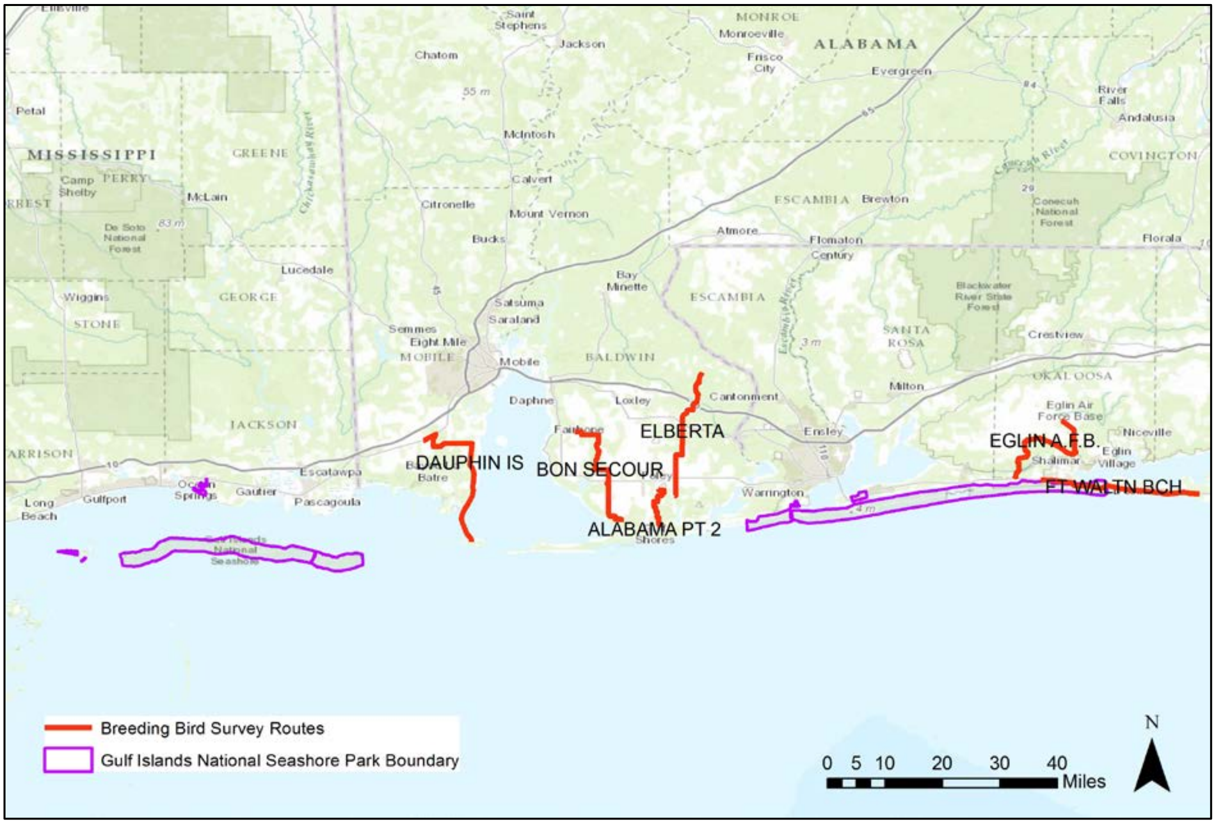

Figure 34. Breeding bird survey routes used to create a reference list of expected species inhabiting Gulf Islands National Seashore and adjacent areas (USGS 2001).

4.9.6 Condition and Trend

A total of 86 species were considered on the reference list as breeding in the region around GUIS. Using the list of birds breeding at GUIS (NPS 2014, NPSpecies 2014), we compared the two lists to assess breeding bird communities. There were 82 species that were both breeding at GUIS and on the BBS routes included in the analysis. Sixteen species at GUIS are recorded as breeding that were not found in at least three BBS routes. These species included owls, hawks, and secretive marsh birds that would not be readily detected by the BBS protocols. In this case, we decided to calculate the similarity coefficient twice, once withholding these observations and once including them. The coefficient is calculated by dividing the total number of species in both communities (a) by the number of species found in only one (b) or the other (c), using the following equation:

$$S_j = \frac{a}{a+b+c}$$

The Jaccard's similarity coefficient between the reference breeding bird list and the list from GUIS was 0.80. If we removed the sixteen species that were likely underrepresented in the reference list, the coefficient would increase to 0.95. This coefficient score indicates that the majority of species expected from the park were present.

We did not assign a rank to the GUIS bird assemblage (Table 31). The park has a good diversity of species and supports species of conservation concern, but the available data were merely a checklist of the expected species in the park. It is evident that GUIS provides habitat for a number of valuable and sensitive species and is probably an important refuge for migratory birds, given the urban landscape surrounding the park and its position on the Gulf of Mexico. The presence of Brown-headed Cowbirds suggests that the GUIS avian breeding population is potentially subject nest parasitism. In other fragmented systems where cowbirds are present, observed parasitism has been high (Robinson et al. 1995).

Data on the abundance and distribution of species is necessary in order to understand and evaluate the true condition of GUIS's bird assemblages, and these were not available for this assessment. Although breeding bird monitoring by GULN has begun at GUIS, data have only been summarized for one year across a few sites throughout the park (Granger 2013). Furthermore, given that the data were collected to incorporate imperfect detection, future analyses by NPS should consider accounting for detectability issues with distance sampling (Buckland et al. 1993, Royle et al. 2004). These analyses may not have been possible because of data scarcity with only one year of point-count data. Since more data were necessary to make assessments of the bird assemblages at GUIS, we did not assign a trend (Table 31). Estimates of nesting success for species of concern would be very useful to determine the resource condition and the effects of potential stressors on the resource (e.g., nest parasitism, flooding pressures, invasive species, etc.). Additional data collected as part of the I&M protocols and analysis using distance-sampling will likely help with this assessment.

As of this report, recent I&M data on the bird assemblages at GUIS were both spatially and temporally demarcated. However, although these data were collected using standardized techniques, they have not been sufficiently summarized to assess the resource. Since the data were collected in the last five years, they received a currency check. As only one year of point-count data were available for bird assemblages at GUIS, they did not receive a thematic sufficiency check or a temporal coverage check. Point-count surveys have only been conducted across some of GUIS to date, and therefore the spatial coverage check was withheld. Therefore, the data available to make the assessment were ranked marginal. The development of the Avian Conservation Implementation Plan (ACIP; Watson 2005) and continued I&M data collection (Granger 2012) will certainly aid in future assessments of GUIS bird assemblages.

Table 31. The condition of GUIS bird assemblages was unranked. No trend was assigned. The data used to make the assessment were marginal.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Bird Assemblages		Relevancy √	Proximity √	Currency √
		Sufficiency	Coverage	Coverage
		3 of 6: Marginal		

4.9.7 Shorebird and Seabird Assemblages

Context and Relevance

Shorebirds and seabirds are an important component of beach and estuarine vertebrate fauna. Numerous anthropogenic pressures threaten the habitat upon which these taxa depend. The U.S. Atlantic and Gulf Coasts support a large diversity of nesting and migrating shorebirds and seabirds (Withers 2002). GUIS supports a large and diverse population of migrating and nesting shorebird and seabird species, and many species of conservation concern use the park for nesting, overwintering, or migratory stopover habitat. The northern Gulf region of FL may be the most important region for the nesting of the state threatened Snowy Plover (Himes et al. 2006, Burney 2009). Human alterations to the hydrology of the landscape and urban development in this area (especially vehicular traffic, and increased human commensals) are perhaps the main threats to the GUIS bird community.

Resource Knowledge

GUIS-FL has routinely monitored shorebirds since approximately 1990. Monitoring efforts have included general beach surveys for the presence of all species, and specific surveys to monitor nesting effort and success of selected species. Similar efforts are routinely conducted by various state, federal, and NGO entities throughout the Gulf Coast region.

The summary of the current understanding of GUIS-FL shorebird and seabird assemblage diversity was derived from data collected during regular surveys conducted by NPS personnel. These survey data were collected from 1990-2011 at Fort Pickens, Perdido Key, and Santa Rosa beaches within GUIS. Data were collected by observers walking the beaches and reporting the number and species of shorebirds and seabirds detected. Start and end times were recorded for each sampling event. Effort varied among years, and total yearly search times were generally lower for the 1990-1995 period and greater for the 1996-2011 period. The combined dataset included samples collected during all 12 months of the year. Observations were primarily made for shorebird and seabird species, but the dataset also included some records of songbirds, wading birds, and raptor species that were reported from the surveyed habitat. These combined efforts reported 107 bird species, including 31 shorebirds 21 seabirds, and 56 other species. The most commonly reported species, numerically, included the Sanderling (*Calidris alba*), Laughing Gull (*Larus atricilla*), and Bonaparte's Gull (*Larus philadelphia*, Table 32).

Table 32. Fifteen most commonly detected species from general shorebird surveys conducted 1990-2011 at Fort Pickens, Perdido Key, and Santa Rosa beaches in Gulf Islands National Seashore.

Scientific Name	Common Name	Number
Calidris alba	Sanderling	144,539
Larus atricilla	Laughing Gull	84,577
Larus philadelphia	Bonaparte's Gull	41,610
Larus delawarensis	Ring-billed Gull	36,803
Chlidonias niger	Black Tern	34,777
Sterna antillarum [a]	Least Tern	21,313
Pelecanus occidentalis	Brown Pelican	18,914
Larus argentatus	Herring Gull	18,179
Catoptrophorus semipalmatus	Willet	17,321
Mergus serrator	Red-breasted Merganser	16,281
Sterna forsteri	Forster's Tern	11,922
Charadrius nivosus [a]	Snowy Plover	8,914
Sterna sandvichensis sandvichensis	Sandwich Tern	8,103
Arenaria interpres	Ruddy Turnstone	6,936
Sterna maxima	Royal Tern	6,622

[a] Indicates Florida state threatened species.

Observed species richness varied among the three beaches and among years. Fort Pickens annual richness varied from 14 to 44 species, with a mean value of 30.0 (SD ± 9.2) species over a total of 20 years during which data were collected. Perdido Key annual richness varied from 13 to 47 species, with a mean value of 28.0 (SD ± 9.6) species over a total of 19 years. Santa Rosa annual richness varied from 11 to 33 species, with a mean of 22.7 (SD ± 7.4) species over 19 years.

The list of observed species from the shorebird/seabird survey data included a number of species of management concern (Table 33). Species of management concern included state and federally listed species or species of concern, as well as species identified in the regional shorebird conservation plan as species of particular management concern (Hunter et al. 2002). Several species, including the state-threatened Snowy Plover and Least Tern (Table 32) were among the most commonly reported species in the general shorebird surveys (Table 33).

Table 33. Shorebird/seabird species of particular management concern with total numbers of individuals reported from surveys conducted at GUIS-FL 1990-2011.

Scientific Name	Common Name	Total	Fed [a]	FL [b]	PIF [c]
Bartramia longicauda	Upland Sandpiper	4			x
Calidris canutus	Red Knot	445			x
Calidris himantopus	Stilt Sandpiper	2			x
Calidris pusilla	Semipalmated Sandpiper	233			x
Charadrius nivosus	Snowy Plover	8,914		T	x
Charadrius melodus	Piping Plover	97	T	T	x
Charadrius wilsonia	Wilson's Plover	389			x
Haematopus palliatus	American Oystercatcher	53		C	x
Limnodromus griseus	Short-billed Dowitcher	112			x
Limosa fedoa	Marbled Godwit	3			x
Numenius americanus	Long-billed Curlew	1			x
Numenius phaeopus	Whimbrel	11			x
Pelecanus occidentalis	Brown Pelican	18,914		C	
Rynchops niger	Black Skimmer	3,096		C	
Sterna antillarum	Least Tern	21,313		T	
Tryngites subruficollis	Buff-breasted Sandpiper	1			x

[a] Shown are federal status (T = Threatened).

[b] Florida state status (T = Threatened, C = species of concern).

[c] Whether the species was indicated as of “extremely high” or “high” management concern based on Partners in Flight (PIF) ranks reported in Hunter et al. (2002).

Intensive surveys of nesting shorebirds have been conducted at GUIS-FL for a few species, including Least Tern, Black Skimmer, and Snowy Plover. Snowy Plover nesting data were chosen to assess the shorebird resource because multiple years of data were available and habitat needs of this species likely represent some of the more crucial aspects necessary for successful shorebird/seabird nesting at GUIS.

The summary of the current understanding of Snowy Plover nesting effort and success at GUIS was derived from data collected during annual nesting surveys conducted by NPS personnel. Surveys were conducted at Fort Pickens, Perdido Key, and Santa Rosa beaches using standardized protocols from 1998-2012. Data were collected during the nesting season, as possible, generally from March through July. Data were collected by trained observers moving slowly through Snowy Plover nesting habitat noting the presence and status of nests, nesting birds, and hatchlings. Unpublished NPS field reports indicate that the occurrence of Hurricanes Dennis, Katrina, and Rita in 2005 created large areas of suitable nesting habitat for snowy plovers in GUIS. An increase in nesting effort, possibly related to these storm events, was noted from the data beginning in 2007. Due to apparent differences in effort and methods prior to 2002, only 2002-2012 data are presented and discussed below. Because of the nature of the resource, uncertainty exists about the true fate of some nests. In the following discussions, efforts were made to consider all recorded data and field notes when determining nest fates.

From 2002-2012, 998 Snowy Plover nests containing 2,783 eggs were reported from GUIS-FL. Of these nests, 561 (56%) were considered to have hatched or “probably hatched”, where hatching was defined as at least one egg from a nest hatching. Of known nests, 105 (11%) were determined to have been predated, where “predated” was defined as all eggs in the nest being destroyed by predators. Of known nests, 41 (4%) were considered unhatched, where “unhatched” was defined as all eggs in the nest failing to hatch despite the apparent absence of predation. The fates of the remaining 291 (29%) nests were considered unknown, where “unknown” was defined as the case where the fate of all eggs in the nest was not observed and where no signs indicating hatching or predation were reported. Fort Pickens supported the greatest number of nests among the three beaches for the 2002-2012 period, with 473 reported nests. Perdido Key had 267 and Santa Rosa had 258 nests reported for the period. An increase in reported Snowy Plover nesting effort was noted beginning in 2007, and this was observed for all three beaches (Figure 35).

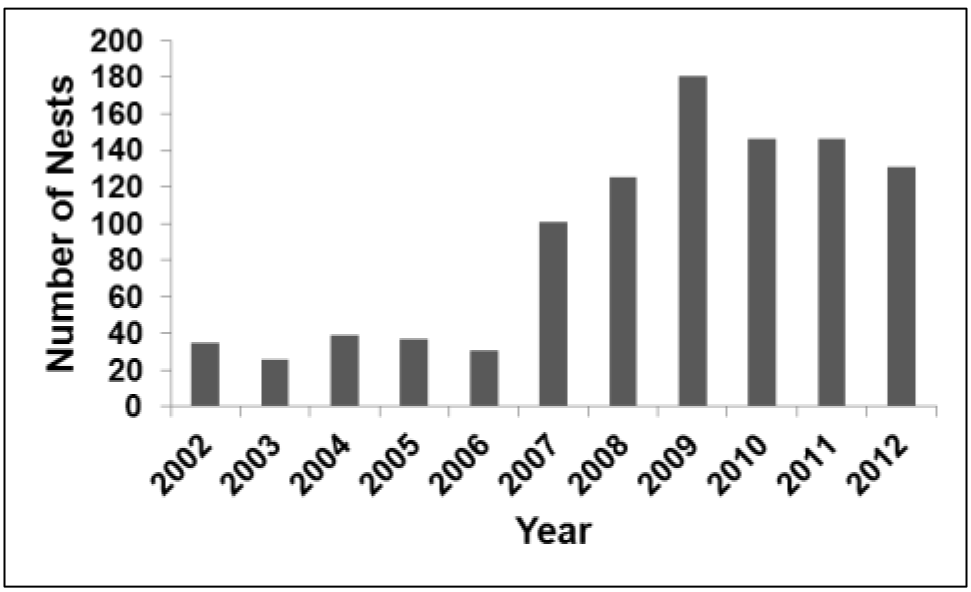

Figure 35. Total number of Snowy Plover nests reported annually, 2002-2012, during nesting beach surveys at GUIS-FL.

<u>Threats and Stressors</u>

Shorebirds and seabirds in GUIS are subject to several natural and anthropogenic threats including nest predators, human recreational activities, road mortality, flooding, and beach renourishment (Hunter et al. 2002, unpublished NPS field data). Human visitors near nesting areas may inadvertently trample Snowy Plover nests or may disrupt nesting adults contributing to nest abandonment. In GUIS, established Snowy Plover nesting areas are closed to human traffic during the nesting season, but this is not necessarily the case for other shorebirds nesting in the park. Adults with unfledged hatchlings may cross roads, putting chicks at risk of road mortality. Mammalian predators including raccoons (*Procyon lotor*) and wild or domestic canines contribute to nest mortality at GUIS (unpublished NPS data). Coyotes (*Canis latrans*) have become a problem in recent years for shorebirds breeding at GUIS (T. Pinion personal communication), although they likely have a greater impact on nesting success of shorebirds, primarily preying on eggs and chicks. Other non-native species potentially pose a problem to nesting shorebirds as well. For example, black rats have been implicated for numerous extinctions of seabirds worldwide and have the largest mean impact on nesting seabirds (Jones et al. 2008). Fire ants (*Solenopsis* spp.) also occur in the park and may attack new hatchlings in the nest. Finally, beach renourishment may contribute to changes in beach invertebrate assemblages upon which most shorebird species depend (Hunter et al. 2002).

Data

Because shorebird and seabird data were available primarily for the FL beaches of GUIS (Fort Pickens, Perdido Key, and Santa Rosa), assemblages were assessed for these areas of the park. Because the nature of the data were generally similar for these three beaches, a single assessment was made for the combined area.

For the exploration of shorebird and seabird assemblage diversity, the survey data collected by GUIS personnel were used. These data were chosen because of availability and because they were representative of the general diversity of GUIS shorebirds and seabirds. These data included observations collected during timed surveys in all months of the year from 1990-2011. Efforts were made to remove ambiguous and obviously erroneous records from these data. Additionally, only shorebirds or seabirds were examined. As amended, these data included records of 508,010 individuals from 107 species. This dataset was termed the analysis dataset. The entirety of the analysis dataset was used for determining the overall shorebird/seabird species richness and most commonly observed species. Because of apparent changes in effort and methods beginning in 1996, the 1996-2011 portion of the dataset was used when discussing trend.

For assessing Snowy Plover nesting effort and success, the nesting survey data collected by GUIS personnel were used. These data included observations collected during nesting surveys conducted during the Plover nesting season from 1998-2012. Efforts were made to remove ambiguous and obviously erroneous records from these data. Because of changes in methodology beginning in 2002, only 2002-2012 data were used for all aspects of the Snowy Plover nesting assessment. This dataset was termed the analysis dataset. The analysis dataset included records on the timing and fate of 998 Snowy Plover nests containing 2,783 eggs.

To provide context for the discussion of Snowy Plover nesting effort, data available from FL shorebird monitoring program were used. These data were available from the FWC website (FWC 2010). The data selected from this source included records of individual Snowy Plover nests reported from a number of beach nesting areas in the northwestern portions of the FL coast. Because data were available only for selected years, and because the reported efforts varied greatly among available years, three years with the most available collection sites were chosen. These years were 2006, 2009, and 2010. This dataset included records of 1,099 nests from 18 locations.

Methods

Shorebird and seabird assemblages in GUIS were assessed primarily using qualitative discussions of observed assemblages and observed Snowy Plover nesting efforts. Defensible quantitative methods of ranking condition of such assemblages were not readily available in the literature. Because data were collected by standardized methods over significant time periods, it was possible to qualitatively discuss changes in assemblages and nesting effort over time. Statistically robust trend analyses were not conducted.

Several metrics were calculated to aid the discussion of GUIS shorebird and seabird assemblage condition and trend. Species richness was simply the total number of different number of species observed over a given time period. Detections per effort (DPE) was defined as the number of individual birds, of any species, reported during a given time period, divided by the total number of minutes of observation occurring during that period. Nesting effort was the total number of nests reported for a given time period. Proportion of known-fate nests hatched was defined as the number of nests known to have at least one egg hatched divided by the total number of known-fate nests for a given location and year. Known-fate nests included only nests where nest fate was unambiguously reported, and excluded “probable” hatches.

For Snowy Plover nesting effort, a comparison was made among GUIS beaches and other surveyed beaches in northwestern coastal FL (FWC 2010). These surveys were conducted by a variety of entities and collected by the FWC (FWC 2010). The FWC collection included surveys conducted at Fort Pickens, Perdido Key, and Santa Rosa Beaches. The nest numbers reported by FWC differed from the numbers reported in NPS-specific survey data. This likely occurred because of differing methods and timing of the efforts. For consistency, comparisons were made using only FWC data for this particular case. Due to variations in methods, effort, area surveyed, and observer ability, this comparison is not suitable for a robust statistical analysis. It is presented here to provide context for a discussion of Snowy Plover nesting in GUIS.

Condition and Trend

From annual surveys, at least 51 species of shorebird and seabird species have been observed in GUIS, and at least 56 species of wading birds, songbirds, and raptors also have been detected in the sandy beach habitats of Fort Pickens, Perdido Key, and Santa Rosa. Annual species richness varied among years and among the three sites surveyed (Figure 36). Generally, Fort Pickens had the greatest species richness and Santa Rosa had the lowest (Figure 36). No obvious positive or negative trend was evident in species richness for the 1996-2011 period (Figure 36). At least 16 species of special management concern, including three federal or state threatened species, were reported from GUIS (Table 33). Of these species, three were among the 15 most commonly reported species in the survey (Table 32). Of 14 high priority species included in a regional shorebird conservation plan (Hunter et al. 2002), 13 were reported to occur in GUIS. DPE, in individuals observed per minute, also varied among sites and years, with no obvious trend for the 1996-2011 period (Figure 37).

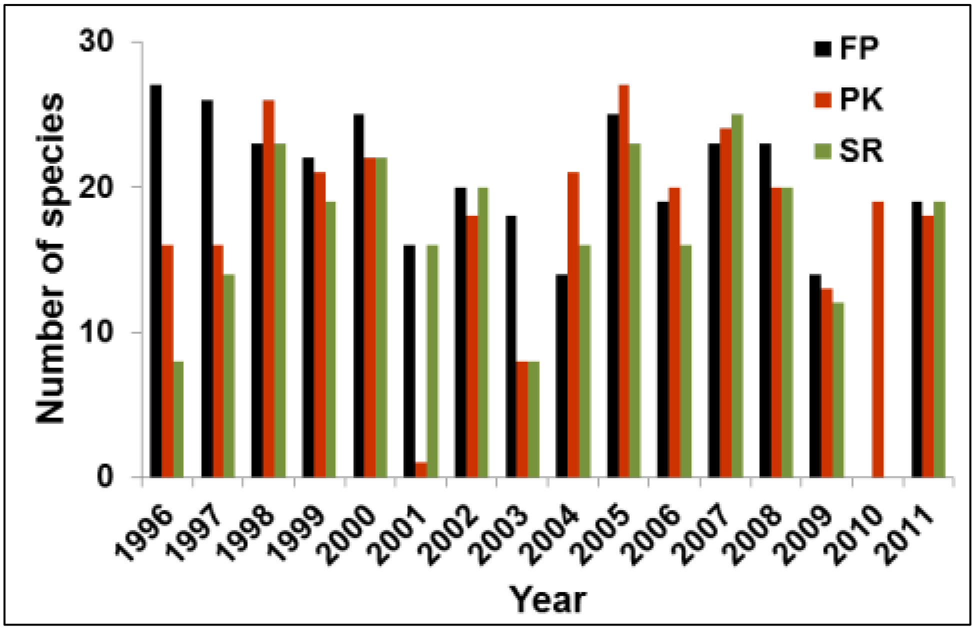

Figure 36. Annual beach-nesting bird species richness for 1996-2011 for shorebird/seabird surveys conducted at Fort Pickens (FP), Perdido Key (PK), and Santa Rosa (SR) beaches in Gulf Islands National Seashore.

