National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Timucuan Ecological and Historic Preserve

Natural Resource Report NPS/TIMU/NRR—2022/2394

ON THE COVER

Round Marsh in Timucuan's Theodore Roosevelt Area (NPS photo by Duplaga)

Natural Resource Condition Assessment

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Natural Resource Report NPS/TIMU/NRR—2022/2394

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Timucuan Ecological and Historic Preserve (TIMU) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at TIMU. The final project framework contains nine resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by CAHA resource managers, NPS Southeast Coast Network staff, or outside experts.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for four of the eight components due to these data gaps.

For those components with sufficient available data, the overall condition varied. Three components were determined to be in good condition: upland hardwood hammocks, salt marshes, and water quality. However, water quality and salt marshes were at the edge of the good condition range, and any small decline in conditions could shift them into the moderate concern range. Of the components in good condition, trends could not be assigned for upland hardwood hammocks and water quality, and salt marshes are considered stable. One component (air quality) was of high concern, primarily due to emissions from surrounding developments (e.g., power plants, transportation, industry), but with an improving trend. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in TIMU, largely related to the proximity of human development and climate change. Those of primary concern include air and water pollution, habitat loss/fragmentation, and sea level rise. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem, as well as its historically significant structures and landscape.

Acknowledgments

We acknowledge Timucuan Ecological and Historic Preserve and Southeast Coast Inventory and Monitoring Network staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, Steven Kidd, Anne Lewellen, Brian Gregory, Lisa Cowart Baron, Forbes Boyle, Michael Parrish, Eric Starkey. Their logistical insight and critical review of interim documents was essential to this project’s completion. Additional insight and reviews were provided by Chris Hughes, Ksienya Taylor, Denesia Cheek, and Ches Vervaeke. Dale McPherson, Regional NRCA and RSS Coordinator, and Jeff Albright, Natural Resource Condition Assessment Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

ARD: Air Resources Division

ARDs: Automatic Recording Devices

BBS: Breeding Bird Survey

BRDs: Bycatch Reduction Devices

CAA: Clean Air Act

CANA: Canaveral National Seashore

CBC: Christmas Bird Count

CFU: Colony Forming Units

COJ: City of Jacksonville

CUIS: Cumberland Island National Seashore

DBH: Diameter-at-Breast-Height

DO: Dissolved Oxygen

dv: Deciview

EPA: Environmental Protection Agency

FIM: Fisheries Independent Monitoring

FLC IPMT: Florida and Caribbean Invasive Plant Management Team

FLDEP: Florida Department of Environmental Protection

FOCA: Fort Caroline National Memorial

FOMA: Fort Matanzas National Monument

FTU: Formazin Turbidity Units

FWC: Fish and Wildlife Conservation Commission

FWRI: Fish and Wildlife Research Institute

GIS: Geographic Information System

I&M: Inventory and Monitoring

ICW: Intracoastal Waterway

IOA: Indices of Abundance

JEA: Jacksonville Electric Authority

JU: Jacksonville University

LBD: Lethal Bronzing Disease

LWD: Laurel Wilt Disease

MDN: Mercury Deposition Network

MPN: Mean Probable Number

NAAQS: National Ambient Air Quality Standards

NADP: National Atmospheric Deposition Program

NOAA: National Oceanic and Atmospheric Administration

NPS: National Park Service

NRCA: Natural Resource Condition Assessment

NTU: Nephelometric Turbidity Units

NVCS: National Vegetation Classification System

OIMMP: Oyster Integrated Mapping and Monitoring Program

PM: Particulate Matter

ppt: Parts per Thousand

RSET: Rod-surface Elevation Table

SECN: Southeast Coast Network

SJR: St. John’s River

SJRWMD: St. Johns River Water Management District

SLR: Sea Level Rise

SMUMN GSS: Saint Mary’s University of Minnesota, GeoSpatial Services

TIMU: Timucuan Ecological and Historic Preserve

TDS: Total Dissolved Solids

TOC: Total Organic Carbon

TRA: Theodore Roosevelt Area

UNF: University of North Florida

USGS: United States Geological Survey

VCP: Variable-Circular Plot

VES: Visual Encounter Survey

VOCs: Volatile Organic Compounds

WCS: Weighted Condition Score

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.” NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park’s resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

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

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 reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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[1] 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. 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-up response (e.g., ecological thresholds or management “triggers”).