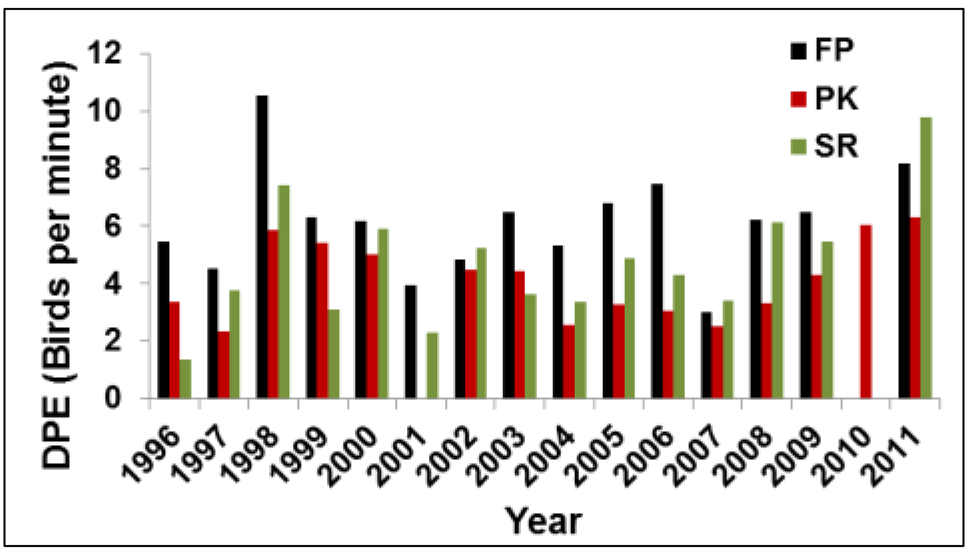

Figure 37. Annual detections-per-effort (DPE) in individuals observed per hour for 1996-2011 for birds observed on shorebird/seabird surveys conducted at Fort Pickens (FP), Perdido Key (PK), and Santa Rosa (SR) beaches in Gulf Islands National Seashore.

Snowy Plovers, a FL state threatened species, nest successfully within GUIS. Annual surveys indicate the number of nests varies among sites and among years (Figure 38). An obvious increase in nesting effort was observed starting in 2007 (Figure 38). This increase may have resulted from an increase in suitable nesting habitat resulting from several hurricanes occurring in 2005 (unpublished NPS data), although this is informed conjecture. Except for the change in nesting noted between 2006 and 2006, no obvious trend was observed in the data for the 2002-2012 period. Proportion of known-fate nests with at least one hatched egg varied among sites and years, and ranged from 0.33 to 1.0 and showed no obvious trend for the 2002-2012 period (Figure 39). Because the number of known-fate nests was low for some years, this metric must be viewed with caution.

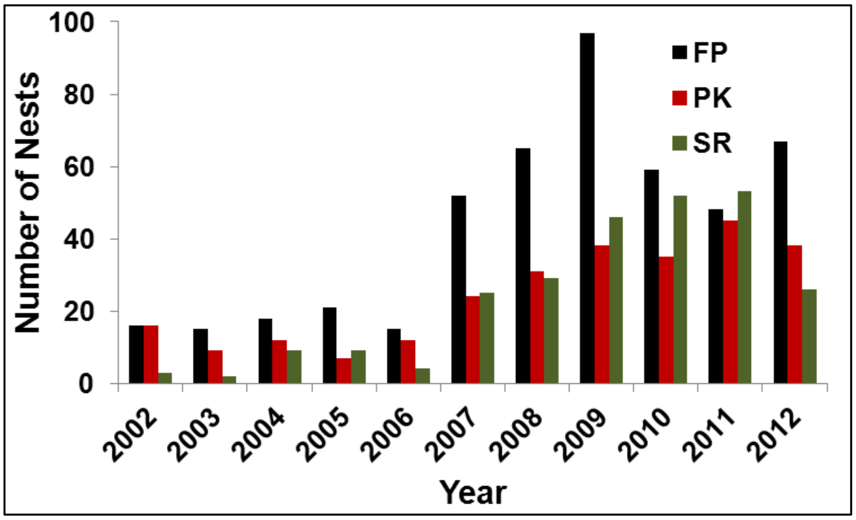

Figure 38. Annual number of observed Snowy Plover nests for 2002-2012 for nesting surveys conducted at Fort Pickens (FP), Perdido Key (PK), and Santa Rosa (SR) beaches in Gulf Islands National Seashore.

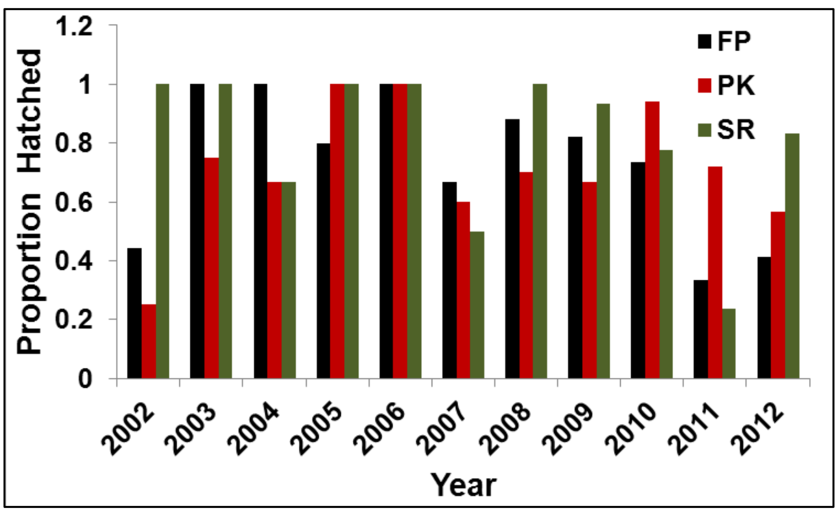

Figure 39. Proportion of known-fate nests with at least one hatched egg for 2002-2012 for nesting surveys conducted at Fort Pickens (FP), Perdido Key (PK), and Santa Rosa (SR) beaches in Gulf Islands National seashore.

A comparison of the number of Snowy Plover nests among northwestern FL beach sites suggested that the GUIS beaches are regionally important nesting sites for Snowy Plovers (Table 34). Fort Pickens generally fell within the highest five beaches, in terms of reported nest numbers, among the 18 beaches for which data were reported.

Table 34. Numbers of Snowy Plover nests reported from nesting surveys in northwestern Florida for selected years.

Beach	2006	2009	2010
Buck Beach	1	7	
Camp Helen	3	3	7
Crooked Island East	21	53	3
Crooked Island West	13	60	6
Deer Lake	3	3	6
Dog Island	10		1
Eglin Air Force Base	13	68	54
Fort Pickens [a]	14	94	35
Navarre Beach	3		
Perdido Key [a]	13	37	17
Santa Rosa [a]	8	46	23
Shell Island	9	51	13
St. Andrews	3	3	4
St. George	42	10	59
St. Joseph	41	79	58
St. Vincent	16	20	10
Tyndall Air Force Base	2		41
Windmark Beach	8	5	

[a] GUIS beaches (also shown in red font)

The condition of the GUIS-FL shorebird and seabird assemblages was ranked as good (Table 35). This assessment was based primarily upon qualitative factors. The park is shown to support a diverse and rich shorebird and seabird assemblage, including large numbers of conservation concern species. The protected Snowy Plover nests successfully within the park and park habitat for this species may have increased as a result of major storm events. Regional data suggests that the park may be among the more important nesting sites for Snowy Plovers in northwestern FL. The trend of GUIS shorebird and seabird assemblage condition was ranked as stable (Table 35). This assessment was based on a qualitative interpretation of several multi-year datasets. No obvious increases or decreases were observed in richness, DPE, nesting effort, or nest hatching. Data available when this assessment was made may not reflect the current condition of shorebird assemblages or nesting success at GUIS. In fact, recent introduction of coyotes (*Canis latrans*) to GUIS beaches in addition to the 2010 BP oil spill has significantly increased predation pressure on both nesting plovers and terns (C. Bromley and T. Pinion personal communication). With these new pressures in mind, the current state of the resource may be in poorer condition with a declining trend than the conclusions drawn from data available through 2012.

The data used to make the assessment were ranked as good (Table 35). The data were appropriate and sufficient for use in condition assessment, were collected within park boundaries, and were relatively long-term with good seasonal coverage. Because the data did not include observations made outside of the FL portion of the park, the spatial coverage attribute did not receive a check.

Table 35. The condition of GUIS-FL shorebird and seabird assemblages was good. The trend of this condition was stable. The data used to make the assessment were good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Shorebird & Seabird Assemblages (GUIS-FL)		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage	Coverage √
		5 of 6: Good		

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4.10 Rare Beach Mice

4.10.1 Context and Relevance

Beach mice are subspecies of oldfield mice (*Peromyscus polionotus* spp.) and are adapted to live in coastal dune habitats of the U.S. Atlantic and Gulf Coasts. Beach mice are highly endemic, with most populations occurring on a single barrier island or along short, discreet stretches of coastal habitat. Geographic endemicity causes beach mouse populations to be highly vulnerable to habitat loss and anthropogenic pressures, and some populations exhibit large changes in density from year to year (Holler and Moyers 1991, Branch et al. 2011). The vulnerability and unique nature of beach mouse subspecies make them an important management concern.

Two species of beach mice are known to occur in Gulf Island National Seashore: the Perdido Key beach mouse and the Santa Rosa beach mouse. The Perdido Key beach mouse (PKBM) is found only on the Perdido Key barrier island, and this island comprises its entire native range (Holler et al. 1989, Gore and Greene 2011). The PKBM is listed as endangered federally and by the state of FL, and is one of the most critically imperiled subspecies of beach mouse. The Santa Rosa beach mouse (SRBM) occurs on Santa Rosa Island, and the island comprises its entire native range (Gore and Shaefer 1993). The SRBM is not listed at the state or federal level.

4.10.2 Resource Knowledge

The PKBM occurs as a single, discreet population in GUIS, and has been the subject of substantial research and management effort. The pre-development density and distribution of PKBM are unknown, although informed conjecture suggests they were likely widely-distributed within appropriate habitat throughout Perdido Key. Within the last 30 years, PKBM have apparently been limited to two areas, one located on the eastern end of the island within GUIS, and the other at the western end of the island in the state of Alabama (Humphrey and Barbour 1981, Holler et al. 1989). In the early 1980s, a small population of PBKM was located within GUIS (Humphrey and Barbour 1981). By 1986 this population had apparently become extirpated, although the Alabama population of mice persisted (Holler et al. 1989). From 1986-1989 a reintroduction program translocated 15 pairs of PKBM from Alabama to GUIS resulting in the establishment of a breeding population in GUIS (Holler et al. 1989). However, by 2008 the Alabama population of PKBM had been extirpated, leaving the GUIS population as the only known individuals of the species (Gore and Brown 2008, Gore and Greene 2011). Evidence suggests this small population exists in a fragile state—genetically isolated, prone to relatively large fluctuations in size, and subject to numerous threats and stressors (Holler and Moyers 1991, Gore and Shaefer 1993, Gore and Brown 2008, Gore and Greene 2011).

The SRBM occurs throughout the dune habitats of Santa Rosa Island, including those habitats found in GUIS. Studies suggest that in the early 1940s the species was ubiquitous in suitable habitat on Santa Rosa Island, with a relatively large population numbering in the thousands of animals (Blair 1946). More recent studies suggest that the SRBM has been excluded from some of its original habitat, but remains widely distributed throughout the undeveloped areas of the island (Pries 2006, Pries et al. 2009, Branch et al. 2011).

4.10.3 Threats and Stressors

Beach mice face a variety of natural and anthropogenic threats. Loss of habitat from beach development may be the most important of these threats and has probably been the most important cause of population declines (Gore and Shaefer 1993, Gore and Green 2011). Predation by feral or free-ranging domestic animals may pose a threat to beach mice, although this has not been clearly shown in GUIS (Gore and Schaefer 1993). Due to the small population size of the PKBM, it is likely threatened by predation by native animals. The house mouse (*Mus musculus*) may competitively exclude beach mice in some cases (Humphrey and Barbour 1981), although this observation may also result from other factors related to human habitations where house mice are found (Gore and Schaefer 1993). Black rats (*Rattus rattus*) occur on islands within GUIS-MS and are noted from as nearby as Panama City, FL (Scoggin 2008). Black rats have been implicated in numerous extinctions of endemic rodents via competition and predation (Harris 2009), and could pose a serious threat to FL beach mice. Hurricanes and major storm events may threaten the persistence of beach mouse populations (Pries 2006, Gore and Brown 2008, Pries et al. 2009, Gore and Greene 2011). Current populations are more vulnerable to these natural events than were pre-development populations of beach mice.

4.10.4 Data

The two species of beach mice in GUIS occur in discreet, mutually exclusive areas. These areas are the obvious choice of scale for reporting beach mouse condition. PKBM Reporting Area includes the dune habitat of the Perdido Key portion of GUIS. The SRBM Reporting Area includes the dune habitat of the Santa Rosa portion of GUIS. Other areas of the park are not considered. Data used in the assessment were taken from selected literature sources (Table 36). The selected studies employed a variety of approaches and reported a variety results. Basic summarized results of key findings related to presence, density, and distribution of beach mice were selected for presentation (Table 36).

Table 36. Summary of presence and distribution findings from selected studies of Perdido Key beach mice and Santa Rosa beach mice.

Species (*Scientific name*)	**Study**	**Sample Period**	**Sample Method**	**Summary of Beach Mouse Presence and Distribution**
Perdido Key Beach Mouse (*Peromyscus polionotus trissyllepsis*)	Humphrey and Barbour 1981	1979	Sherman	23 captures of 12 individuals in 720 trap nights in GUIS.
	Holler et al. 1989	1986-1988	Sherman	None trapped in GUIS in 1986. 55 individuals trapped in GUIS in 1988 following reintroduction of 15 pairs.
	Holler and Moyers 1991	1990-1991	Sherman	From 52 to 72 individuals captured in GUIS during four sample periods, with population estimates ranging from 64 to 118.
	Gore and Brown 2008	2008	Sherman	56 captures of 30 individuals from 1,794 trap nights in GUIS, with population estimate of 238.
	Gore and Greene 2011	2010	Sherman	40 captures of 20 individuals from 2,280 trap nights in GUIS.
Santa Rosa Beach Mouse (*Peromyscus polionotus leucocephalus*)	Blair 1946	1941-1942	Not Reported	682 captures and population estimates ranging from approximately 10,000 to 17,000. Sampling within and outside GUIS.
	Pries 2006	2004-2005	Track Pipes	100% detection in front dunes, 73% detection in scrub dune habitat pre-hurricane, 52% detection in front dunes, 74% scrub dunes post hurricane. Sampling within and outside GUIS.
	Branch et al. 2011	2007-2008	Sherman, Track Pipes	Presence detected in all trap grids with estimates of abundance ranging from 2.3 to 19.5 individuals per grid among trapping seasons. Sampling within and outside GUIS.

4.10.5 Methods

This assessment relied primarily upon qualitative interpretation of the findings of a variety of research and management efforts. For three studies for which sufficient data were available, simple metrics of captures per effort were calculated. In each case, Sherman live traps were used to sample PKBM. Captures per trap night was calculate by dividing the number of captures for the entire study by the number of trap nights, where trap night was defined as a single trap set for a single night. Similarly, "individuals per trap night" was calculated by dividing the total number of unique individuals captured during the entire study by the number of trap nights. Statistical comparisons among these metrics were not appropriate; these findings were presented to provide context to the discussion of PKBM condition.

4.10.6 Condition and Trend

Perdido Key Beach Mouse

The PKBM population remains threatened. Although the original density and distribution of the PKBM is poorly understood, it is evident that the current population is greatly reduced from pre-development numbers. Although highly-defensible estimates of population size were not available in the studies discussed in this report, the entire existing population is obviously small and highly isolated, likely numbering at best several hundred individuals (Table 36). A comparison of total captures and of individuals captured per amount of standard effort is suggestive that the existing population is not dissimilar in density to populations observed in GUIS in the past (Figure 40). Due to differences in effort and the small size of the population, caution is warranted when interpreting such data. Furthermore, it is important to note that local populations of PKBM similar in size and extent to the current GUIS population have apparently been extirpated twice on Perdido Key since the mid-1980s.

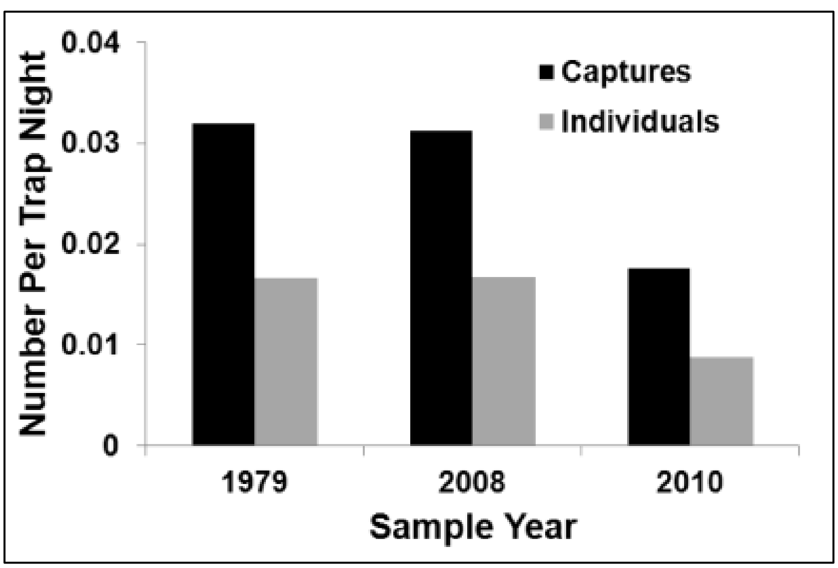

Figure 40. Captures per trap night and individuals per trap night of Perdido Key beach mice reported in three studies in GUIS. Studies were: sample year 1979 (Humphrey and Barbour 1981), sample year 2008 (Gore and Brown 2008), sample year 2010 (Gore and Green 2011).

The condition of the PKBM population on GUIS was ranked as poor (Table 35). This rank was assigned to emphasize the small and highly-imperiled nature of the population. A positive note is that several natural refuges exist under state or federal management that either contain PKBM or are suitable habitats where the endangered mice could survive. No trend was assigned to PKBM condition (Table 37). The data used in the assessment were not suitable for trend analyses. The data used to make the assessment were very good (Table 37). They were suitable to provide a qualitative understanding of beach mouse condition, they were appropriately located within the park and adequately covered the potential habitat, and they were collected over a number of years, including recent years, with adequate seasonal coverage.

Table 37. The condition of the Perdido Key beach mouse population was poor. No trend was assigned to Perdido Key beach mouse condition. The quality of the data used to make the assessment was very good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Rare Beach Mice: Perdido Key		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage √
		6 of 6: Very Good		

Santa Rosa Beach Mouse

The SRBM has been pressured by human activity and apparently does not exist in some habitats it previously occupied. However, the SRBM remains relatively widely-distributed and is generally found throughout suitable undeveloped habitat as it occurs on Santa Rosa Island (Table 36). The condition of the SRBM in GUIS was ranked as fair (Table 38). This ranking reflects the fact that the species appears to have remained relatively stable, without major existing threats to its persistence. However, this rank also reflects the fact that the SRBM population is by nature highly isolated and endemic and therefore is more at risk from any kind of threat than a species that is more widely distributed. Furthermore, experience with other beach mouse subspecies has proven that this taxa is generally fragile. No trend was assigned to SRBM condition (Table 38). The data used in the assessment were not suitable for trend analyses. The data used to make the assessment were good (Table 38). They were suitable to provide a qualitative understanding of SRBM condition, they adequately covered the potential habitat, and they were collected over a number of years, including recent years, with adequate seasonal coverage. Because some of the data, as reported in the literature used, could not be assigned specifically within GUIS boundaries as opposed to areas outside GUIS boundaries, the spatial proximity attribute did not receive a check.

Table 38. The condition of the Santa Rosa beach mouse population was fair. No trend was assigned to Santa Rosa beach mouse condition. The quality of the data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Rare Beach Mice: Santa Rosa		Relevancy √	Proximity	Currency √
		Sufficiency √	Coverage √	Coverage √
		5 of 6: Good		

4.10.7 Literature Cited

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4.11 Herpetofauna Assemblages

4.11.1 Context and Relevance

The southeastern U.S. contains the highest diversity of herpetofauna in North America, and amphibians and reptiles are important components of southeastern U.S. ecosystems (Gibbons and Buhlmann 2001). Global declines in amphibians (Stuart et al. 2004) and reptiles (Gibbons et al. 2000) have been noted for decades, and herpetofauna have become the focus of increasing management concern and effort. Three park-specific inventories of the herpetofauna have been conducted at GUIS (Richmond 1962, Seigel and Doody 1996, Mohrman and Qualls 2008). Many federally and state listed and species of special concern inhabit GUIS, including the gopher tortoise, alligator snapping turtle (*Macroclemys temminckii*), American alligator, and multiple marine turtles offshore.

GUIS is nearly 2,400 ha and represents multiple habitats including pine savanna, freshwater ponds and wetlands tidal marshes, beaches, and maritime forests (Mohrman and Qualls 2008). This region of the United States was historically rich in herpetofauna and has potential for relatively high diversity of reptiles and amphibians. It is likely that the herpetofauna communities of GUIS are highly dynamic, given the environmental conditions (e.g., hurricanes, island migration, availability of fresh water, etc.) to which they are exposed (Mohrman and Qualls 2008). Furthermore, human alterations to the landscape including levee installation, clearing for agriculture and development, and petroleum production could all contribute to a reduction in herpetofauna populations and species richness.

4.11.2 Resource Knowledge

Multiple efforts provided information on GUIS herpetofaunal assemblages. A few studies were conducted that included specific areas of the park, but were not intended to inventory the entire park. For example, Allen (1932) conducted a survey of amphibians and reptiles in Harrison County, MS which included surveys on Horn and Cat Islands. A preliminary report of the herpetofauna at the Gulf Coast Research Laboratory in Ocean Springs, MS was produced by Scanlon and Nichols (1953). In 1962, Richmond (1962) thoroughly surveyed Horn Island and documented 29 herpetofauna species. This survey was followed up again in 1968 and included a few additional species (Richmond 1968). Seigel and Doody (1996) conducted a second survey that included locations throughout GUIS including Fort Pickens, Naval Live Oaks, Horn Island, Davis Bayou, Ship Island, and Petit Bois Island. They recorded 17 amphibian and 36 reptile species. The increase in species detected is likely attributed to an increase in trapping effort and greater area covered. A re-survey of Naval Live Oaks and Fort Pickens by Seigel et al. (1997) following Hurricanes Erin and Opal detected five species that were not found by Seigel and Doody (1996). Seigel et al. (1997) used the same methodology as Seigel and Doody (1996), employing coverboard arrays, minnow traps, turtle traps, and hand-collection.

A three-year comprehensive inventory of GUIS reptiles and amphibians was conducted from 2004-2006 (Mohrman and Qualls 2008) and detected a total of 51 herpetofauna species. Methods included: drift fences, pitfall and funnel traps, coverboards, unbaited minnow traps, baited hoop nets, arboreal PVC-pipes (PVC), road surveys, and active hand-searching. Starting in 2011, GULN began monitoring the herpetofauna of GUIS at the Naval Live Oaks Beaver Pond unit (NLO) of GUIS-FL (Woodman 2013). GUIS-NLO is 575 ha and includes plant species representative of northern Gulf coastal forests (e.g., longleaf pine, and live oak, *Quercus virginiana*) and spring-fed ponds and wetlands that could provide critical breeding habitat for amphibians. The GULN monitoring uses terrestrial coverboard, arboreal PVC-pipe, and aquatic funnel-trap fixed-point sampling methods coupled with environmental conditional monitoring. Sites are sampled monthly for each year. Figure 41 shows an aerial image of the sampling location at GUIS.

Figure 41. Overview map showing locations of monitoring site used in an ongoing reptile and amphibian monitoring program in Gulf Islands National Seashore – Naval Live Oaks Beaver Pond, Florida district (Source: Woodman 2013).

The GUIS-NLO amphibian and reptile monitoring protocol reported 22 species in monitoring year (MY) 2012 and 22 in 2013 (Woodman 2013, Woodman and Finney 2014). Results of this sampling are a subset of the available herpetofauna at GUIS-NLO, as GULN sampling methods largely target terrestrial and some arboreal taxa, with an additional focus on near-shore aquatic amphibians (R. Woodman personal communication). These 22 species represented 51 percent of the total expected species based on previous surveys. No species were detected that had not been previously reported from the NLO. At the time of this report, the GULN I&M herpetofauna narrative reports included data from October 2011 – September 2012 and October 2012 – September 2013 (Woodman 2013, Woodman and Finney 2014). For reptiles, these data showed relatively low abundances all year with the greatest average relative abundances during spring and fall (Figure 42). With the exception of a peak in April 2013, amphibians had relatively lower abundances in spring and summer, increasing in fall and winter (Figure 43). Different trends were found for reptile species richness in 2012, with highest richness in summer months in 2012 and highest in spring months in 2013 (Figure 44). Richness was fairly stable throughout the seasons for amphibians (Figure 45), but varied between years in the summer months.

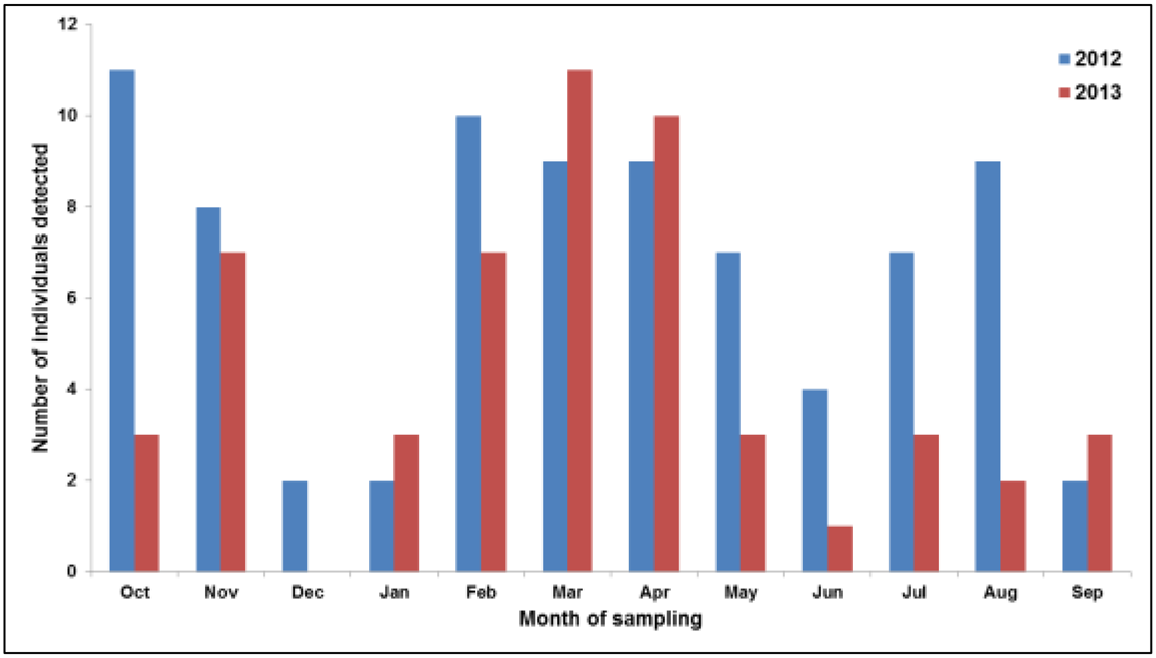

Figure 42. Relative abundance of reptiles collected during amphibian and reptile monitoring at Gulf Islands National Seashore, Naval Live Oaks from October 2011 – September 2013. Year indicates the monitoring year (2012 or 2013) [Source data: Woodman 2013, Woodman and Finney 2014].

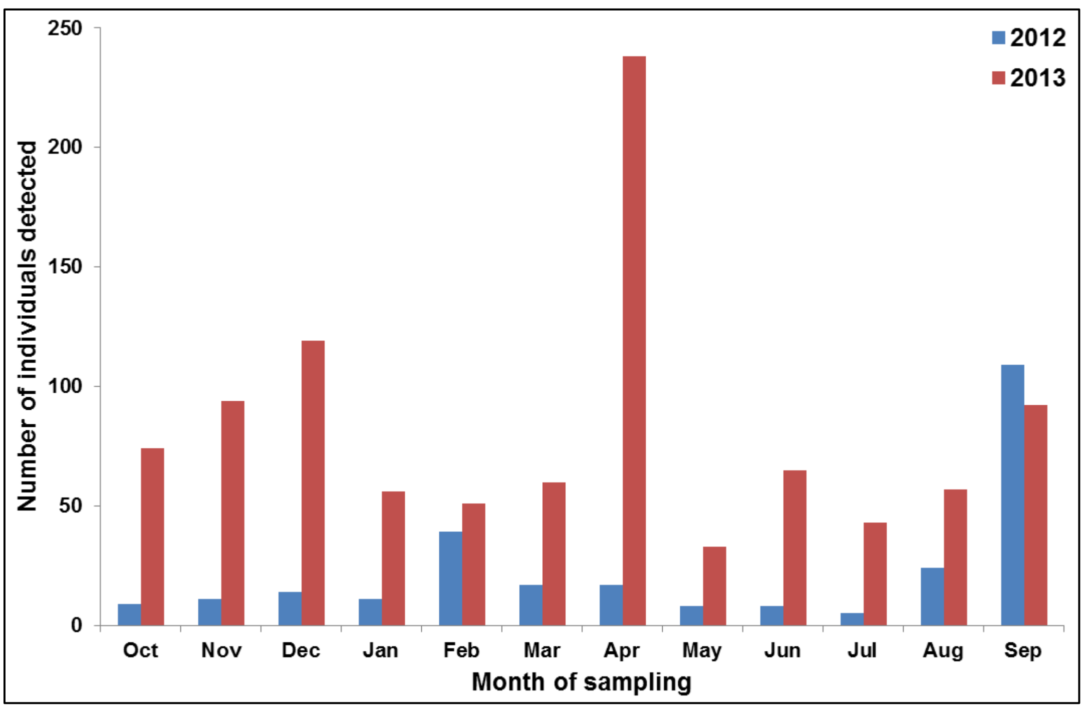

Figure 43. Relative abundance of amphibians collected during amphibian and reptile monitoring at Gulf Islands National Seashore, Naval Live Oaks from October 2011 – September 2013. Year indicates the monitoring year (2012 or 2013) [Source data: Woodman 2013, Woodman and Finney 2014].

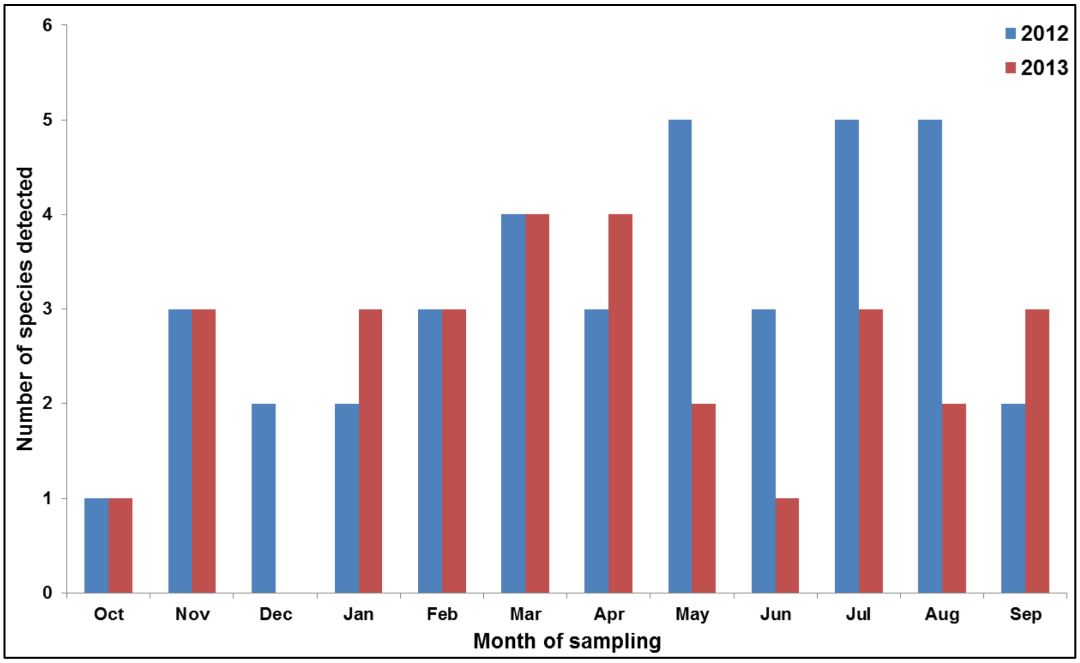

Figure 44. Species richness of reptiles collected during amphibian and reptile monitoring at Gulf Islands National Seashore, Naval Live Oaks from October 2011 – September 2013. Year indicates the monitoring year (2012 or 2013) [Source data: Woodman 2013, Woodman and Finney 2014].

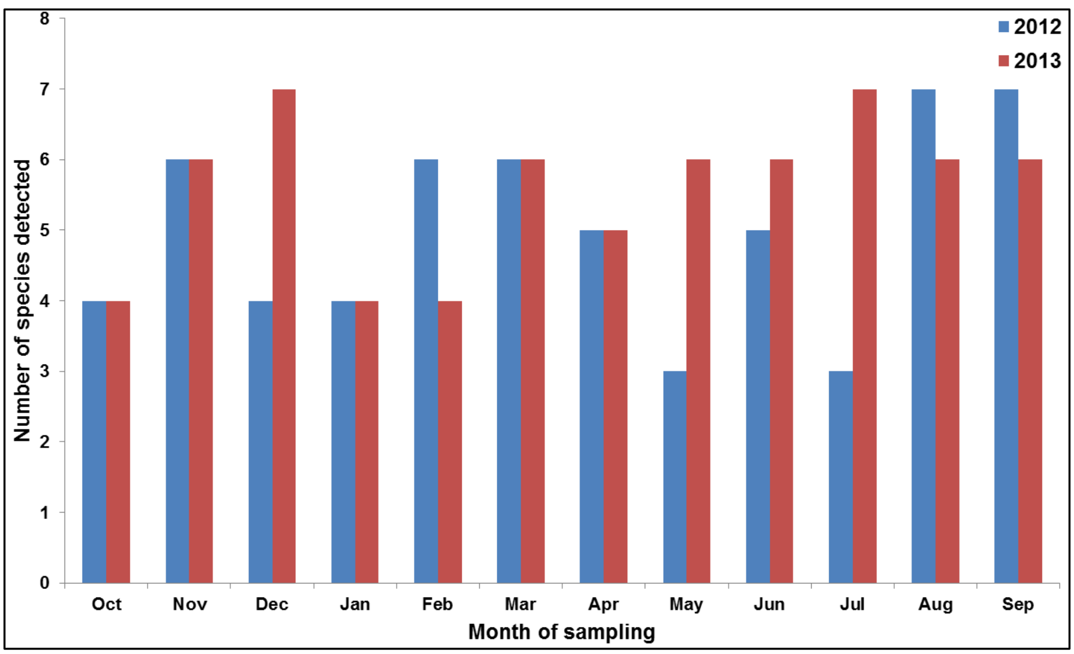

Figure 45. Species richness of amphibians collected during amphibian and reptile monitoring at Gulf Islands National Seashore, Naval Live Oaks from October 2011 – September 2013. Year indicates the monitoring year (2012 or 2013) [Source data: Woodman 2013, Woodman and Finney 2014].

In addition to the community-wide survey efforts, GUIS has conducted targeted monitoring of both sea turtle and gopher tortoise populations. Marine turtles breed on GUIS beaches and have been monitored in the park using standardized protocols in the Florida district since the 1990's (Cooper et al. 2005). Leatherback and loggerhead sea turtles have both been reported nesting in the park (Shabica 1980), along with green sea turtles and Kemp's ridleys (Nicholas 2010). Daily surveys are conducted primarily with volunteer help to identify and monitor nests and aid in the first hatchling movements to the Gulf of Mexico. Gopher tortoise populations have been monitored in GUIS-NLO since 1997 (NPS 2000). A Gopher Tortoise Action Plan was developed in 2000 to mitigate negative impacts to the population from impending development pressures that included a relocation strategy.

Combined, the efforts described above have reported 70 species of herpetofauna from GUIS, including 17 frogs/toads, five salamanders/newts, 10 lizards, 25 snakes, and 13 turtles/tortoises, and one alligator. Multiple federal or state listed threatened or endangered herpetofauna species have been reported from the park, including the American alligator, gopher tortoise, green sea turtle, loggerhead, leatherback, and Kemp's ridley.

4.11.3 Threats and Stressors

Known threats to herpetofauna include habitat loss and fragmentation, habitat degradation, pollution, disease, climate change, direct consumptive use, and invasive species (Gibbons et al. 2000, Semlitsch 2000). Wetland habitats are of particular importance to amphibians (Semlitsch 2000) and are important to many species of reptiles as well (Gibbons et al. 2000). Notable pressures on GUIS's herpetofauna community include: non-native plants and animals, anthropogenic habitat alterations, and climate change (Gibbons et al. 2000, Mohrman et al. 2004, Woodman 2013).

Feral animals represent a possible concern for management of the park's herpetofauna. Feral or free-ranging domestic cats are present in the park (Gore and Schaefer 1993) and may prey on herpetofauna (Woods et al. 2003). Declines in herpetofauna have been attributed to introduction of non-native ants (Allen et al. 2004), armadillos (*Dasypus novemcinctus*, Carr 1994) and feral hogs (*Sus scrofa*, Seward et al. 2004, Jolley et al. 2010). Species that exhibit mass terrestrial migrations and arboreal species that require ground-level thermal shelter in cooler conditions may be more at risk to depredation events by hogs (Jolley et al. 2010). Moreover, feral hogs have challenged monitoring efforts by moving coverboards and preying on herpetofauna underneath in other parks, as was recently observed at Jean Lafitte National Historical Park and Preserve (R. Woodman personal communication). Fortunately, although historically present (Baron 1979), feral hogs do not currently inhabit GUIS.

In addition to pressures from non-native, invasive animals, the GUIS herpetofauna are likely vulnerable to the spread of invasive plants. Non-native plant introductions can result in plant community shifts in both aquatic and terrestrial ecosystems (see Terrestrial Vegetation section 4.6.2). These shifts can have cascading effects on the herpetofauna that inhabit these systems, including impacts on individual survival, growth and development, and foraging success (Brown et al. 2006, DeVore 2011). In particular, cogon grass has been shown to displace native plant species via allelopathy and can form dense monocultures that gopher tortoises avoid (McCoy et al. 2013). Invasive plants are a concern at GUIS, and consideration should be given to monitor their effects on herpetofauna in light of this previous research.

Human alteration to the landscape may affect GUIS's herpetofauna communities in a variety of ways. Exclusion of fire from pine savanna habitats has been shown to affect the abundance of endemic pine-forest species (e.g., oak toad, *Anaxyrus quercicus*, and Southeastern Five-lined Skink, *Eumeces fasciatus*), via changes to the structure and species composition of the forest (Means et al. 2004, Mushinky 1992). Environmental contaminants can be a major source of mortality for herpetofauna, especially amphibians (Gibbons et al 2000). Over 40 percent of U.S. petroleum refining capacity is along the Gulf Coast, in addition to 30 percent of the U.S. natural gas processing plant capacity (EIA 2014). Oil spills, including the 2010 British Petroleum's Deepwater Horizon major offshore spill, are likely to affect marine turtle populations and potentially affect herpetofauna breeding in Gulf-fed marsh and pond waters. Marine turtles are also disturbed by light pollution from the nearby developed areas (Nicholas 2010). Urban glow leads to disorientation for nesting turtles and emerging hatchlings on GUIS beaches, and is considered to be the most major environmental issue that affects the park's marine turtle populations.

Finally, salt water intrusion into freshwater environments could create unsuitable habitat for many amphibian species at GUIS, particularly in the larval stages. Dramatic reductions in tadpole populations for one sampling region of GULN monitoring at Jean Lafitte National Historical Park and Preserve were noted after the first 2008 hurricane, and these reductions were attributed to strong storm effects including increases in salinity (R. Woodman personal communication). Although this was not documented in recent monitoring (Woodman 2013), increased hurricane activity in this region and loss of marsh from erosion might increase the frequency of these intrusions (Short and Neckles 1999). Most Southeastern amphibian species require freshwater habitats for successful reproduction and development of larvae (Jensen et al. 2008). Because many species of herpetofauna are relatively slow to disperse, and because many rely upon rare aquatic habitats, re-population of areas recovering from degradation may be slow.

4.11.4 Data

<u>Herpetofauna Assemblages</u>

For our analyses of GUIS herpetofaunal condition, we used the data available from the most recent park inventory (Mohrman and Qualls 2008), and from the new and ongoing herpetofauna monitoring (Woodman 2013, Woodman and Finney 2014). Inventory data consisted of a narrative report of the overall project results, including tables of the species detected at each park location. All inventory data were collected in 2004 – 2007. Data for the herpetofauna monitoring effort included a brief descriptive narrative and an electronic database to include capture type, number of individuals captured, and snout-vent-length of all individuals measured (when applicable) for all herpetofauna. Monitoring began in October 2011 and continued monthly through September 2013. Data from these combined efforts were called the "analysis dataset".

<u>Marine Turtles</u>

Since neither the inventory nor the GULN monitoring was designed to assess the condition of marine turtle populations, we assessed this group separately. To measure health of the marine turtle populations at GUIS, we considered available data from the 1994 – 2012 sea turtle monitoring program (Nicholas 2010, NPS unpublished data). Data from sea turtle monitoring included a narrative report and an electronic database to include nest-specific data from 1994-2012 at the GUIS-FL district summarized by species. Nest-specific data included clutch size, length of incubation period, hatch date, hatching success, and number of young observed to enter the Gulf of Mexico. We also considered trends in total number of nests for all breeding sea turtles.

4.11.5 Methods

Herpetofauna Assemblages

We compared the species actually reported from the analysis dataset to a list of expected species for the region. Our expected list included all species previously reported in the park by Richmond (1962, 1968) and Seigel and Doody (1996), and those species observed by NPS personnel (NPSpecies 2014). We also considered species located in the nearby region from other studies (Jackson and Jackson 1970, Langford et al. 2007) and those that were classified as "probably present" on NPSpecies (2014). Our reported list was comprised of species reported by (Mohrman and Qualls 2008) and recent I&M efforts (Woodman 2013, Woodman and Finney 2014). Since these protocols do not adequately sample marine turtles, they were excluded from the datasets for this analysis. In order to evaluate temporal trends in the herpetofauna condition, we compared only two years of monitoring data gathered as part of the I&M efforts (Woodman 2013, Woodman and Finney 2014), since only these were standardized in space and time to allow comparisons.

Marine Turtles

To assess the condition of the marine turtle populations at GUIS, we considered nesting data that are necessary to maintain a healthy breeding population (e.g., measures of productivity – number of young hatched, number of hatchlings entering the Gulf of Mexico, etc.). We evaluated the condition for sea turtles at GUIS by using management objectives for nesting success (as measured by number of nests) and population growth established by the U.S. National Marine Fisheries Service (NMFS) and USFWS recovery plans (NMFS 2014). Since loggerhead turtles make up a significant portion of the sea turtles nesting at GUIS, we compared annual population growth rates (as measured by nest counts) at GUIS-FL to population growth rates of all subpopulations in the Gulf of Mexico using methods described by NMFS and USFWS (2008). To examine temporal trends in all species known to breed at GUIS-FL, we analyzed changes in hatching success, number of young entering the Gulf, and mean incubation length with linear regression analysis. We excluded the first two years of standardized monitoring data collection from this analysis, as data were not collected on the number of young entering Gulf waters.

4.11.6 Condition and Trend

Herpetofauna Assemblages

Overall, about 76% of all herpetofaunal species expected in the region were reported from GUIS (Table 39). Crocodilians and lizards were the best represented with 100% of expected species reported. Anurans were also well represented with 84% of the expected salamander species reported. While we acknowledge that the compilation of expected lists is somewhat subjective, the findings from the GUIS efforts suggest that the park harbors a high percentage of herpetofaunal species expected for the region. Moreover, recent inventory and monitoring efforts have unveiled at least two previously undetected species, the Mediterranean house gecko (*Hemidactylus turcicus*, Mohrman and Qualls 2008) and the spiny soft-shell turtle (*Apalone spinifera*, Woodman and Finney 2014).

Table 39. Herpetofaunal species expected to occur and those actually reported within both the Florida and Mississippi districts of Gulf Islands National Seashore. Expected species are those listed as likely to occur by Richmond (1962, 1968), Seigel and Doody (1996), and NPS observations, as well as those expected in the greater region (Jackson and Jackson 1970, Langford et al. 2007). Reported species are those reported by Mohrman and Qualls (2008) and by GULN amphibian and reptile monitoring from 2011-2013 (Woodman 2013, Woodman and Finney 2014).

Group	Expected	Reported	% Expected Reported
All species	77	53	76
Amphibians	27	20	74
Reptiles	50	33	66
Anurans	19	16	84
Salamanders	8	4	50
Crocodilians	1	1	100
Lizards	10	9	90
Snakes	28	16	57
Turtles	12	8	67

The relatively high abundance of exotic vegetation (see Exotic Vegetation section 4.6.2) likely has a negative effect on GUIS herpetofaunal assemblages, although these factors have not been quantified in the park. Salamanders (particularly Ambystomids) were notably absent from the reported GUIS herpetofauna community. Their absence from the reported species may be attributed to issues of detection and/or abundance. Sampling protocols for this group must consider varying detectability throughout the year (easiest during migrations or breeding season). Dodd et al. (2007) documented significant declines over a 28-year period for four amphibian species in nearby St. Marks National Wildlife Refuge, and three of these four species were missing from the most recent inventory and monitoring efforts in GUIS (but had been previously reported at the park). Furthermore, localized population extinctions have been documented for species that were subjected to extended droughts (Palis et al. 2006, Walls et al. 2013), as could be accentuated by climate change. We qualitatively considered these factors to decrease herpetofaunal assemblage quality. However, there is no evidence that GUIS is more affected by these factors than is typical within the broad region.