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

[5] 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.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves 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 existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the 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. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

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 park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-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

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] 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 draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

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)**

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

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[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] 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.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Timucuan Ecological and Historic Preserve (TIMU) was established by Congress on 16 February 1988 to protect the natural ecology of over 18,700 ha (46,200 ac) of lands and waters along the St. Johns and Nassau Rivers in northeast Florida (NPS 2016c). The preserve was named in honor of the native Timicua people who inhabited the St. Johns River valley for thousands of years, until the mid-18th century. As mandated in the enabling legislation, TIMU is administered by the staff at Fort Caroline National Memorial, which commemorates the French Colony of la Caroline on the St. John's River (NPS 2016c). In addition to its diverse natural resources, TIMU protects Kingsley Plantation (Figure 1), the oldest surviving example of an antebellum Spanish Colonial plantation, and at least 200 archeological sites reflecting over 6,000 years of continuous human history (NPS 2016c).

Figure 1. Kingsley Plantation, as seen from the Fort George River (NPS photo).

2.1.2 Geographic Setting

The TIMU boundary includes 18,722 ha (46,263 acres) of diverse ecological communities, primarily within the city limits of Jacksonville, Florida (NPS 2016c). As of 2017, approximately 16% of this area was owned by the NPS and 40% was owned by other public entities (NPS 2017a). There are also around 7,733 ha (19,110 ac) of private property within the park boundary, including some residential developments. Several state parks and a naval base fall within or adjacent to the park boundary (Figure 2).

Figure 2. Location of TIMU and adjacent public lands in northeast Florida.

Typical of the southeastern U.S., TIMU has a humid subtropical climate (Davey et al. 2007). Summer high temperatures are typically in the 31–33°C (88–92°F) range with winter lows around 8–10°C (46–50°F) (NCEI 2011). Tropical storms frequently pass within 16 km (10 mi) of the park, but hurricane impacts have been rare historically (NPS 2016c). However, Jacksonville did experience flood damage from Hurricane Irma in 2017, and from Hurricane Matthew in 2016 (Thorbecke 2016, Hong 2017). Temperature and precipitation normals from the nearest long-term weather monitoring station (Mayport) are shown in Table 1.

Table 1. 30-year climate normals (1981–2010) from the Mayport station (USW00003853), near the mouth of the St. Johns River (NCEI 2011).

Month	Average daily temperature min °C (°F)	Average daily temperature max °C (°F)	Average precipitation in cm (in)
January	7.9 (46.3)	17.7 (63.9)	7.6 (3.0)
February	9.5 (49.1)	19.2 (66.6)	6.6 (2.6)
March	12.3 (54.2)	21.8 (71.2)	9.1 (3.6)
April	15.4 (59.8)	25.1 (77.2)	5.8 (2.3)
May	19.8 (67.7)	28.9 (84.0)	6.0 (2.4)
June	22.9 (73.2)	31.6 (88.8)	12.7 (5.0)
July	23.8 (74.9)	32.9 (91.2)	12.9 (5.1)
August	24.1 (75.3)	32.2 (89.9)	13.4 (5.3)
September	23.1 (73.6)	30.2 (86.4)	16.6 (6.5)
October	19.3 (66.8)	26.9 (80.4)	11.6 (4.6)
November	14.2 (57.5)	23.0 (73.4)	5.2 (2.0)
December	9.7 (49.4)	19.0 (66.2)	6.4 (2.5)
Annual	**16.8 (62.3)**	**25.7 (78.3)**	**113.9 (44.8)**

2.1.3 Visitation Statistics

Over the past decade, TIMU has received over 1 million annual visitors nearly every year (NPS 2020a). Since 2005, annual visitation has ranged from 903,000 visitors (2005) to 1.24 million (2015), with a mean of 1.09 million visitors (NPS 2020a). There are two NPS visitor centers at the park, at Fort Caroline and Kingsley Plantation, as well as an interagency visitor center at the Ribault Club on Fort George Island (NPS 2021). Common visitor activities include visiting historic sites, wildlife watching, fishing, and kayaking through the marshes (Figure 3).