Because behavior and habitat associations vary widely among herpetofaunal species, multiple methods should be used when sampling an assemblage (Gibbons et al. 1997, Tuberville et al. 2005). Drift fencing with pit-fall traps is among the most effective and commonly used method of sampling herpetofauna assemblages, and may be especially useful for sampling salamanders (Greenberg et al. 1994, Ryan et al. 2002, Wilson and Gibbons 2009). Mohrman and Qualls (2008) employed drift fencing among a number of sampling techniques, but GULN monitoring does not (Woodman 2013, Woodman and Finney 2014). Without pit-falls, terrestrial salamanders were potentially underrepresented by sampling methods in GULN surveys (Table 39). However, while drift fences and pit-falls are known to be effective methods, the potential lethality is not considered acceptable within the monitoring context (R. Woodman personal communication). Woodman (2013) addresses that the aquatic turtles that are common at GUIS-NLO are likely underrepresented by sampling methods. We feel that future efforts at discovering the full diversity of herpetofaunal assemblages at GUIS-NLO should consider using alternative trapping methods. This would likely increase the reported number of species in this region. Despite these caveats, since a majority of the expected species were reported (Table 39), we believe that the monitoring efforts to survey herpetofauna at GUIS are likely sufficient to detect most available species.

The comparison of two years of data is likely insufficient to examine temporal trends in individual species. There were a few items of note from this comparison. Significantly more Southern cricket frogs (*Acris gryllus*), greenhouse frogs (*Eleutherodactylus planirostris*), and squirrel treefrogs (*Hyla squirella*) were captured in 2014 (Figure 46). Four additional amphibians were detected in 2014, the two-toed amphiuma (*Amphiuma means*), pig frog (*Lithobates grylio*), Southeastern slimy salamander (*Plethodon grobmani*), and the Mississippi slimy salamander (*Plethodon mississippi*). Two additional reptiles were detected in 2014 (five-lined skink—*Eumeces fasciatus* and eastern coral snake—*Micrurus fulvius*) The second year of monitoring produced 683 more captures employing the same techniques (Woodman and Finney 2014) and continued GULN efforts will likely detect additional species and possibly improve capture rates.

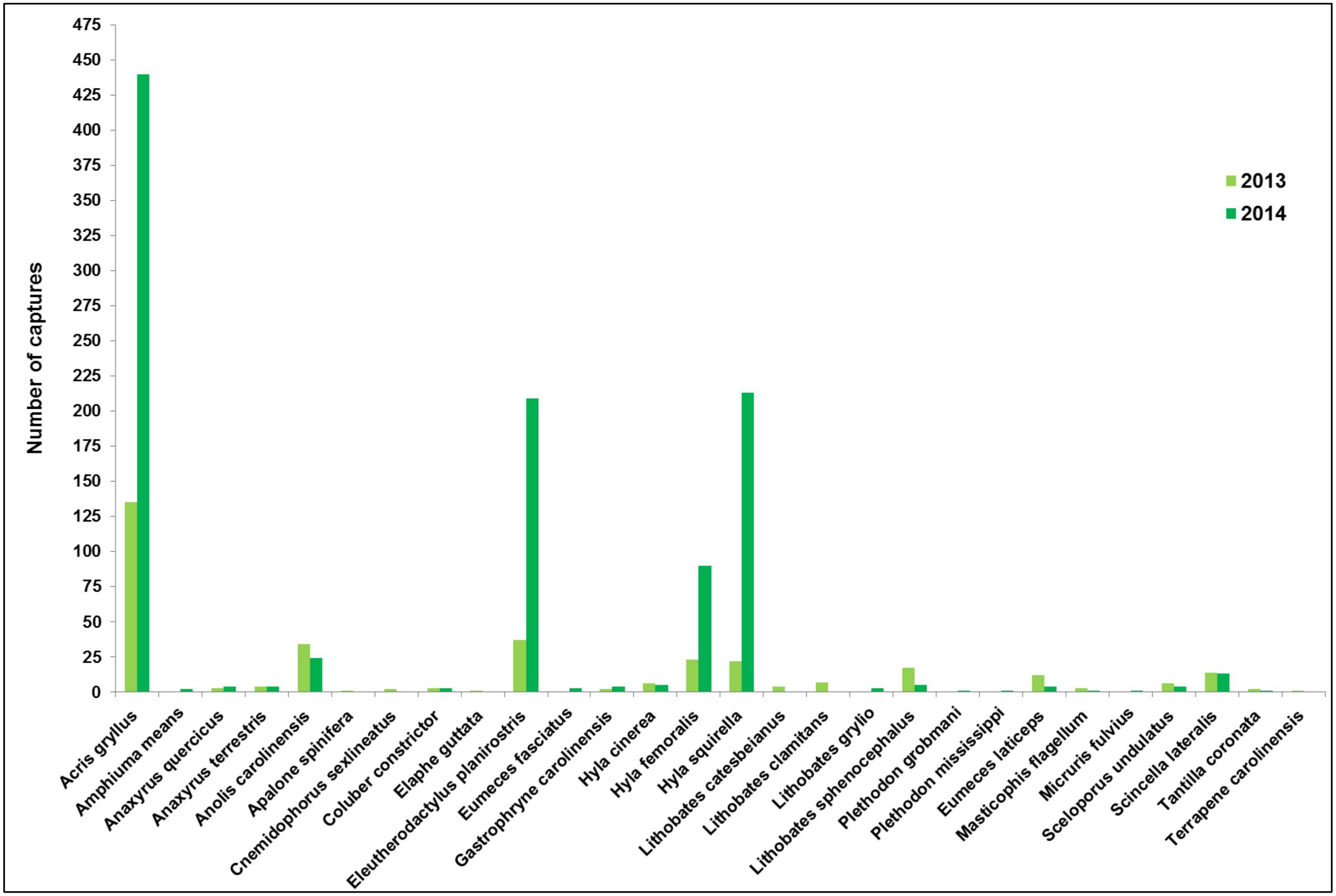

Figure 46. Relative abundance of herpetofauna collected during amphibian and reptile monitoring at Naval Live Oaks, Gulf Islands National Seashore, from October 2011 – September 2013 (Woodman 2013, Woodman and Finney 2014).

We assigned the condition of GUIS herpetofaunal assemblages as good (Table 40). The park had a moderately diverse fauna and the available sample had many of the expected species. The data collected at the time of this report likely represent the majority of the species of GUIS's herpetofaunal assemblages. Recent monitoring protocols did not employ all methods typically used in inventory studies, although they were all included in the inventory conducted by Mohrman and Qualls (2008). Data collected by the GULN are designed to assist in detecting change and are not designed to collect the greatest richness possible, thus we did not consider this reduction in sampling methods to hinder the utility of the datasets in assessing condition. We did not assign a trend to herpetofaunal assemblage condition. The ongoing efforts to monitor park amphibians and reptiles promise to be very useful in assessing temporal trends assemblage health into the future. The quality of the data used the make the assessment was good. The historic inventory and current monitoring efforts were adequately summarized and sufficiently explicit to determine the type and amount of effort used in all locations throughout the park. The data were collected in appropriate habitats but were not fully spatially explicit, and GULN monitoring is within a small restricted region of the park, so the data did not receive a check in the coverage category. Since the data were collected in the last five years and every month for the last two years, they received checks in both temporal categories.

Table 40. The condition of GUIS herpetofaunal assemblages was good. The quality of the data used to make this assessment was good. No trend was assigned to herpetofaunal assemblage condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Herpetofaunal Assemblages		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage	Coverage √
		5 of 6: Good		

<u>Marine Turtles</u>

Sea turtle monitoring at GUIS-FL indicates that sea turtle nest success has remained relatively stable over the last 20 years. Linear regressions did not indicate a trend in either mean number of hatchlings produced or those that were observed entering the Gulf of Mexico. From 1996 – 2012, mean number of hatchling sea turtles exceeded the average number for this time period in seven years (Figure 47). Notably, five of these seven years occurred in the last decade of monitoring, suggesting that sea turtle nesting success is improving in this region. A very similar pattern was observed for mean number of young to make it to Gulf waters, with eight years of above-average numbers of turtles reaching the Gulf, and five of those eight years were within the past decade (Figure 48). These data and analyses indicate that the breeding sea turtle productivity at GUIS-FL is relatively stable and potential improving, likely because of efforts made by park personnel and volunteers are part of the monitoring program. More years of monitoring data may prove useful in assessing these nesting trends.

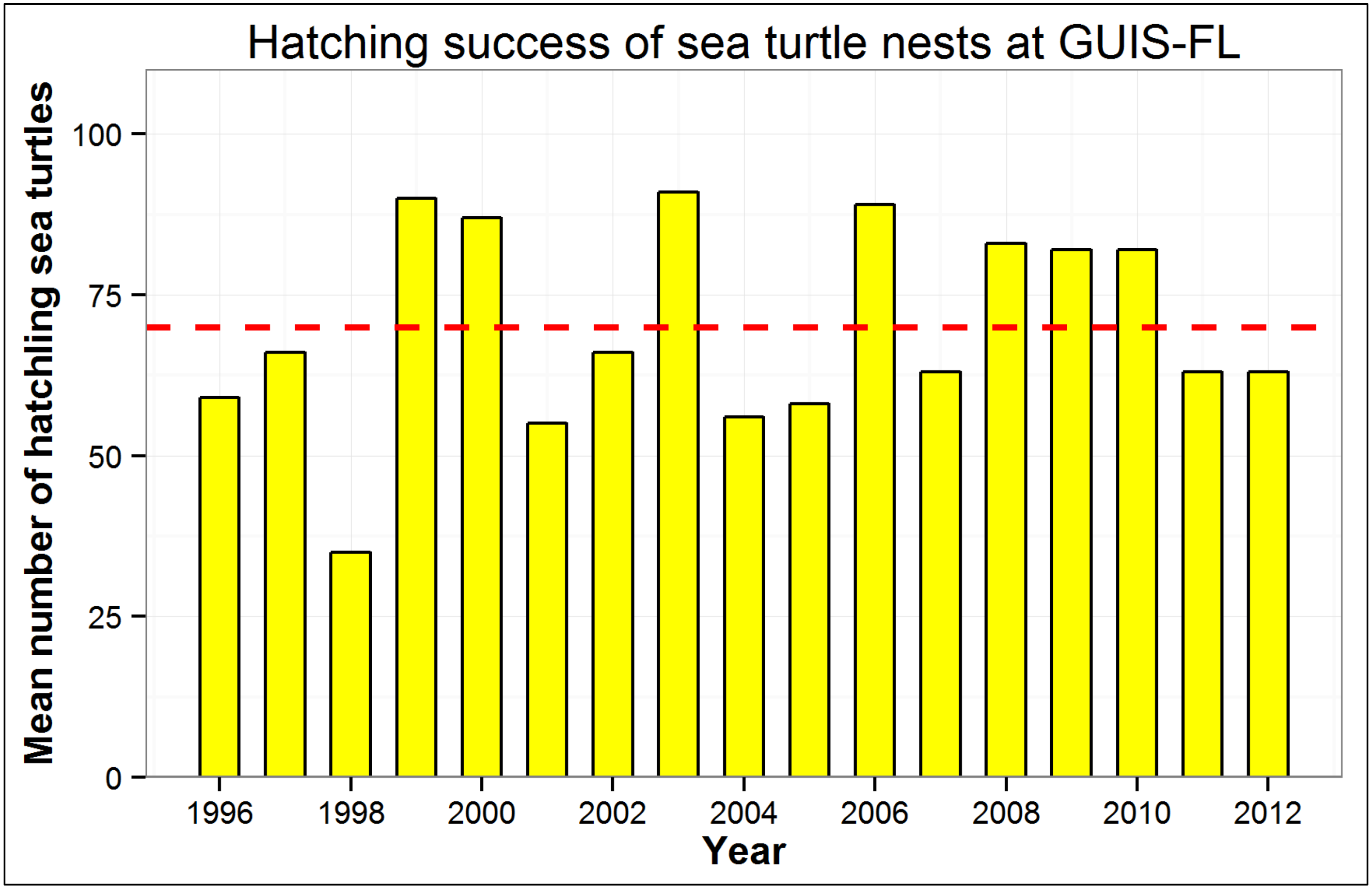

Figure 47. Mean number of hatchling sea turtles observed at GUIS-FL district during 1996 – 2012 monitoring years. Dashed line indicates the average number of hatchling sea turtles for the entire monitoring period [Source data: NPS unpublished data].

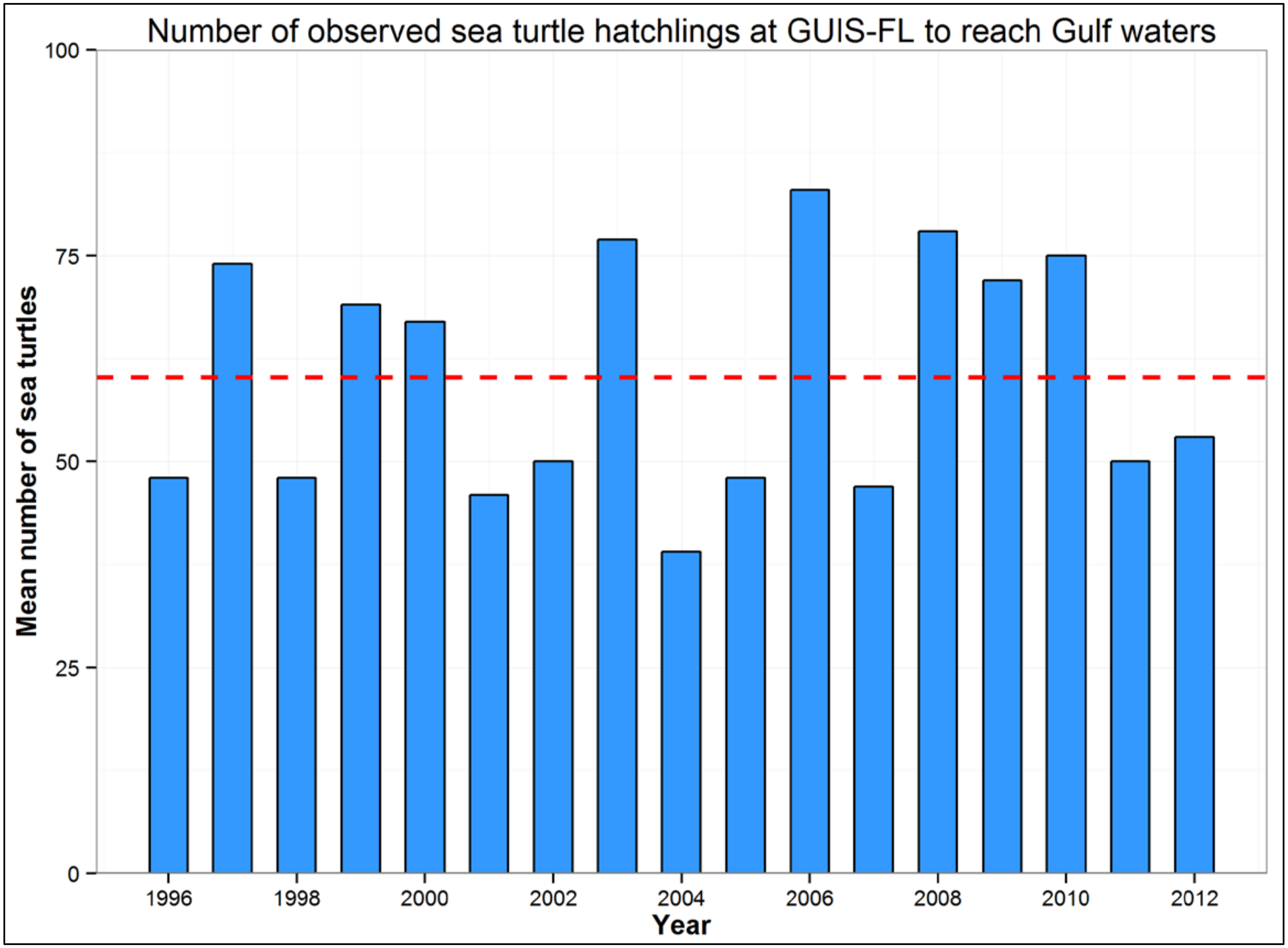

Figure 48. Mean number of hatchling sea turtles observed entering the Gulf of Mexico at GUIS-FL district during 1996-2012 monitoring years. Dashed line indicates the average number of hatchling sea turtles that entered the water for the entire monitoring period [Source data: NPS unpublished data].

Monitoring data of the total number of sea turtle nests at GUIS-FL from 1994 – 2012 suggested mixed results. The comparison of GUIS-FL loggerhead annual population growth rates to the Gulf of Mexico subpopulations implied that GUIS subpopulations are on par with growth rates for Peninsular Florida, and possibly higher than rates found for other subpopulations (Figure 49). Confidence intervals were too wide to detect a significant difference, however. Moreover, given that estimation of population growth based solely on nest counts likely positively biases the results, this estimate is presumably higher than the realized population growth rate for GUIS.

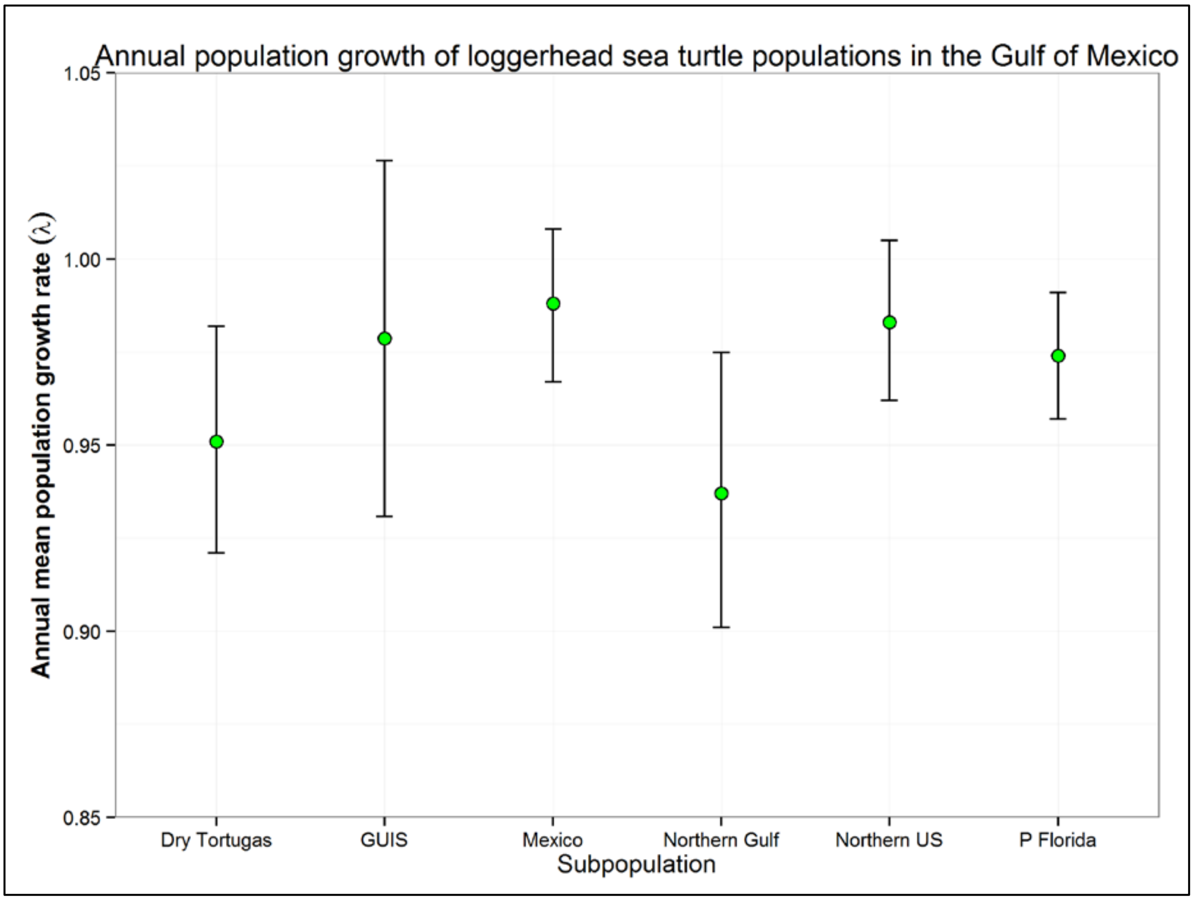

Figure 49. Annual population growth rates (mean and confidence intervals) of loggerhead sea turtles calculated by regressing log-transformed nest counts over time, per NFMS and USFWS (2008) methods [Source data: NFMS and USFWS (2008), NPS unpublished data].

Nest counts for all species of sea turtles at GUIS-FL showed significant declines through 2007 (Figure 50), as was consistent with trends for Peninsular Florida (citation). Although periodicity in total number of nests is natural, data from the monitoring indicated a steady decline until 2008 (Figure 50). However, data from 2008 to present indicated a reversal in this decline, with 2011 recording the maximum number of nests on GUIS-FL beaches since the start of monitoring (Figure 50). While this trend could be an artifact of detection error, the use of standardized protocols and intense monitoring effort likely minimizes issues of detectability. Given that objectives of the Turtle Working Group recovery plans include increases to number of nests in all of the recovery units (NMFS 2014), this recent trend reversal in the total number of nests is encouraging.

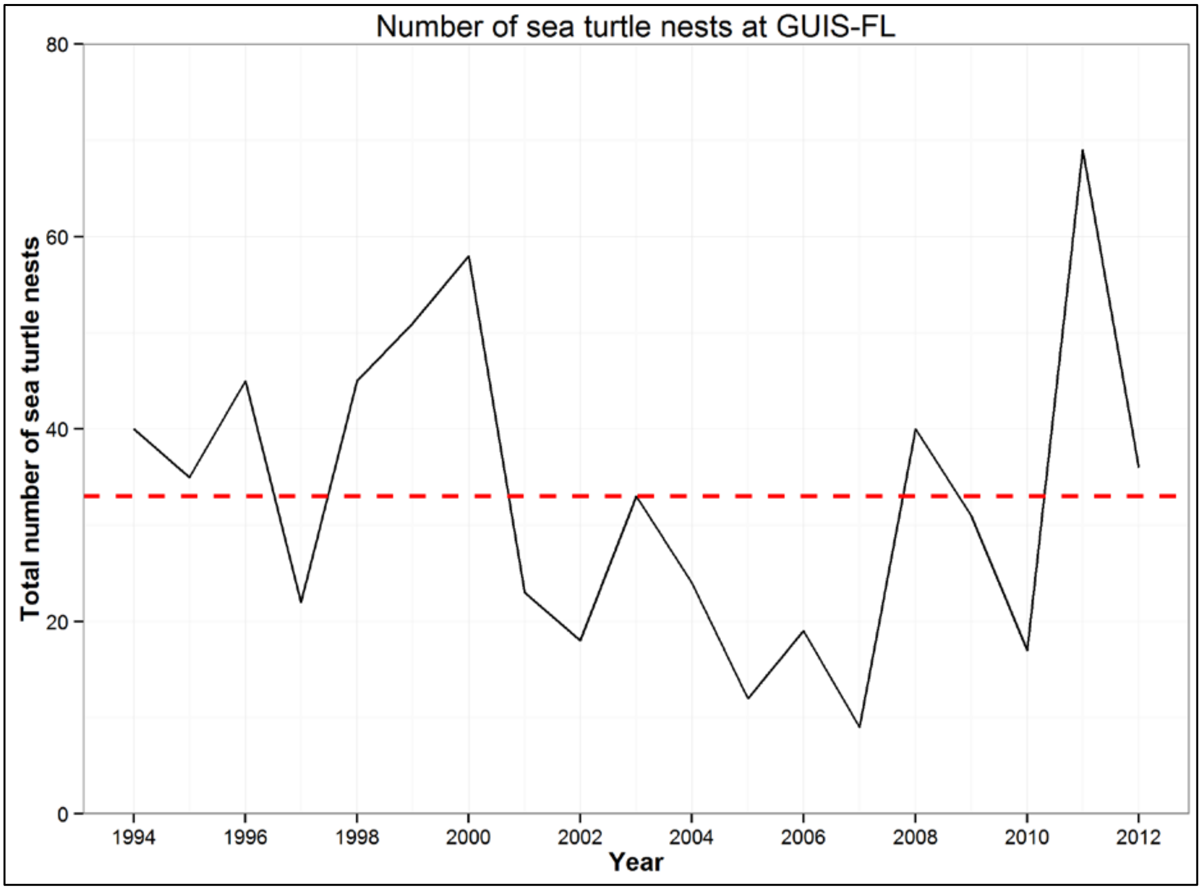

Figure 50. Total number of sea turtle nests detected at GUIS-FL district during 1994 – 2012 monitoring years. Dashed line indicates the average number of sea turtle nests found for the entire monitoring period [Source data: NPS unpublished data].

Climate change may pose one of the biggest threats to marine turtles breeding at GUIS. Increases to ambient air temperature, and consequently sand temperature, may increase egg temperature and accelerate development of young (Limpus et al. 1983, Matsuzawa et al. 2002). Furthermore, marine turtles, like many other reptiles, exhibit temperature-dependent sex determination, with a ratio skewed towards more female offspring at higher temperatures (Standora and Spotila 1985). Higher sand temperatures could also result in massive nesting failure in areas where sea turtles are on the edge of their thermal tolerance. Data from GUIS-FL indicate a decrease in mean incubation length for all nests monitored from 1994-2012 ($\beta = -0.814$, $P = 0.001$). Previous research has validated that incubation duration can serve as a predictor of hatchling sex ratios (Mrosovsky et al. 1999), thus the decrease in mean incubation length could mean that offspring production at GUIS-FL is becoming more skewed toward females. Differences in male and female breeding behavior may offset an increase in skewed sex ratios (Hays et al. 2010), but more targeted studies are needed to determine if increased male visitation to breeding sites is sufficient to maintain populations (Saba et al. 2012). Future monitoring at GUIS-FL should consider evaluating sex ratios of the hatchlings and if proven to be biased towards females, consider mitigation strategies to increase production of male hatchlings (e.g. providing shade to the nests, sprinkling at night, etc.; Jourdan and Fuentes 2013).

We assigned the condition of GUIS marine turtle populations as fair (Table 41). This ranking reflects the fact that the species of turtles nesting at GUIS appear to remain relatively stable, but light pollution remains a major threat. Without large-scale human intervention, including moving of nests to more suitable grounds away from disturbance, most hatchlings would become disoriented and not be able to make it to the Gulf of Mexico. Sea turtle hatching success would likely decline precipitously if nest monitoring ceased.

The data collected at the time of this report likely represent the majority of sea turtle species nesting at GUIS-FL, and adequately capture their nesting success. Given current data on nesting, we cautiously assigned a stable trend to marine turtle population condition. This assessment was based on a qualitative interpretation of the multi-year monitoring program, as well as results of the linear regressions. No obvious increases or decreases were apparent in nest success and a negative trend in number of turtles nesting annually at GUIS has recently reversed. Despite these trends, we recognize that these populations still require significant human intervention in order to persist, and thus this condition assessment should not suggest a change in management strategy.

The data used to make the assessment were very good (Table 41). They were suitable to provide a qualitative understanding of GUIS-FL marine turtle condition, they adequately covered the potential habitat, and they were collected over a number of years, including recent years, with appropriate temporal coverage. Despite the rigorous data collection on patterns of nesting sea turtles for the Gulf of Mexico, data needs to assess the overall health of sea turtle populations are apparent. A better understanding of the population dynamics of these turtles and how monitored demographic parameters influence estimates of fecundity and abundance is critical to properly managing for these endangered and threatened species.

Table 41. The condition of GUIS-FL marine turtle populations was fair. A stable trend was assigned to the marine turtles attribute. The quality of the data used to make this assessment was very good.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Marine Turtles		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage √
		6 of 6: Good		

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4.12 Adjacent Land Use

Adjacent land use is considered a high-priority vital sign in the GULN, as it affects many processes inside the park. Changes outside the park can influence spread of non-native species, impact air and water quality, inhibit viewsheds and soundscapes, and generally increase visitor impact (GULN 2009). These effects may act differently depending on the temporal spatial scale of consideration (Kotliar and Wiens, 1990). One of the most relevant considerations associated with landscape dynamics at GUIS is habitat loss and fragmentation, which, though independent of each other, often happen in association. Complete loss of habitat through anthropogenic conversion is one of the greatest threats to biodiversity (Fahrig 2003, Bender et al. 1998, Turner et al. 2001). Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself. The range of a particular species, for example, may be larger than the protected area of a park unit, in which case the periphery area can play a large role in determining species composition within the park. In addition, changes in the landscape can alter communities over vastly different temporal scales such that effects of a disturbance may not be apparent for many years (Kuussaari et al. 2009). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of both natural and cultural resources in the park (Monahan et al. 2012).

4.12.1 Suitable Habitat

It is often difficult to relate large scale landscape monitoring into succinct and specific land management goals at the level of a park unit. Several studies have attempted to do this by identifying land use change thresholds that generally affect certain changes in ecosystems. In a review of habitat fragmentation and its effects on species populations, Andrén (1994) notes that patch size and isolation become important only when the overall proportion of suitable habitat is low, and offers that this critical threshold occurs when less than 30% suitable habitat is available.

Although it is certainly difficult to assign a single critical proportion for multiple species and ecosystems, such a threshold may serve as a guideline for general changes in the landscape (Monahan et al. 2012). This threshold is similar to the notion of percolation theory in landscape ecology, which states that there is some critical habitat threshold, often identified theoretically as 60%, where habitat occurs at a threshold of connectivity in the landscape (Gardner and Urban 2007). Field studies suggest that this threshold may, in reality, be much lower, and several offer critical thresholds closer to Andrén's (1994) stated proportion of 30% habitat (With and Crist 1995).

4.12.2 NPScape and Landcover Analyses

Context and Relevance

Besides the direct implications of encroachment on park lands, development can also result in unique effects on coastal structure at GUIS. Coastal construction can change the impact of waves and currents, resulting in concentrated forces in unobstructed areas, and new erosional patterns that alter beach and dune structure. For this reason, undeveloped park lands immediately adjacent to developed areas may be disproportionately susceptible to these types of disturbance, especially areas on Perdido Key and Santa Rosa Island along the Gulf (NPS 2007). Furthermore, islands such as those at GUIS represent an inherently different landscape than mainland habitats, as they are delimited by water.

Thus, in general, outside pressures that act on the landcover of these areas may differ from other mainland parks.

Data and Methods

In order to document land use change and provide landscape-scale information, this section uses the suite of data sources and products created by NPScape, which is an ongoing land use monitoring project designed by NPS to help interpret the role of the overall landscape on natural resources in individual park units (NPScape 2012). NPScape allows users to manipulate data and products in such a way to meet their own needs (Monahan et al. 2012). Landscapes are analyzed and defined using various areas of analyses, the main of which are two pre-set park buffer widths of 3 km and 30 km. Other areas of analysis may be substituted where appropriate. Because of GUIS is primarily comprised of barrier islands surrounded by open water, we restricted the analyses to land area only when applicable. NPScape analyses focus on six main landscape measures: landcover, housing, roads, population, pattern, and conservation status. As of this writing, the NPScape project has released its second product development phase for NPS units, which includes updated data sources and areas of analysis from the original release.

NLCD

Table 42 and Figure 51 depict landcover proportions for 2011 National Landcover Dataset (NLCD) produced by the Multi-Resolution Land Characteristics Consortium (MRLC) for level-2 Anderson classifications, which refer to the level of detail in landcover categories (Table 43; Jin et al. 2013, NPS 2014a). For the 2011 NLCD classification, barren land (e.g. beach/dune) represents the largest proportion of landcover type (8.5%) next to open water within the park boundary, followed by herbaceous wetlands (2.3%). Within the 3-km buffer, which incorporates developed coastal mainland, these two classes become low intensity development (3.8%) and barren land (3.2%). Within the broadest landscape scale buffer of 30 km, evergreen forest (12.9%) and woody wetlands (13.0%) are the predominant cover classes next to open water.

As part of the NPScape product, the NLCD classification is also reclassified into two main categories of natural and converted landcover (Table 42; Monahan et al. 2012). The ratio of these categories (converted area/natural area) is referred to as the U-index (O'Neill et al. 1988), and is intended as a direct representation of landscape anthropogenic disturbance. The field of landscape ecology widely supports a critical habitat threshold of 60% to meet connectivity requirements—referred to as percolation theory (Wade et al. 2003, Gardner and Urban 2007, Gross et al. 2009). Empirical data support even lower thresholds (Andrén 1994, With and Crist 1995). The U-Index is one method of assessing the impact of anthropogenic change on an area via converted landcover, as opposed to natural landcover that provides essential habitat (O'Neill et al. 1988). Viewed in this context, the U-Indices representing the ratio of converted to natural habitat for the NLCD classifications are encouraging. The U-index calculated for the park boundary was very low (0.18, Table 43), reflecting a virtually unaltered original landscape. U-indices for the 3-km and 30-km buffers were respectively 0.92 and 0.40 (Table 43), falling at the 0.60 available habitat threshold for the 30-km buffer. At the 3-km buffer, the U-index indicates a highly converted landscape for GUIS. This result is partially because of the percent of open water (81.2%) falling within the 3-km buffer (Table 43), leaving only

19.8% of the buffer (i.e., a small land mass) to be used to calculate the U-index. Yet within this 3-km scale, areas just adjacent to park boundaries are highly developed and unnaturally fragmented (Figure 52). Additionally, the natural landcover category includes multiple vegetation classes, and therefore individual areas of essential habitat likely demonstrate less connectivity than would a U-index using fewer types of natural landcover. Conversely, indices are encouraging for both the park boundary and the 30-km buffer, and are at or below even the conservative theoretical threshold for connectivity.

Table 42. Aggregation of NLCD landcover classes into Anderson level I and II classifications and change product converted and natural categories. [Source: Monahan et al. 2012]

Anderson Level I	Anderson Level II	Natural/Converted
Open Water	Open Water	Natural
	Perennial Ice/Snow	
Developed	Developed Open Space	Converted
	Developed Low Intensity	
	Developed Medium Intensity	
	Developed High Intensity	
Barren/Quarries/Transitional	Barren Land	Natural
	Unconsolidated Shore	
Forest	Deciduous Forest	Natural
	Evergreen Forest	
	Mixed Forest	
Shrub/Scrub	Dwarf Scrub	Natural
	Shrub/Scrub	
Grassland/Herbaceous	Grassland/Herbaceous	Natural
	Sedge/Herbaceous	
	Lichens	
	Moss	
Agriculture	Pasture/Hay	Converted
	Cultivated Agriculture	
Wetlands	Woody Wetlands	Natural
	Emergent Herbaceous Wetlands	

Table 43. Landcover area and proportions of GUIS for each buffer class based on NLCD Anderson level 1 and 2 classifications and the change product, as aggregated by Monahan et al. (2012). Overall calculations of natural versus converted landcover were computed for all classes, excepting Open Water.

NLCD 2006 Anderson Level-2	-30 km buffer- Area (km^2)	-30 km buffer- % Area	-3 km buffer- Area (km^2)	-3 km buffer- % Area	-no buffer- Area (km^2)	-no buffer- % Area
Open Water	5204.5 [a,b]	45.1 [a,b]	1381.6 [a,b]	81.2 [a,b]	444.4 [a,b]	84.2 [a,b]
Developed, Open Space	737.4	6.4	48.0	2.8	2.3	0.4
Developed, Low Intensity	457.7	4.0	64.8 [c]	3.8 [c]	4.4	0.8
Developed, Medium Intensity	167.6	1.5	30.4	1.8	4.5	0.9
Developed, High Intensity	56.2	0.5	9.2	0.5	1.6	0.3
Barren Land	138.4	1.2	54.2 [d]	3.2 [d]	45.1 [c]	8.5 [c]
Deciduous Forest	8.4	0.1	0.2	0.0	0.0	0.0
Evergreen Forest	1493.0 [d]	12.9 [d]	29.0	1.7	4.3	0.8
Mixed Forest	26.1	0.2	0.5	0.0	0.0	0.0
Shrub/Scrub	560.8	4.9	6.5	0.4	1.9	0.4
Herbaceous	333.7	2.9	5.3	0.3	2.3	0.4
Hay/Pasture	191.3	1.7	1.3	0.1	0.1	0.0
Cultivated Crops	201.6	1.7	0.0	0.0	0.0	0.0
Woody Wetlands	1504.0 [c]	13.0 [c]	44.5	2.6	4.9	0.9
Emergent Herbaceous Wetlands	448.6	3.9	26.0	1.5	11.9 [d]	2.3 [d]
Overall Converted	1811.3	28.7	153.7	48.0	12.8	15.4
Overall Natural	4513.1	71.4	166.2	52.0	70.5	84.6
U-Index	**0.40**		**0.92**		**0.18**	

[a] Open water area is an underestimate due to incomplete NLCD classification of offshore area.

[b] Highest proportion of landcover area (also highlighted in darker green).

[c] Second highest proportion of landcover area (also highlighted in medium green).

[d] Third highest proportion of landcover area (also highlighted in lighter green).

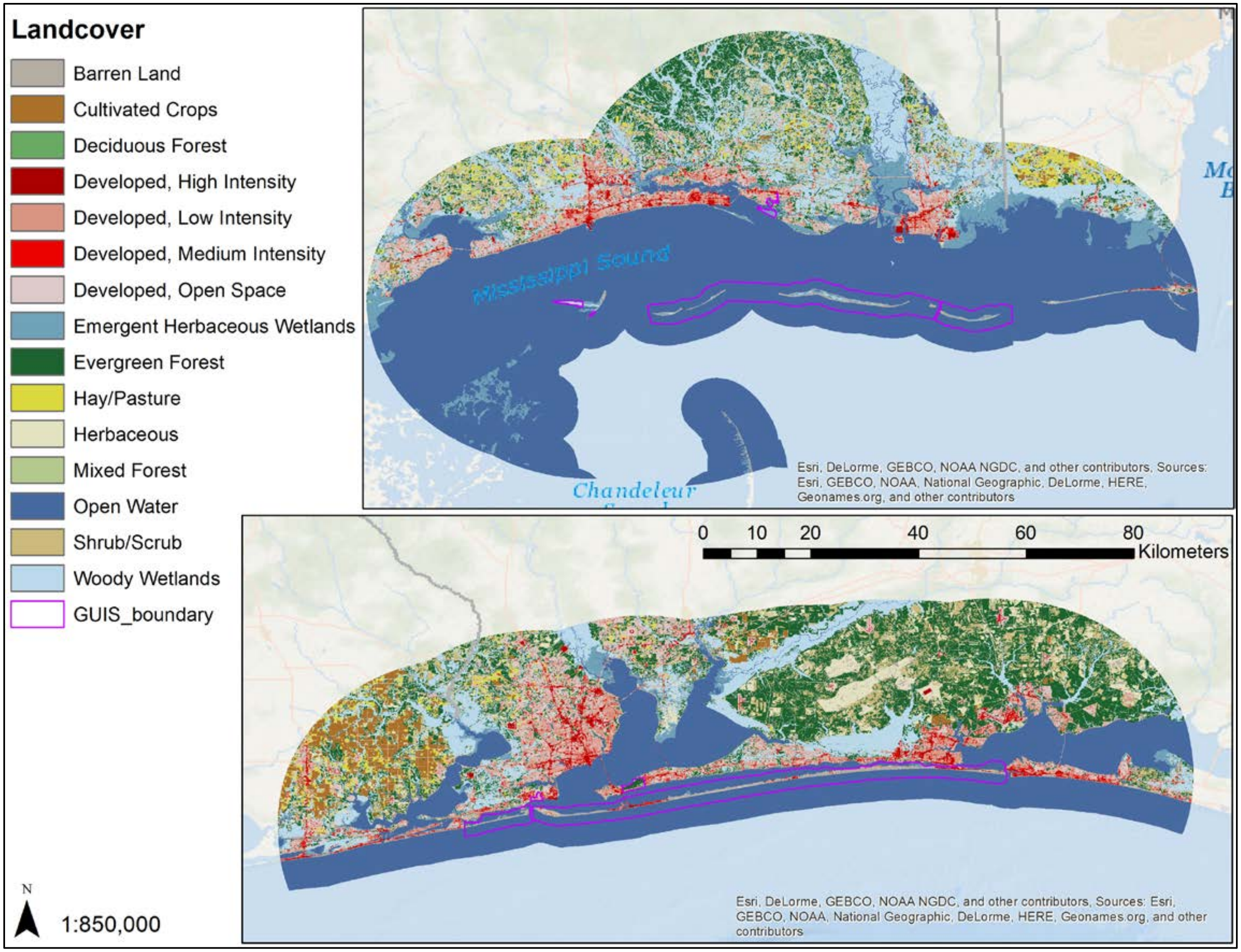


Figure 51. NPScape landcover product showing 2011 NLCD level-2 Anderson classification for GUIS for 30-km buffer.

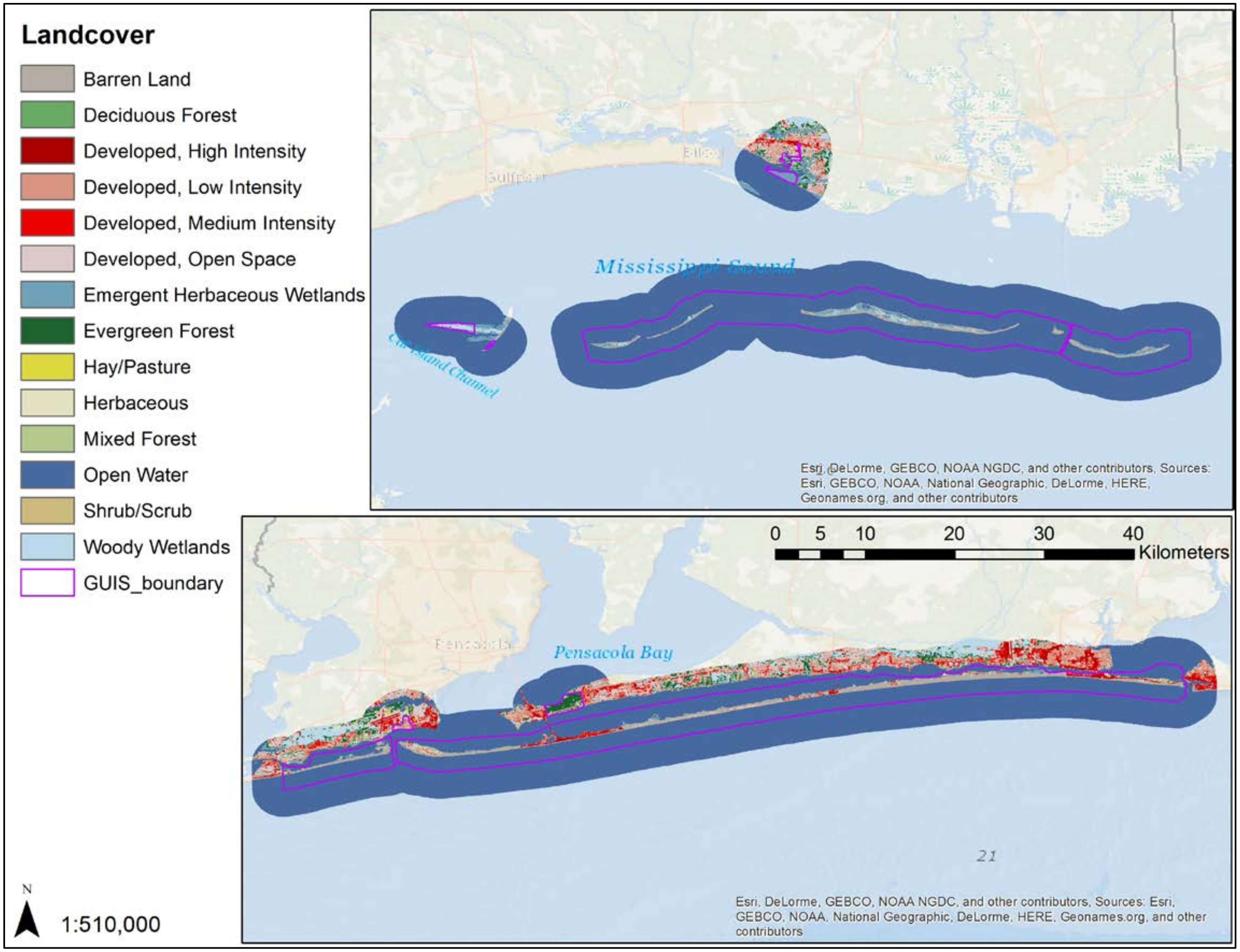


Figure 52. NPScape product showing 2011 NLCD level-2 Anderson classification for GUIS for 3-km buffer.

4.12.3 Impervious Surface

Context and Relevance

One of the most direct influences of anthropogenic conversion on natural areas comes from the amount of impervious surface within a watershed. Highly urbanized areas with large amounts of impervious surface can disrupt hydrologic regimes in several ways, such as increased amounts of flow and decreased infiltration rates. This, in turn, can result in lower water tables, stream flashiness, and intermittent flow (Arnold and Gibbons 1996, Harbor 1994). Decreased water tables in areas with high areas of impervious surface can negatively affect wetland areas maintained by ground water flow. In smaller catchments, storm events can also greatly increase peak flow over a short period of time.

Many studies have outlined threshold levels of impervious surface at different scales for biotic integrity, and like the thresholds of connectivity for essential habitat, these values vary widely. A study in Maryland by Klein (1979) reported a threshold of 12–15% imperviousness before encountering a drop in stream quality, while severe inhibition was generally associated with levels of imperviousness of 30% and above. Lussier et al. (2008) suggest 8–10% as the range of imperviousness, typical of suburban areas, wherein macroinvertebrates are affected. In several Wisconsin watersheds, Wang et al. (2001) measured the effects of urbanization on fish habitat using several biotic and abiotic factors and found 8% imperviousness as a threshold for negative effects. In a review of the effects of impervious cover and urbanization, Paul and Meyer (2001) outlined an even lower threshold for change in geomorphological characteristics, starting at proportions of 2–6%. Other studies have shown even lower thresholds, including impaired stream biota at levels as low as 0.5–2% (King et al. 2011).

Data and Methods

The 2011 NLCD version of impervious surface includes different levels of development intensity in addition to developed open space. (Xian et al. 2011, NPS 2014a). Figure 53 shows weighted impervious area of the 16 adjacent cataloging units within the 30-km buffer. Most of the park land is protected from the hydrological alterations of impervious landcover, because levels of imperviousness on barrier islands in the MS and FL districts are essentially zero or very low. This is primarily because GUIS is surrounded by open water, which is completely permeable. The city of Ocean Springs adjacent to Davis Bayou is an exception, however, as is the highly developed Okaloosa Area on the east end of Santa Rosa Island.

When restricting calculations of impervious surface to only land area at or within the GUIS region, the proportion of impervious surface within park boundaries was at a moderate level (7.1%). However, the proportion of impervious surface within the 3-km buffer increased to 16.6% and then decreased to 5.7% for the 30-km buffer for GUIS. At the 3-km buffer, the level of imperviousness is well above all published thresholds that suggest impacts to surrounding water quality, fish habitat, and stream biota (Klein 1979, Wang et al. 2001, Lussier et al. 2008).