Figure 3. The outdoor exhibit at Fort Caroline (left) and visitors kayaking and fishing in the park's marshes (right) (NPS photos).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

TIMU lies within the Environmental Protection Agency's (EPA) Southern Coastal Plain Level III Ecoregion. The Southern Coastal Plain is a diverse ecoregion that includes coastal marshes, lagoons, barrier islands, and swampy lowlands along the Atlantic and Gulf coasts (EPA 2013). The region was historically covered by a variety of pine, hardwood, and mixed forests, but much of the area is now in less diverse second-growth forest, pasture for livestock, or human development (EPA 2013). The EPA divides Level III Ecoregions into smaller Level IV Ecoregions. The majority of TIMU falls within the Sea Islands/Coastal Marsh Ecoregion, with small portions in the Sea Island Flatwoods (Figure 4).

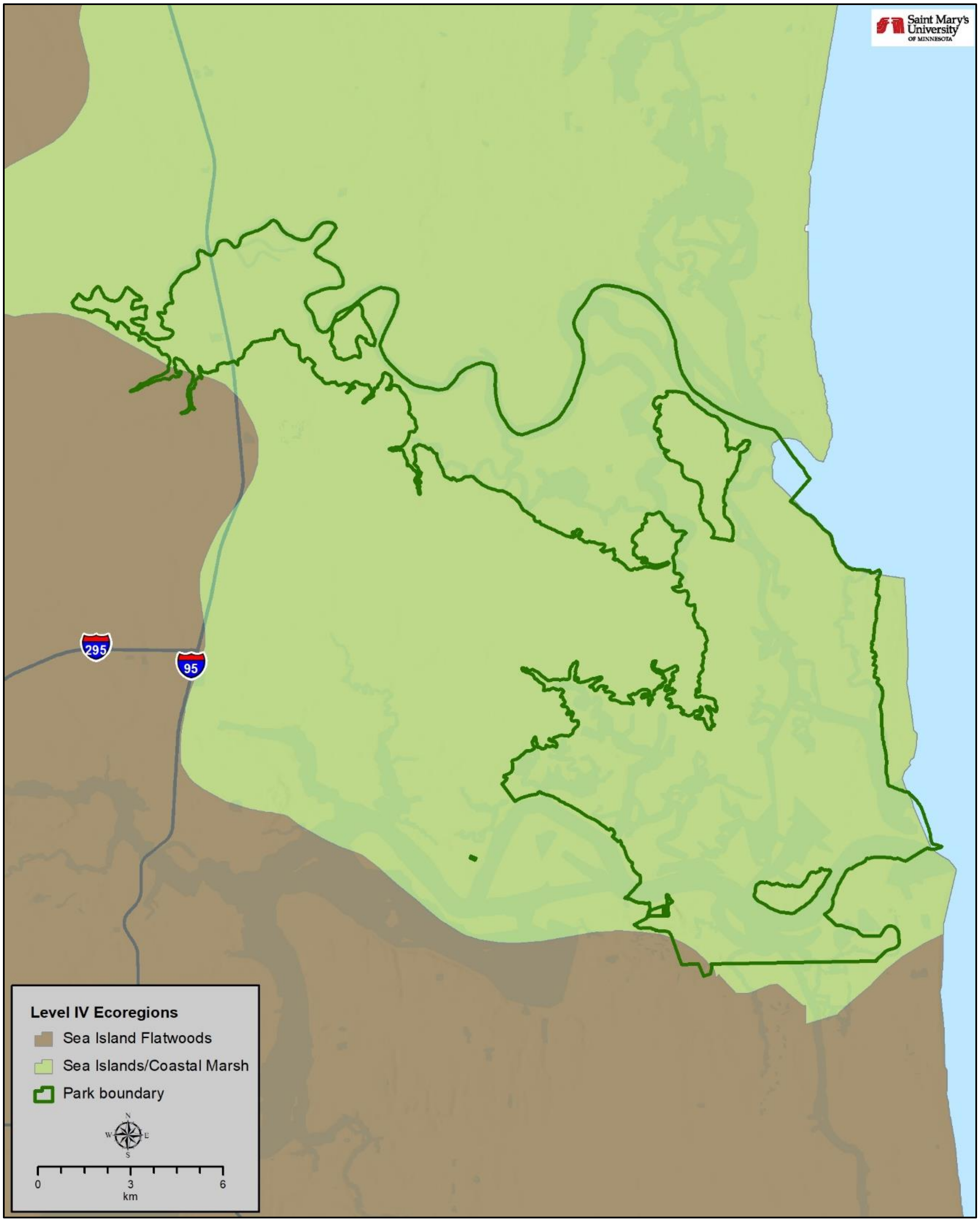

Figure 4. EPA Level IV Ecoregions of TIMU (EPA 2010).