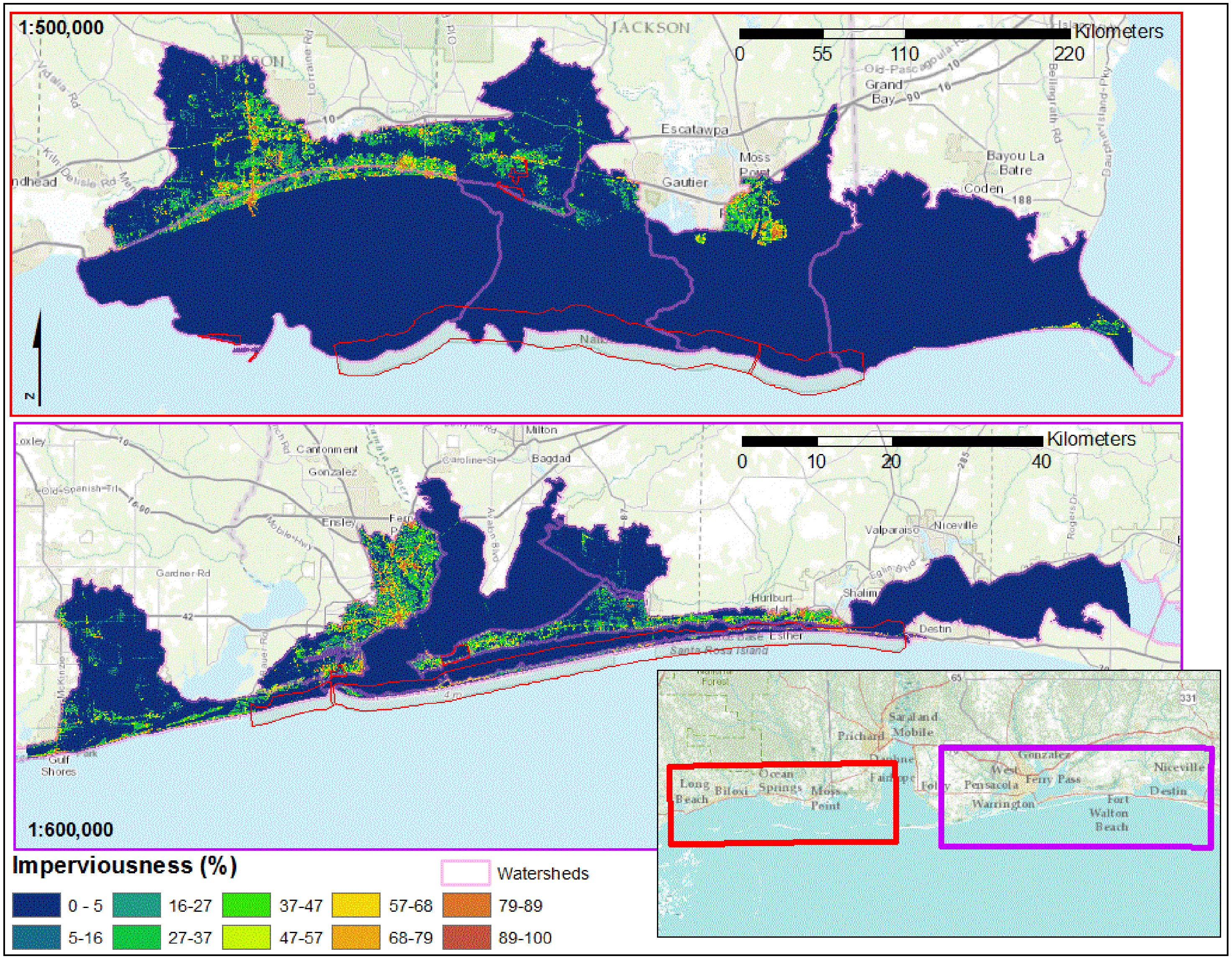


Figure 53. Weighted imperviousness by cataloging unit.

4.12.4 Roads

Context and Relevance

Roads are one of the main drivers of landscape fragmentation (Monahan et al. 2012), and can also disrupt hydrological processes (Jones et al. 1999). Trombulak and Frissell (1999) outline the seven main effects of roads on biotic integrity as follows: (1) construction-related mortality, (2) vehicle mortality, (3) animal behavior modification, (4) alteration of the physical environment, (5) alteration of the chemical environment, (6) spread of exotics, and (7) increased use by humans. Even in relatively undeveloped areas, effects are pervasive and can impact areas several hundred meters beyond the roadside (Forman et al. 2002, Forman, 2000). Monahan et al. (2012) outlines several sources of information documenting the effects of roads on natural resources and terrestrial biodiversity. Two NPScape metrics were calculated to describe the effects of roads in the GUIS vicinity: road density and effective mesh size (NPS 2014b).

Road density, or total road length (km) per area (km^2), can directly affect wildlife populations. Steen and Gibbs (2004) reported altered sex ratios and populations of painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) in high road density sites (>1.5 km km^{-2}) in central New York. Gibbs and Shriver (2002) found that areas with >1 km km^{-2} and >100 vehicles $lane^{-1}$ day^{-1} were likely to contribute to the mortality of land turtles, especially in the eastern U.S. where road densities are higher. Roads are a main contributor to human-caused vertebrate mortality in addition to altered population densities around zones of road avoidance (Parris and Schneider 2009). Exotic plant species can also be introduced and spread via road corridors up to 1 km from the roadside. Traffic exhaust can influence roadside vegetation up to 200 m away (Forman and Alexander 1998).

Effective mesh size refers to road-created contiguous patches greater than 500 m from a road, or the area enclosed by the road network. Girvetz et al. (2007) define this metric as “the average size of the area that an animal placed randomly in the landscape would be able to access without crossing barriers.”

Data and Methods

Each of the road metrics were calculated for the 3-km and 30-km buffer widths and are shown in Table 44. Figure 54 shows road density in the surrounding landscape. As previously noted, the barrier islands are isolated in the landscape and the greatest effect of adjacent roads within the park boundary is evident in Ocean Springs adjacent to Davis Bayou. Figure 55 shows roadless patch areas organized into size classes. No pattern was apparent between different size patches in the MS and FL units. With the exception of bay inlets and water bodies, mainland areas overall represent a highly dissected landscape. When open water is excluded from the analysis, average roadless patch area in the region is much smaller, especially at the 3-km buffer (Table 44).

Table 44. Mean landscape road metrics for GUIS at each buffer width, calculated both with and without the open water class.

Buffer Width	Road Density -km per km2-	Roadless Patches -km2-	
		With open water	Without open water
3 km	4.89	36.67	1.43
30 km	3.09	14.61	1.67

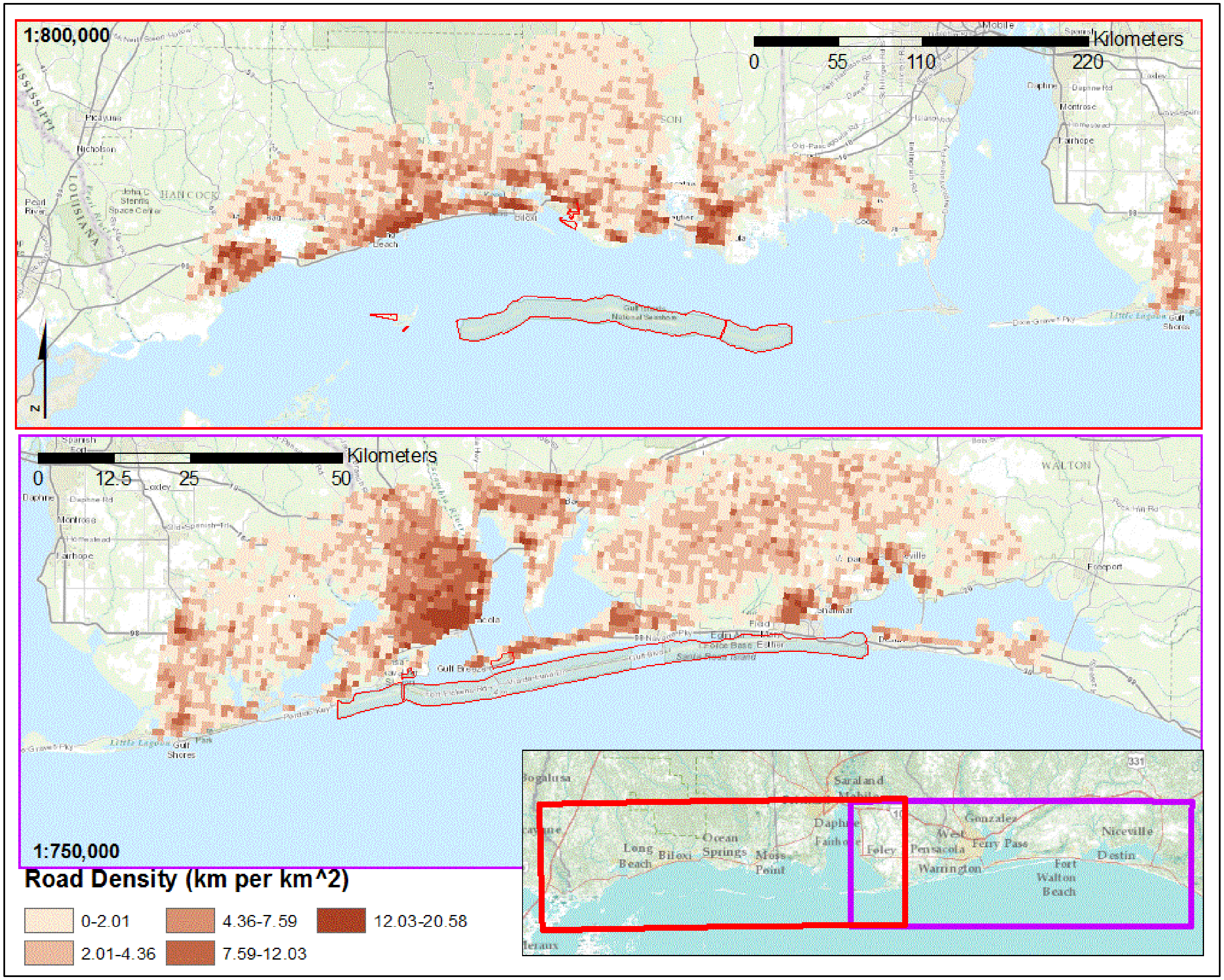


Figure 54. Road density surrounding GUIS within a 30-km buffer width.

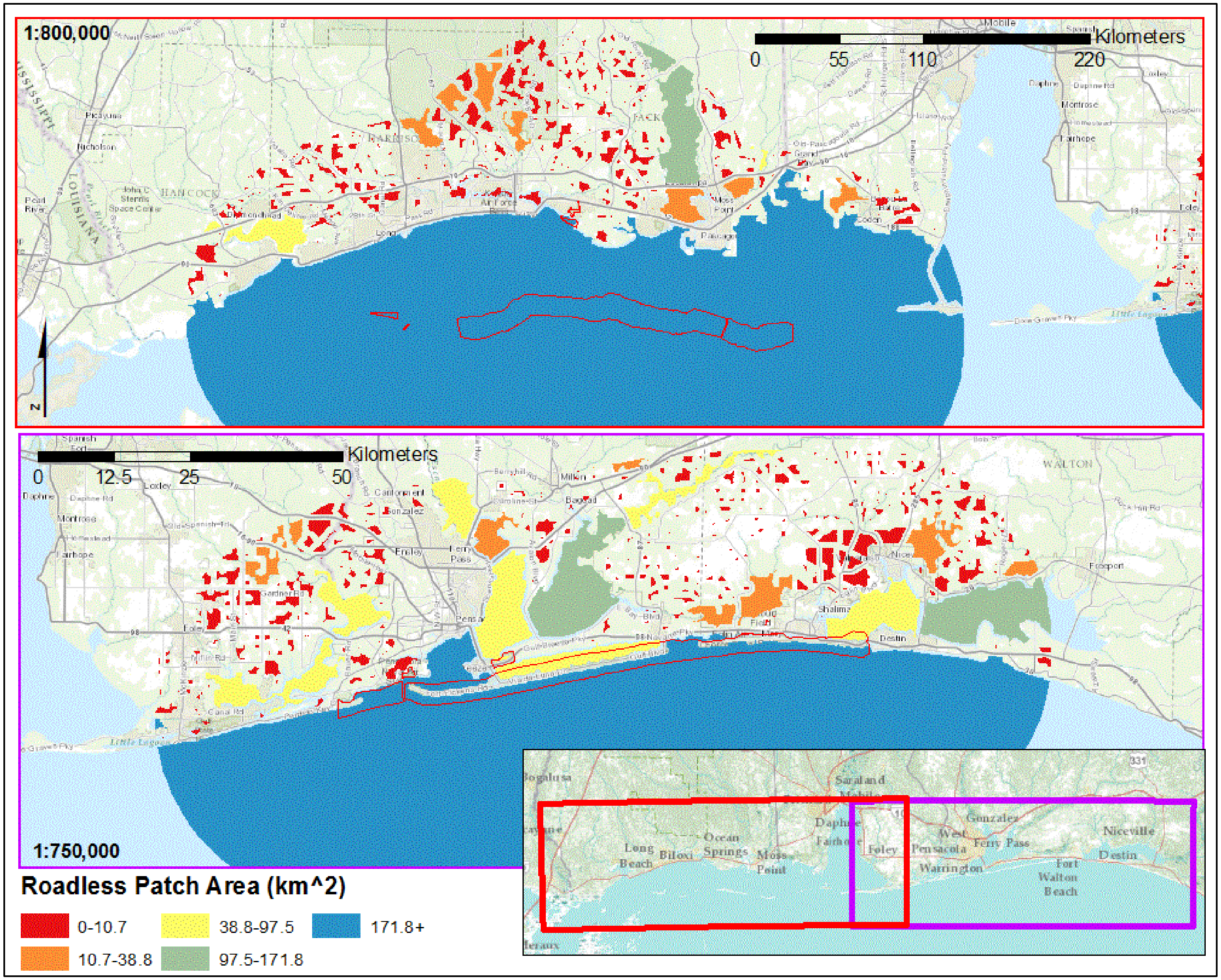


Figure 55. Roadless patch area surrounding GUIS within a 30-km buffer width.

4.12.5 Population and Housing

Context and Relevance

Population pressure can provide an approximation of how much impact humans have on the landscape in a given area. Areas of high population have been shown to contribute to the decline of terrestrial biodiversity (Kerr and Curie 1995), which is usually the result of habitat loss stemming from land use conversion (Wilcove 1998). Monahan et al. (2012) provide a comprehensive reference list for the effects of population pressure on different taxa, and outline the following six main effects resulting from human settlements: (1) loss of habitat to structures and non-habitat cover types, (2) habitat fragmentation, (3) resource consumption, (4) disturbance by people and their animals (pets, livestock, etc.), (5) vegetation modification, and (6) light and noise pollution. In general, they offer that the impact of human settlements is far-reaching, and certain species are more sensitive to humans and their effects than others.

Data and Methods

NPScape products developed to analyze trends include population and housing density maps created at the county level from U.S. Census Bureau data. Monahan et al. (2012) report that housing density is closely correlated with population density, but as Liu et al. (2003) point out, housing density also accounts for changing household demographics, such as average household size and per capita consumption.

Figure 56 shows population density by census block group. Population centers around Biloxi and Ocean Springs, MS and Pensacola, FL are visible as the most densely populated areas, with the latter area showing a slightly greater amount of sprawl. Population data for counties within the 30-km buffer show mostly steady increases during the period 1790 to 1990 (Figure 57), with especially rapid increases in population in Mobile (AL) and Escambia Counties, which correspond respectively to population centers Mobile, AL and Pensacola, FL.

The NPScape product for housing density divides areas into 13 development classes, plotted for six decades from 1950 and 2000. Figure 58 depicts the change in proportion represented by each housing density class within the 30-km buffer for GUIS. There is a visible decrease in proportions of least density housing classes over this time period, which appears consistent with the findings of Hansen et al. (2005), who noted that beginning in 1950, exurban development (6-25 units km^{-2}) became the fastest-growing form of land use in the US.

Monahan et al. (2012) acknowledge that housing density might be most useful when used as a constituent of other, more complex and ecologically-relevant landscape metrics. Although population and housing also correlate highly with other more ecologically-relevant factors like impervious surface and road density, their ease of use makes them valid for comparisons across scales and regions. To that end, NPScape also produced a plot of population densities for all areas of NPScape analyses in 2000 (Figure 59), which shows a range of densities that are highly skewed towards more densely populated landscapes. Although GUIS appears low along the overall scale, the density of the landscape (124.9 individuals km^{-2}) appears higher than the median among parks, suggesting somewhat exceptional population pressure.

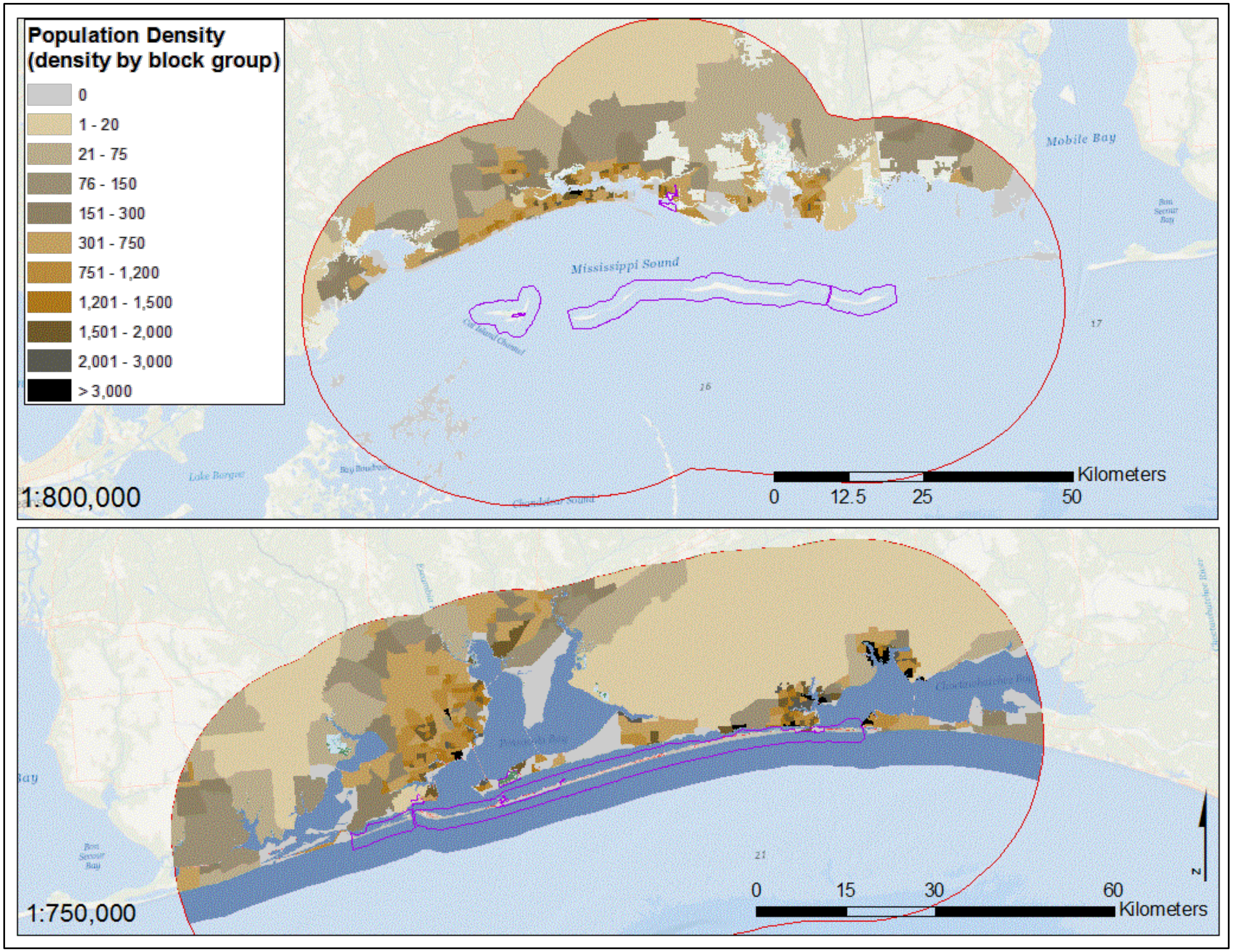


Figure 56. Population density surrounding GUIS in 2010.

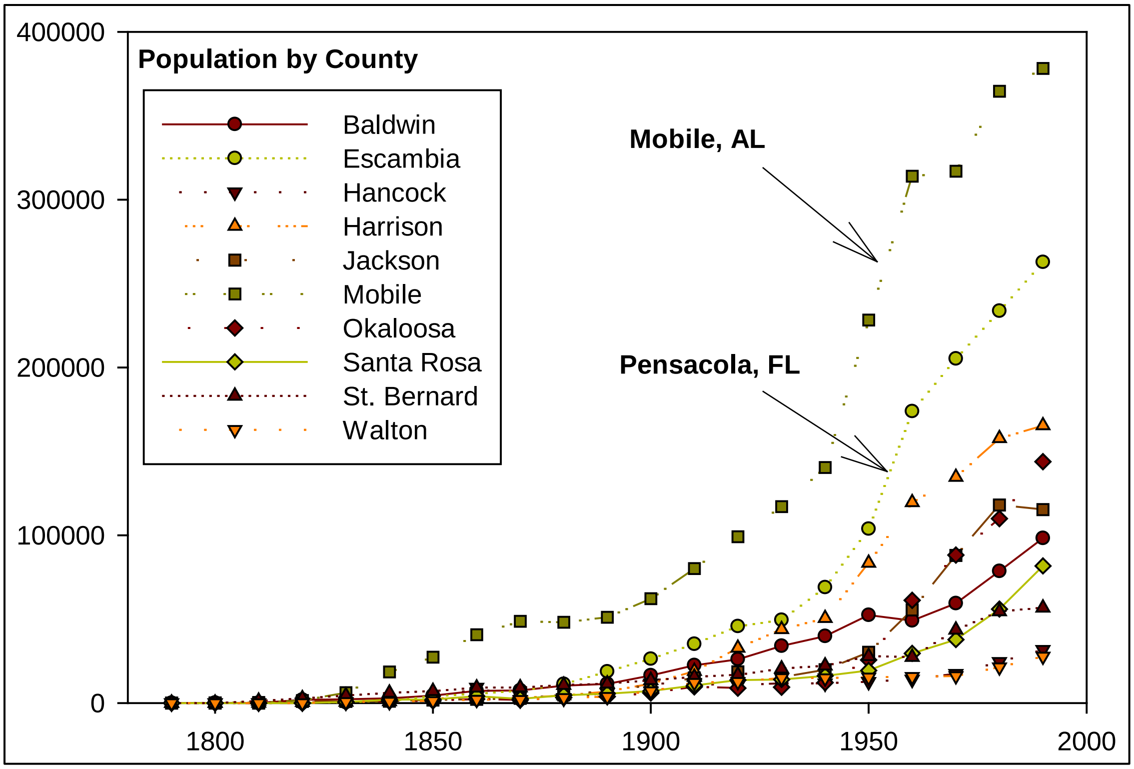


Figure 57. Population for counties within the GUIS landscape for the period 1790 to 1990.

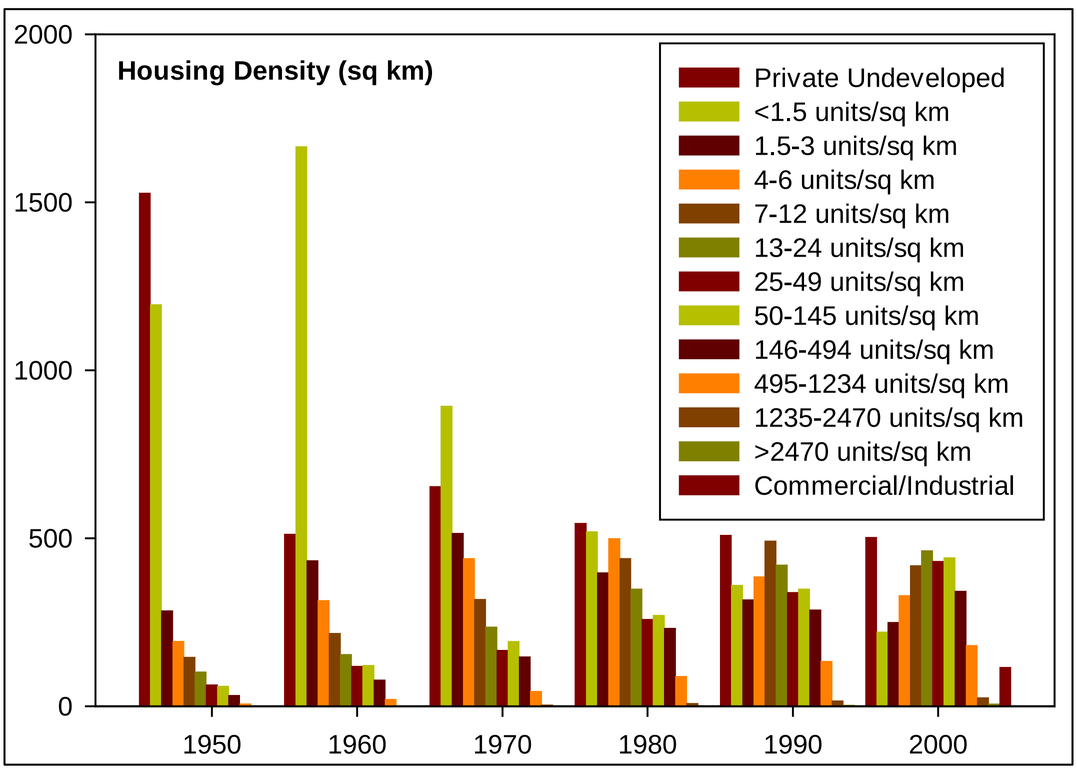


Figure 58. Housing density classes by decade for the GUIS landscape from 1950 to 2000.

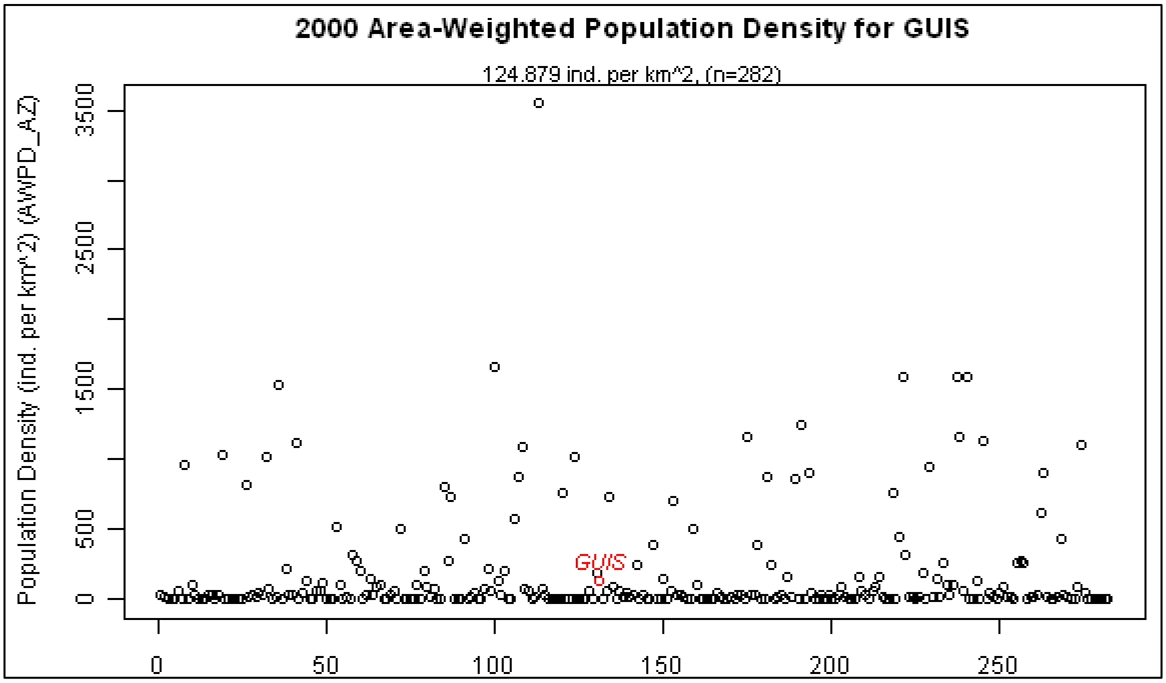


Figure 59. NPScape (Phase 1) product showing population density of GUIS in 2000 relative to landscapes of other NPS units.

4.12.6 Pattern

Context and Relevance

The configuration and composition of landcover types and specific landscape features play a large role in the dynamics of ecological processes, and more specifically, can play a role in determining the species assemblages found in a certain area (Turner 1989). Natural landcover and the amount of suitable habitat it provides is one component of species composition, though it is also affected by the arrangement of that habitat. These two components of landcover are often confounded, and thus individual effects are difficult to identify (Trzcinski et al. 1999). However, landscape metrics intended to describe general patterns of landcover can be helpful in determining which features strongly influence patterns of species distribution. Monahan et al. (2012) pointed out that some of the most commonly used landscape metrics include patch size and shape, connectivity, core habitat, and edge habitat.

The geographic position of GUIS makes the importance of these NPScape metrics harder to realize. As the park is primarily comprised of barrier islands, the surrounding matrix of aquatic habitat is likely uninhabitable for species that typically exist on land (Andrén 1994). Thus, the effects of pattern may be more pronounced for GUIS within the park boundary, but less relevant at the 3-km and 30-km buffers. We have included these analyses to maintain consistency with previous NRCA conducted for the GULN.

Edge

Edges are the boundary between two different patch types and as certain landcover types are divided and become more patchy, edge density increases, which can affect numerous ecological processes.

Conditions at patch edges may be intermediate of those at adjacent patches, such that a forested edge next to an open patch may be hotter, drier, windier, and lighter than interior forest conditions, which may in turn also result in different species composition (Ries et al. 2004). Edges may also alter species composition by facilitating the transport of pollen or other organisms into interior habitat area. Species interactions may also be affected by the presence of edges. Numerous studies report that birds undergo increased rates of parasitism and predation within edge habitats and demonstrate greater rates of nest success in larger patches (Paton 1994, Donovan et al. 1997, Andrén and Angelstem 1988).

Patch Size

The patch size of individual landcover types is closely related to the effects of edges on organism interactions and resource movement. A larger patch will usually contain more core habitat than a smaller patch size, meaning that the habitat is not subject to the higher predation rates and other outcomes associated with edge effects. The amount of edge, however, can increase or decrease depending on the shape of the patch, which lends usefulness to the perimeter (edge) to area ratio—another commonly used landscape metric. However, as Andrén (1994) notes, patch size is also confounded by fragmentation, and thus each of these three metrics (patch size, edge, and fragmentation) must be considered in tandem.

<u>Data and Methods</u>

The NPScape project constructed maps of core habitat using edge widths of 30 m and 150 m. In an assessment of microclimate variation along forest edges, Matlack (1993) found that edge effects for several factors were detectable at sites of eastern deciduous forest up to 50 m from the edge. Another estimate by Ranney (1977) suggested that edge habitats extend from 5 m up to 20 m and may affect a variety of factors including tree species composition, primary productivity, structure and development, animal activity, and propagule dispersal. Both of the above estimates most closely match the 30 m edge width used in the NPScape product describing forest habitat types shown in Figure 60. In this product, landscape elements are classified according to morphological spatial pattern analysis (MSPA) types, which include core, islet, perforation, edge, bridge, branch, loop and background. Table 45 shows definitions for these features and their respective contribution for each of the classes using a 30 m edge definition.

As GUIS is largely comprised of barrier islands and interior forested areas are limited, edge effects may be acting at a different scale than those found by Ranney (1977) and Matlack (1993). Thus, metrics below are primarily included to maintain consistency with other NRCA reports of the region. However, since the Gulf of Mexico is the eventual outflow for watersheds within the 30-km buffer region, it is possible that changes to forest pattern may affect water quality downstream at the outflow (thereby affecting the park). At GUIS, core forest area is higher in the Florida landscape, especially around Eglin Air Force Base, while in MS much of the forest is dissected, except for that in the DeSoto National Forest. On the whole, core forest is higher in the 30-km buffer (34.1%) than the 3-km buffer (15.5%), though a much smaller proportion of the smaller buffer is forested – only 22.5 square kilometers, all of which occurs on the mainland. NPScape also developed a forest density product based on moving window analysis, shown in Figure 61. While similar to the MSPA, it describes broader-scale forest patterns using seven density classes: intact, interior, dominant, transitional, patchy, and rare (Riitters 2011).

Table 45. Morphological spatial pattern analysis (MSPA) class types used by NPScape for GUIS forest patches at 30 km, 3 km, and no buffer widths. Edge width was defined as 30 m.

		-30 km buffer-		-3 km buffer-	
Pattern type	**Definition**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Core	Interior forest area not influenced by edge	1,461.2	34.1	3.5	15.5
Islet	Patch too small to contain core area	75.9	1.8	3.3	14.7
Perforated	Edge (linear) internal to core forest type (30 km)	20.6	0.5	--	--
Edge	Perimeter (linear) of forest patch (30 km)	517.6	12.1	7.3	32.4
Bridge	Non-core (linear) forest connecting disjunct core patches	81.4	1.9	1.1	4.7
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	190.4	4.4	5.9	26.3
Background	Non-forested enclosure	1754	41.0	--	--
Loop	Non-core (linear) forest connected to same forest patch at both ends	178.7	4.2	1.4	6.4

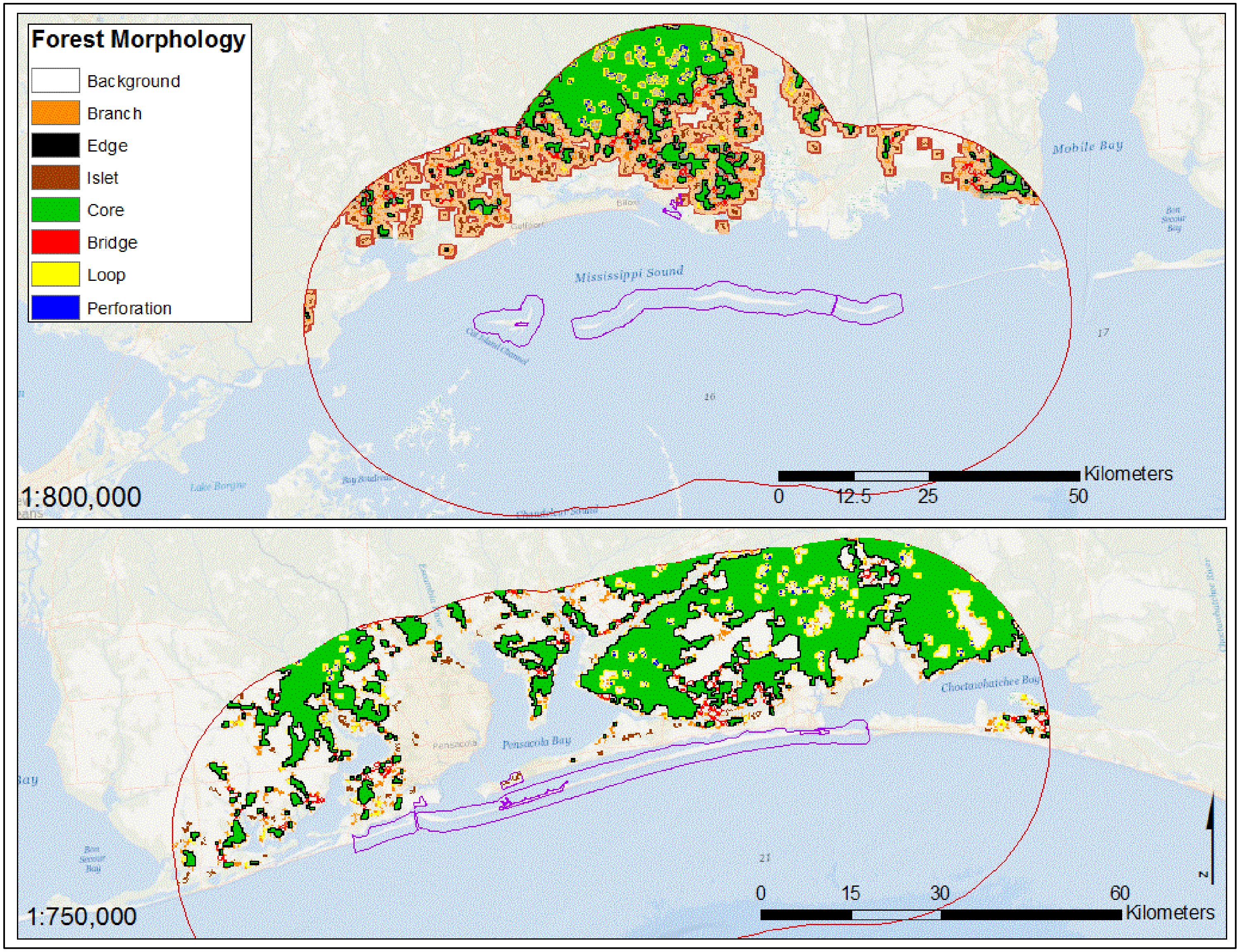


Figure 60. Forest morphology resulting from morphological spatial pattern analysis (MSPA).

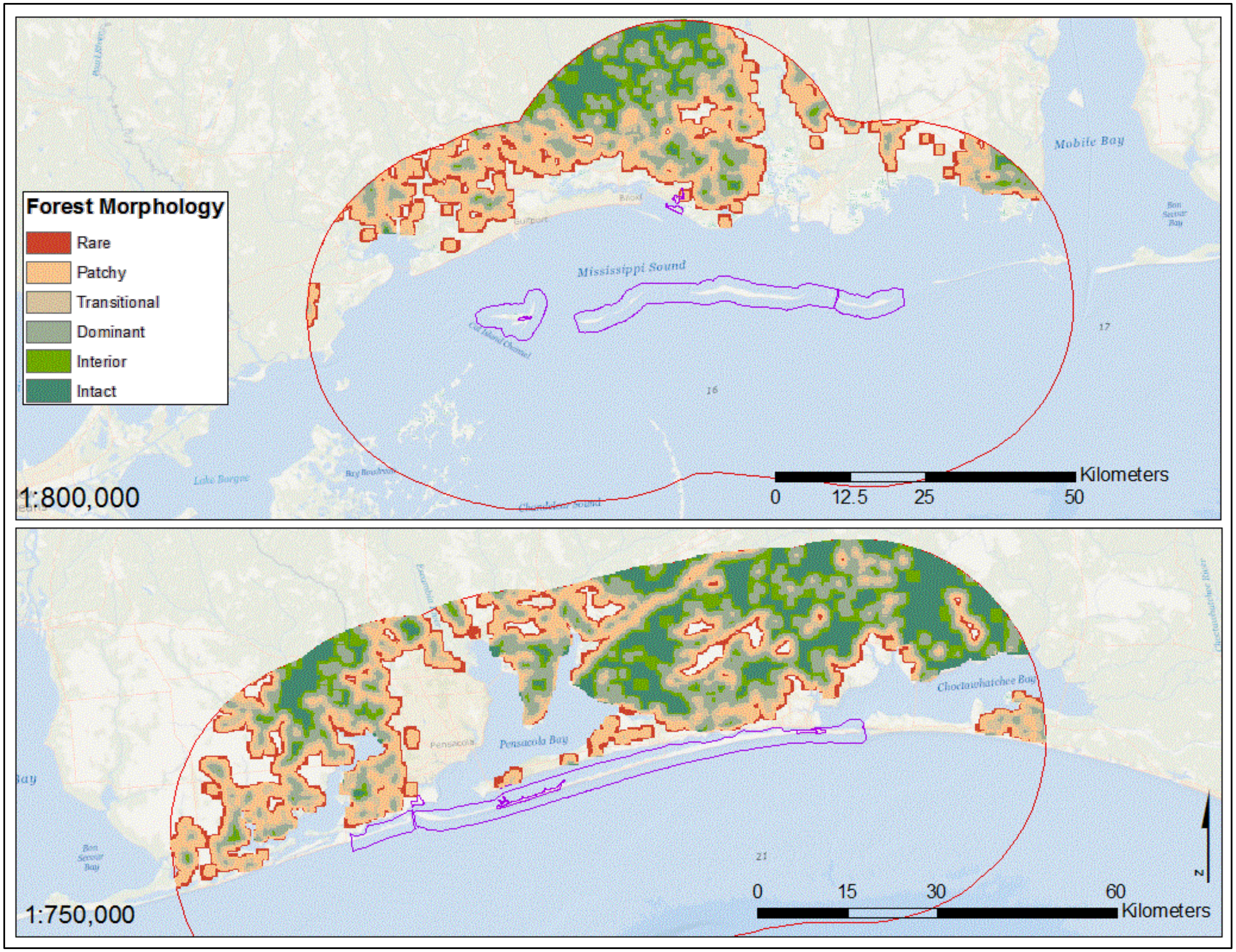


Figure 61. NPScape product showing forest density for GUIS with a 30-km buffer.

4.12.7 Conservation Status

Context and Relevance

The creation of protected areas is generally considered a safeguard against habitat loss and degradation. These protected areas, in combination with other landscape factors posing a risk to natural resources, can help prioritize areas for further conservation at fairly large scales.

Similar to the variety of thresholds discussed for critical habitat, impervious surface, and road density, Monahan et al. (2012) point out that conservation goals describing ideal amounts of protected area also vary widely. As Soulé and Sanjayan (1998) note, preservation goals such as 10% to 12% protected area are posed frequently for their political appeal (Rodrigues and Gaston, 2001; Svancara et al. 2005), but such low proportions, when considered in the context of species-area relationships, are grossly inadequate and could translate into a loss of up to 50% of species richness. A review of evidence-based studies outlining conservation targets by Svancara et al. (2005) yielded an average threshold of 41.6 % ± 7.7 % (n = 33), wherein the studies considered were ones whose "research results…identified thresholds at which habitat fragmentation or loss has deleterious effects on the feature of interest." This threshold was much higher than the average threshold value of 13.3 % ± 2.7% for policy-based targets that were based in little or no scientific grounding. Although it is difficult to identify a one-size-fits-all threshold, evidence-based examples express the need for much higher thresholds of protected area, as well as those that individually target the biological needs of communities, species, and ecosystems of the area in question (Svancara et al. 2005). It is likely that islands, such as GUIS, harbor more protection at lower thresholds, as they may not be similarly affected by the protected status of the mainland areas.

Conservation Risk Index

Besides thresholds of protection, Monahan et al. (2012) outline out a metric described by Hoekstra et al. (2005) called the Conservation Risk Index (CRI). Similar to the U-Index calculated as the ratio of natural to converted land, the CRI is calculated as the ratio of converted area to protected area. Hoekstra et al. (2005) outlines thresholds for the index based on the IUCN Red List species, such that areas where habitat conversion is > 20% and CRI > 2 is classified as vulnerable; those with conversion > 40% and CRI > 10 as endangered; and those with conversion > 50% and CRI > 25 as critically endangered. Although originally created as a means to gauge human alteration threats to regional biomes, the CRI is still a useful reference for the GUIS landscape, despite its much finer park-level scale of analysis.

Data and Methods

To this end, the Gap Analysis Program (GAP) has developed the Protected Areas Database (PAD) of the U.S., based primarily on the prescribed management of individual land units rather than ownership (USGS 2010). This database ranks protected areas on a scale of 1 (highest protection) to 4 (lowest protection) depending on the relative degree of biodiversity protection offered by each unit (Monahan et al. 2012). GAP status levels 1 and 2 are commonly used to define protected areas, treating them separately from the 3 and 4 statuses that are typically reserved for "multiple-use" areas, such as those managed by the Bureau of Land Management

(BLM) or the USFS. Most NPS units are classified at level-1 or 2, though some of the cultural parks are level 3 (Monahan et al. 2012). GUIS is classified with level-2 protection.

Between the two GUIS units, more protected land falls within the mainland area of the MS landscape, including several level 1 protected areas such as the Mississippi Sandhill Crane and Grand Bay National Wildlife Refuges (NWR), the Grand Bay Savanna Tract, and the disjunct Breton NWR. In the Florida unit, only a portion of the small Lillian Swamp Mitigation Area is classified with level 1 protection. The largest area of protected land in either unit is the De Soto National Forest, which comprises over 156,000 ha in two main disjunct units in Alabama, of which approximately 35,000 ha occur inside the 30-km buffer of GUIS. Overall, 3266 km^2, or roughly 19% of the landscape, are classified as level 1, 2, or 3 by the GAP PAD within the 30-km landscape, not including portions of contiguous areas that fall outside the buffer (Figure 62).

According to Monahan et al. (2012), the CRI is typically applied using GAP level-1 and 2 protected areas. Using these criteria, the ratio of converted land (from NLCD) to protected land is 1.69, combined with the proportion of converted area (40%), would place the landscape in the lowest risk vulnerable CRI designation.

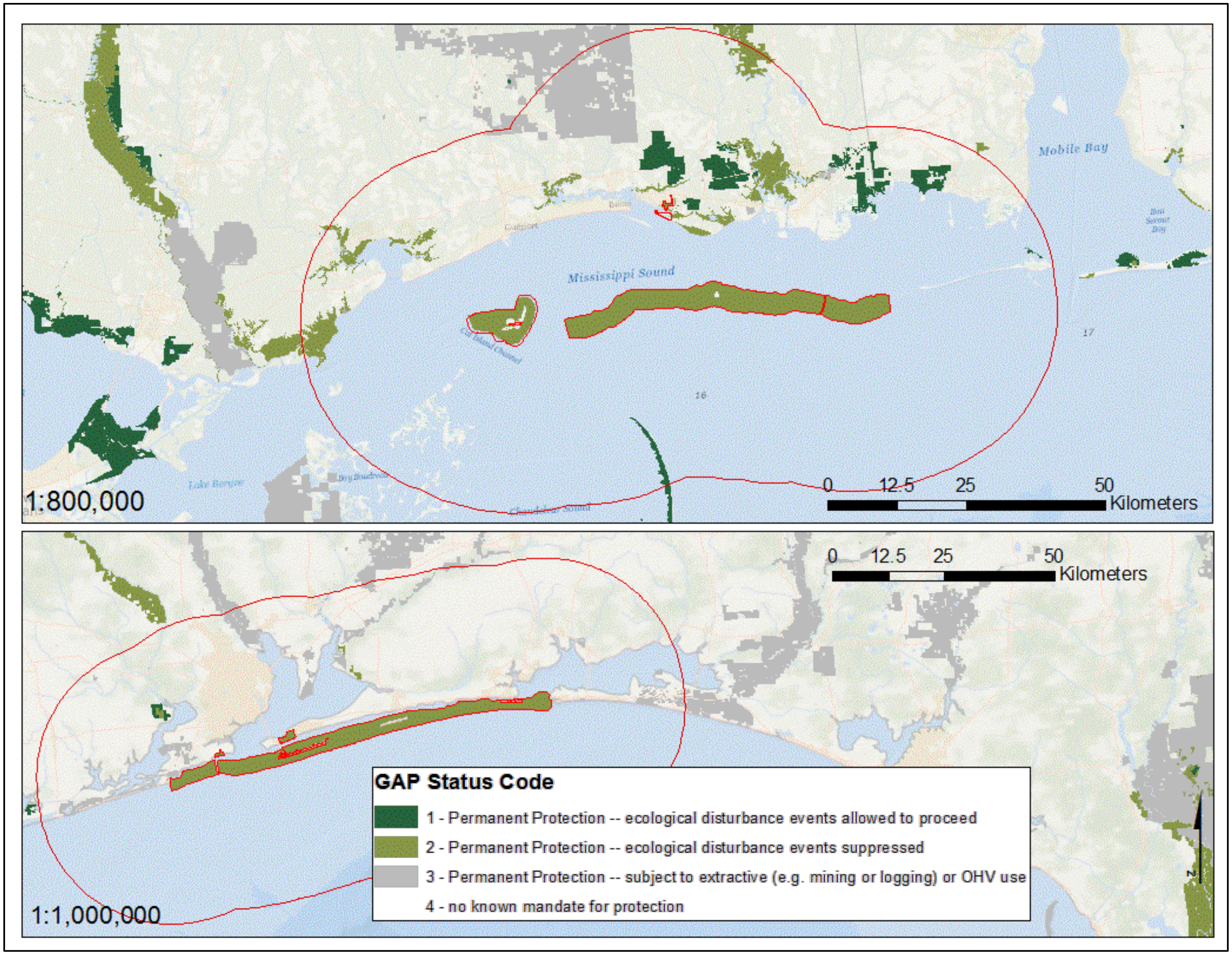


Figure 62. The GAP Protected Areas Database assigns land areas with classifications on a scale of 1 to 4 to describe level of conservation.

4.12.8 Landscape Synthesis and Considerations

The NPScape effort that directs much of the landscape dynamics section was designed to outline specific measureable features that would reflect resource conditions within individual park units. Because most of the park units lie within larger ecosystems and interact with resources far beyond their own boundaries, multiple spatial scales were considered for analysis. In an effort to strike a balance between reproducibility among park units and relevancy across scales and regions, analysis was divided among five main landscape aspects: landcover, roads, population and housing, pattern, and conservation status. Below, each of these five sections is summarized with challenges describing the landscape aspect, followed by the main points pertaining to GUIS for each section.

<u>Landcover</u>

Analyses of landcover was based mainly on data from the National Landcover Dataset (NLCD), which includes several datasets based on 2006 imagery, including the Anderson level-2 landcover classification, imperviousness, and natural vs. converted area.

For each of the three data sources, a U-index representing the ratio of converted to natural area was derived. Most of the park and surrounding landscape at GUIS is open water, followed by open duneland characteristic of the barrier islands. In the immediate mainland landscape, low-intensity development is the most common, while the broader landscape also consists of coniferous forest and wetland.

- A U-index representing the ratio of converted to natural area was calculated, resulting in indices of 0.18, 0.92, and 0.40 for the park boundary, 3-km buffer, and 30-km buffer, respectively.

<u>Impervious Surface</u>

Amount of impervious surface area is another metric used often in landcover analyses. Perhaps more than several other aspects of landscape change and analysis, the effects of imperviousness has a large literature base attempting to relate specific thresholds to changes in water and habitat quality. Some of the lowest thresholds are those potentially resulting in geomorphological changes—mainly stream channel enlargement and destabilization—at levels of 2% to 6% imperviousness (Paul and Meyer, 2001). Klein (1979) suggests that thresholds such as 12% to 15% imperviousness are where stream water quality begins to degrade, while Lussier et al. (2008) suggests that at 8% imperviousness stream biota are affected in suburban watersheds. King et al. (2011) offer the lowest threshold, suggesting that some biota is affected at levels of 0.5 to 2.0% imperviousness.

- Imperviousness proportions are high at GUIS within the 3-km buffer width (16.6%). Nearly the entire park is characterized by 0 to 5% imperviousness range, but this is largely due to the amount of open water surrounding the park.

- Of the hydrologic cataloging units that include the 30-km landscape of GUIS, impervious levels are higher in the surrounding MS mainland, especially in and between the cities of Gulfport and Biloxi. Pascagoula, MS and Pensacola, FL are also hotspots.

Roads

NPScape used three main metrics to describe the effects of roads in the landscape: road density, distance to road, and effective mesh size. Mean rates of traffic were not used in the NPScape assessment but were used to estimate land turtle mortality by Gibbs and Shriver (2002), who suggested a road density threshold at 1.0 km km^{-2}. Steen and Gibbs (2004) offered another threshold of 1.5 km km^{-2} for a central NY study involving aquatic turtles, while Forman and Alexander (2002) suggest that 0.6 km km^{-2} represents the upper threshold of a landscape that can support large predators such as wolves and mountain lions. In addition, Frair et al. (2008) found a low threshold between 0.25 km km^{-2} and 0.50 km km^{-2} where elk populations in Alberta, Canada began to be affected, while effect on the landscape reached a saturation level at 1.6 km km^{-2}. Lin (2006) offers that the average road density throughout the U.S. is 0.67 km km^{-2}.

- Metrics indicate a consistently strong influence of road presence closer to the park within the 3-km buffer (4.9 km km^{-2}), though there is not a large difference in road density compared to the 30-km scale.

- Road density at the broader landscape scale is 3.1 km km^{-2}, which may influence wildlife populations, including those found in the park.

- The effective mesh size (average roadless patch area) for the 3-km and 30-km buffer widths are 36.6 km^2 and 46.1km^2, respectively. The large mean effective mesh size is primarily because of the park's position relative to large waterbodies without road intersections. When open water areas are excluded from the analysis, roadless patch areas are much smaller, 1.43 km^2 and 1.67 km^2 for 3-km and 30-km buffers, respectively.

- In general, mainland areas represent a highly dissected landscape.

Population and Housing

These two measures are highly related and correlate well with other landscape metrics like impervious surface and road density. It is particularly difficult to identify thresholds of housing or population densities that affect specific changes in the landscape. However, Monahan et al. (2012) point out several studies that make general observations regarding influences of human settlements on plants and vertebrates. In a study involving exurban areas in Colorado, for example, Maestas et al. (2002) found (1) increased richness and cover of non-native plant species, (2) increased densities of human-commensal bird species such as Blue Jays (*Cyanocitta cristata*) and Black-billed Magpies (*Pica hudsonia*), and (3) high densities of domestic dogs and cats. In a study in California, Merenlender et al. (2009) found lower proportions of temperate migrant bird species in exurban and suburban areas, and in dense housing areas found higher relative abundances of urban adapter species like American Crow (*Corvus brachyrhynchos*) and Turkey Vulture (*Cathartes aura*).

- Biloxi, MS, Pensacola, FL, and Mobile, AL are the main population centers in the GUIS landscape. Escambia and Mobile counties, associated with the latter two cities, have shown the most rapid increases in since 1900.

- Since 1950, the lowest density housing classes (<1.5 units km^{-2}) appear to show a decreasing trend within the 30-km buffer. The higher density classes (>7 units km^{-2}) appear to be increasing, while the remaining classes show no real trend.

- Although GUIS appears low along the overall scale, the density of the landscape (124.9 individuals km^{-2}) appears higher than the median among parks, suggesting somewhat exceptional population pressure.

Pattern

Landscape pattern can affect availability of resources to different species assemblages and as a result may dictate their abundance. Much of the natural landscape within the GUIS vicinity is forested, with exceptions such as the Blackbelt Prairie region. Fragmentation of natural landcover introduces an edge effect on the remaining habitat, which influences ecological processes. Besides edge effect, the remaining patch size is a fundamental landscape metric that addresses habitat availability. Although the effect of patch size is dependent on scale, both spatially and temporally, small patches often offer insufficient levels of habitat to maintain high levels of biodiversity. Although GUIS is primarily composed of islands that are inherently small patches, patchiness of the surrounding landscape may be important to the sustainability of animal populations for the park.

- Core forested area is higher in the Florida 30-km buffer scale than the more highly dissected MS 30-km buffer.

- Core forest proportion is higher in the overall 30-km landscape than the more immediate 3-km periphery, indicating more intense conversion from growth and development of coastal population centers.

Conservation Status

The NPScape assessment used the Protected Areas Database (PAD) created by the Gap Analysis Program (GAP) to analyze the amounted of protected area within the vicinity of GUIS. Protected areas are assigned a rating of 1 to 4 corresponding to a descending scale of the amount of biodiversity protection offered by each land unit. As a guideline, 10% to 12% protected area is often posed as a minimum objective (Rodrigues and Gaston 2001), though a review of evidence-based studies by Svancara et al. (2005) yielded a considerably higher suggested minimum threshold of 41.6% ± 7.7 %.

An additional guideline for amount protected area outlined by Monahan et al. (2012) is the Conservation Risk Index (CRI), which is the ratio of converted to protected area. Hoekstra et al. (2005) describes thresholds based on the amount of habitat conversion and the CRI, beginning with minimal threat when habitat conversion reaches 20% and CRI > 2.

- According to the CRI calculation, GUIS falls in the least critical of categories – vulnerable.

- There are over 3266 km^2 of level 1, 2, or 3 protected area within the landscape, or roughly 19% of the landscape.

- The CRI risk rating, according to Hoekstra et al. (2005), is defined by a combination of 1) converted land within a landscape and 2) the ratio of converted to protected area. Although the proportion of the landscape converted (NLCD) is high (40%), the CRI indicates that for every 1.8 km^2 of converted land, there is minimally 1 km^2 protected land to counter the conversion for the region.

4.12.9 Landscape Conclusions

Adjacent land use for GUIS was assessed using NPScape analysis products supplied by the National Park Service. NPScape analyses explored landscape changes and conditions that were expected to affect natural resources within GUIS. These analyses were conducted within GUIS's boundaries and at two broader scales (3-km and 30-km buffers around the park). Six general categories of NPScape analyses were used in this NRCA. These were: 1) landcover proportion, 2) impervious surfaces, 3) roads, 4) population and housing, 5) landcover pattern, and 6) conservation status. Multiple metrics were presented and discussed within each of these categories. Combined, these findings provide an overall view of key landscape attributes of GUIS and the immediately surrounding area. Several aspects of adjacent land use are considered capable of supporting a functioning ecosystem with high quality natural resources. Conversely, several landscape attributes indicate increasing pressures from urbanization and human development that are expected to negatively impact the park's natural resources. These points are discussed in more detail below.

Each of the five components assessed by NPScape presents a slightly different outlook on the state of the landscape within the vicinity of GUIS. Considered individually, there are several aspects of the analysis that are encouraging, such as:

1) Because much of GUIS is open water and barrier islands, these areas are naturally offered greater protection from development influences that tend to dissect the landscape and affect wildlife populations.

2) Pattern metrics reveal large areas of core forest throughout the larger GUIS landscape, especially surrounding the Florida unit.

3) Calculation of the CRI places GUIS in the vulnerable category– the designation representing the lowest threat of human alteration to the region according to amount of protected area and rates of land conversion.

Other aspects of the analysis are less encouraging, especially when viewed across all buffer classes:

1) Mainland areas of the park are adjacent to urban centers, resulting in high rates of imperviousness, road dissection, and converted land proportion.

2) At the intermediate landscape scale, mainland portions of GUIS are surrounded by highly developed and converted lands.

3) Despite the fact that much of GUIS is open water, the population density of the 30-km landscape is still relatively high compared to other NPS units, indicating that coastal urban centers likely pose a large threat to the ecological integrity of the mainland areas of GUIS.

4) The complexity of the landscape change vital sign makes it difficult to summarize into a single condition status ranking. By combining NPScape aspects into key points as above, it becomes easier to pick out the most significant landscape qualities. As a result, landscape change is assigned an overall ranking of "fair" (Table 46).

The data quality is very good (Table 46), fulfilling all six of the data quality checks. The NPScape data products provide a comprehensive analysis at a landscape scale using a variety of relevant metrics. Data used in this assessment represents the second phase of NPScape, which includes updates to data sources and processing methods since the original release (Table 47). No trend was assigned to this attribute.

Table 46. The condition status for adjacent land use at GUIS was fair, with no trend assigned. The data quality for this ranking was very good, attaining six out of six data quality checks.

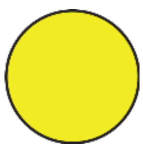
Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Adjacent Land Use		Relevancy √	Proximity √	Currency √
		Sufficiency √	Coverage √	Coverage √
		6 of 6: Good		

Table 47. List of NPScape metric categories and data source currency.

Category	Data Sources	Year
Landcover	National Landcover Dataset (NLCD)	2006
Roads	Tele Atlas streets Database	2005
Population and Housing	US Census Bureau, Waisanen and Bliss, Theobald	2000 2002 2005
Pattern	North American Landcover Dataset (NALC)	2005
Conservation Status	Protected Areas Database (PAD) Version 1.2	2011

4.12.10 Literature Cited

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Chapter 5 Conclusions

5.1 Summary

Gulf Islands National Seashore supports a variety of valuable natural resources. Natural resources for this report were chosen based on data availability, park-level importance, and vital sign status. The level of data completeness varied greatly among natural resource categories, though this aspect was considered independently when assigning condition rankings.

Based on a review of available ecological information at GUIS, we addressed the current condition of 15 natural resource attributes in the park. All attributes were assessed at the park level. Overall, natural resource conditions at GUIS were ranked as 15.8% good, 36.8% fair, and 21.1% poor. The remaining 26.3% were not ranked.

Summarized into broad categories the percentages of condition rankings were:

- Air and Climate (three attributes)—33.3% Fair, 33.3% Poor, 33.3% Not ranked
- Geology and Soils (one attribute, ranked by park district)—50% Fair, 50% Poor
- Water (one attribute, ranked by park district)—50% Good, 50% Poor
- Biological Integrity (nine attributes, two ranked by park district)—18.2% Good, 36.4% Fair, 9% Poor, 36.4% Not ranked
- Landscapes (one attribute)—100% Fair

We assigned trends to natural resource attribute conditions where appropriate. Because long-term data were relatively uncommon, trends were not assessed for most attributes. Overall, natural resource condition trends at GUIS were 15.8% improving, 10.5% stable, and 0% declining. The remaining 73.7% were not assigned a trend.

Summarized into broad categories the condition trend assignments were:

- Air and Climate (three attributes)—67% Improving, 33% Not ranked
- Geology and Soils (one attribute, ranked by park district)—100% Not ranked
- Water (one attribute, ranked by park district)—%100 Not ranked
- Biological Integrity (nine attributes, two ranked by park district)—9% Improving, 18% Stable, 73% Not ranked
- Landscapes (one attribute)—100% Not ranked

We also characterized the quality of data used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Data quality was assessed for all instances where data existed. Therefore, all individual condition assessments were assigned a data quality ranking, regardless of whether the attribute was assigned a condition rank. Overall, natural resource attribute data quality was ranked 31.6% very good, 21.1% good, 31.6% fair, 10.5% marginal, and 5.2% poor.

Summarized into broad categories the data quality rankings were:

- Air and Climate (three attributes)—67% Very Good, 33% Fair
- Geology and Soils (one attribute, ranked by park district)— 100% Fair
- Water (one attribute, ranked by park district)—50% Good, 50% Fair
- Biological Integrity (nine attributes, two ranked by park district)—27.3% Very Good, 27.3% Good, 18.2% Fair, 18.2% Marginal, 9% Poor
- Landscapes (one attribute)—100% Very Good

5.2 Discussion by Category

5.2.1 Air Quality

Air quality is an important issue in the GUIS region and appears to be currently improving. There was a reasonable dataset on park ozone concentration, including data collected within the park, interpolated values, and regional data collected at nearby cities. Values of the 4^{th} highest maximum 8-hour ozone concentration varied slightly among these sources, but were generally within the range of moderate concern.

Atmospheric deposition is a regional concern and sources of pollution exist near the park. Wet and dry deposition of nitrogen oxides and sulfur dioxides was relatively high at regional monitoring stations, and mean values for the last five years were above the NPS ARD threshold for posing threats to ecosystem health. Data suggest that deposition rates are improving in the region. Managing regional air pollution sources and climate conditions are outside the scope of the park’s management, although park management may work to mitigate the impacts of these large-scale forces. No major data gaps were identified for these resources, although wet deposition may vary at a relatively fine scale, suggesting that monitoring within the park may provide useful information not available from regional stations.

5.2.2 Weather and Climate

Data from weather stations around GUIS show long-term trends in temperature and precipitation. Three Cooperative Observer Program (COOP) stations in Pascagoula and Biloxi, MS, and Niceville, FL collected data from as early as 1894. Two Remote Automated Weather Stations (RAWS) have collected wind speed data along with other meteorological observations within the park since 2003. Based on the available monitoring periods, all three COOP stations showed increasing linear trends for precipitation, which is consistent with overall trends observed in the Gulf region over the last few decades. Niceville and Pascagoula showed significantly decreasing linear trends for mean annual temperatures and for mean minimum and maximum temperatures, respectively. Most of the temperature records, however, showed no trend. Wind data was also available from both RAWS during its monitoring period. Although much data was available for long-term monitoring in and around GUIS, we find it inappropriate to assign a valuation, and thus no condition is assigned for weather and climate.

5.2.3 Coastal Dynamics

GUIS consists of seven barrier islands, five in Mississippi (Cat Island, Sand Island, Ship Island, Horn Island, and Petit Bois Island) and two in Florida (Perdido Key and Santa Rosa Island). Mississippi islands are 7 to 15 miles from the mainland, whereas Florida islands are no more than 2 miles from the mainland. These islands also differ in their geomorphological stability (Pendleton et al. 2004), with Mississippi islands historically experiencing greater instability regarding shoreline change. However, all of these barrier islands are undergoing constant change due to coastal processes and are especially vulnerable to storm events. Sea-level rise is a critical management issue for GUIS, especially because of its influence on the park’s geomorphology and habitat composition. The nearest long-term monitoring stations for sea-level rise are the Pensacola, FL and Dauphin Island, AL stations, which are part of the NOAA's National Water Level Observation Network (NWLON; NOAA 2013). Data from these stations indicate a rate of sea-level rise at 2.19 (+/- 0.23) mm yr^{-1} and 3.19 (+/- 0.65) mm yr^{-1}, respectively. Results of an assessment conducted by USGS indicated that GUIS-MS may be more vulnerable to predicted sea-level rise than GUIS-FL. In light of this assessment, the GULN has identified the geomorphology of GUIS as needing monitoring of this resource. Elevation data for the coast collected using LiDAR will be used to determine shoreline position change, collected on a 3–5 year timespan. These data have not been formally summarized or analyzed as of the writing of this report. In addition to sea level rise, sediment transport, dredging and placement of dredge materials on park property (Perdido Key), and active restoration projects all influence the coastal dynamics of GUIS. Although the 2015 implementation of the Mississippi Coastal Improvement Program (MsCIP) is mainly intended to mitigate the effects of hurricane/storm damage, control erosion, and salt water intrusion for the coastal mainland, the barrier island restoration portion of the project will hopefully mitigate these effects and restore sediment volume to the barrier islands of GUIS-MS (L. York personal communication). Data were not sufficient to assess a trend of the coastal dynamics for GUIS, but were possible for shoreline change at both districts, and indicated that the shorelines of two GUIS-FL units are experiencing increased erosion and four barrier islands of GUIS-MS are undergoing increasing land area lost. Data gathered using GULN monitoring protocols will undoubtedly help with future assessments of this resource for the entire park.

5.2.4 Hydrology and Water Quality

Previous monitoring has shown mostly low concentrations of bacterial contamination in the vicinity of both FL and MS districts. Elevated iron concentrations were observed in the early 2000s in the FL district. Measures of nutrient enrichment around the same time period showed higher sources of N in the MS district than the FL district, representing enriched waters mainly around Davis Bayou, especially for total phosphorous. Current monitoring is conducted near East Ship Island in the MS district and at three locations in GUIS-FL on a rotating basis. Monitoring in FL has shown mostly normal levels of dissolved oxygen and temperatures, and low nutrient levels. At MS, samples have shown waters low in dissolved oxygen with periods of hypoxia, along with high turbulence observations. Separate condition status rankings were given for each park district, good for GUIS-FL and poor for the GUIS-MS. Data quality for GUIS-FL was good, lacking only a check for temporal coverage due to only recent monitoring data availability. At GUIS-MS, data quality was fair, reflecting missing checks in thematic sufficiency and spatial coverage. Respectively, this was due to the lack of nutrient data and the presence of only a single monitoring station.

5.2.5 Biological Integrity

Flora

GUIS contains habitat for several types of plant communities, but is divided into four main terrestrial vegetation types: upland coastal forests, palustrine wetlands, estuarine tidal marshes, and dune communities. These dune communities are particularly threatened by areas of adjacent development, while mainland pine savannahs and upland hardwood forests remain dependent on fire. GUIS also hosts18 plant species considered special concern in either MS or FL, and the persistence of which are also dependent on protection from rapid coastal development. Moreover, exotic plant species pose significant threats to both terrestrial and aquatic habitats and are a major management concern at GUIS, with latest data showing roughly 13% of the species in the park are exotic. Of these, a handful are the highest priority targets in the park, which include cogongrass, Chinese tallow tree, Chinese privet, Japanese honeysuckle, torpedo grass, and common reed. Overall, latest estimates show that, as individual units, Davis Bayou, Ft. Pickens, and Ft. Barrancas host the greatest proportion of exotic plant species.

In addition to terrestrial vegetation communities, GUIS supports one of the highest concentrations of seagrass beds in the U.S. is located along the MS barrier islands. Seagrass beds are critical in stabilizing sediment flow, in addition to providing habitat for aquatic species. These beds are subject to several sources of degradation, resulting in declines over past decades. Recent assessments have shown recovery, however, though these ecosystems are still certainly fragile. Several recent assessments have been conducted to estimate coverage of seagrass at GUIS, though these have focused mainly on the MS barrier islands. Estimates range from 142 ha to 1,463 ha of coverage, while currently the greatest threats to seagrass populations include coastal renourishment and damage from recreational boating. Because of the reduced, but recovering, populations of seagrass within GUIS, a condition of fair with an improving trend is assigned.

Fauna

GUIS supports a diversity of vertebrate animal fauna typical of the region. Many species of conservation concern are present in the park. GUIS is designated as an Important Bird Area, recognized as providing habitat for many breeding and migrating species of conservation concern. The park also provides refuge for many amphibian species, harboring a high percentage of species expected for the region. As with plants, the most important threats to native animals appear to be non-native species. Invasive species such as nutria and black rats are known to affect native plant and animal assemblages and are being addressed through park management. Both point and non-point pollution sources also threaten the livelihoods of many of the park’s available fauna. However, the park provides habitat for a number of threatened and endangered species, including the Perdido Key beach mouse, gopher tortoise, and Snowy Plover. Excellent data from ongoing monitoring are available for park herpetofauna, and ongoing marine turtle and shorebird monitoring programs were invaluable in understanding the condition of these resources. Updated GUIS inventories would be useful, particularly for mammal and bird assemblages. Current GULN monitoring efforts will likely add significantly to the knowledge of bird communities in the park.

5.2.6 Landscape Dynamics

The NPScape products provide a means to assess the quality of GUIS's adjacent land use using several different metrics. This section of analysis was divided into five main considerations: landcover, roads, population and housing, pattern, and conservation status. Because much of GUIS includes remote barrier islands and protected aquatic habitat, much of the park unit is secure from the types of intense coastal development that affect mainland areas. Davis Bayou and Santa Rosa Island are the exceptions, which are easily accessible and juxtaposed to areas of intense development, resulting in high road densities and reduced natural landcover. In addition, housing density continues to increase around these areas. Overall, the conservation risk index places the GUIS landscape in the vulnerable category, representing the lowest threat of human alteration to the area. This is due in part to the natural protection afforded by the geography of the barrier islands, and likely underestimates the risk to the mainland units of the park. Given the amount of development and roadways immediately surrounding mainland units, it may be especially important that there is an adequate amount of protected land to buffer to park from development and maintain connectivity between the remaining natural lands in this region.

Appendix A. List of Initial Scoping Meeting Attendees

Gulf Islands National Seashore:

Rick Clark, Chief of Science and Resource Management
Daniel R. Brown, Superintendent
Gary Hopkins, Biologist
Riley Hoggard, Resource Management Specialist

Gulf Coast Inventory and Monitoring Network:

Joe Meiman, Hydrologist

University of Georgia:

Nate Nibbelink, Principal Investigator
Gary Sundin, Research Professional
Luke Worsham, Research Professional

Southeast Regional Office:

R. Dale McPherson, Regional NRCA Program Coordinator

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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