The park falls within two different watersheds or subbasins, the Lower St. Johns and the Nassau (Figure 5). The Nassau subbasin includes all park lands that drain into the Nassau and Fort George Rivers, approximately the northern two-thirds of TIMU. The southern third of the park, including the marshes surrounding Clapboard and Cedar Point Creeks, falls in the Lower St. Johns subbasin.

Figure 5. HUC 8 watersheds (subbasins) of TIMU (EPA 2010).

2.2.2 Resource Descriptions

While nearly half of TIMU consists of tidal salt marshes, the park also supports wooded swamps, hardwood hammocks, pine flatwoods, and coastal scrub or shrub communities (O'Hare et al. 2020). The wooded swamps, primarily in the northern portions of the park, include tree and shrub species such as sweetgum (*Liquidambar styraciflua*), swamp tupelo/blackgum (*Nyssa biflora*), bald cypress (*Taxodium distichum*), loblolly bay (*Gordonia lasianthus*), and swamp bay (*Persea palustris*). Pine flatwoods support primarily slash pine (*Pinus elliottii*) with some longleaf (*P. palustris*) and pond pine (*P. serotina*) (O'Hare et al. 2020). Hardwood hammocks are dominated by oak species (*Quercus* spp.), often draped in Spanish moss (*Tillandsia usneoides*), and an understory of cabbage palmetto (*Sabal palmetto*) (Zomlefer et al. 2007).

The park is home to 620 confirmed vascular plant taxa, including subspecies and varieties (NPS 2020d). Thirteen of these species are considered threatened or endangered by the State of Florida, four of which are endemic to Florida (Table 2).

Table 2. TIMU plant species designated as threatened or endangered by the state of Florida (FDACS 2018, NPS 2020d).

Scientific name	Common name	State status	Habitat
Platanthera ciliaris	yellow fringed orchid	threatened	marshes, flatwoods
Spiranthes laciniata	lacelip ladies'-tresses	threatened	lake shores, flatwoods, marshes
Illicium parviflorum^E	yellow anisetree	endangered	bottomland forest
Opuntia stricta	erect pricklypear	threatened	shell mounds, coastal areas
Drosera intermedia	spoonleaf sundew	threatened	wet flatwoods, drainage ditches
Sideroxylon alachuense^E	Alachua bully	endangered	hammocks
Sarracenia minor	hooded pitcherplant	threatened	flatwoods, bogs, ditches
Pinguicula caerulea	blueflower butterwort	threatened	flatwoods, ditches, roadsides
Forestiera godfreyi	Godfrey's swampprivet	endangered	mesic calcareous woods
Lantana depressa^E	depressed shrubverbena	endangered	pine rockland, coastal strand
Calamovilfa curtissii^E	Florida sandreed	threatened	pinewoods, wet prairies, marshes
Cheilanthes microphylla	southern lipfern	endangered	upland mixed forest, shell mounds
Agrimonia incisa	incised agrimony	threatened	sandhills, woods and thickets

^{E} – Endemic to the State of Florida

Twenty-four mammal species have been confirmed within the park, 21 native and three non-native (Appendix A) (NPS 2020d). Common terrestrial mammals include white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), gray fox (*Urocyon cinereoargenteus*), and gray squirrel (*Sciurus carolinensis*). Bottlenose dolphins (*Tursiops truncatus*) and Florida manatees (*Trichechus manatus latirostris*), the latter a federally threatened species, can be found in the park's waters (NPS 2020d).

The various ecosystems at TIMU provide nesting, stopover, and overwintering habitat for a diverse array of songbirds, wading birds, and waterfowl. More than 300 species have been confirmed at the park, many of which are migratory species (NPS 2020d). Sixteen of these species are classified as endangered or threatened by the U.S. government or the State of Florida, including the Piping Plover

(*Charadrius melodus*), Wood Stork (*Mycteria americana*), and Red Knot (*Calidris canutus rufa*) (Figure 6) (FWCC 2018b).

Figure 6. The Wood Stork (left) and Red Knot (right) are two of the federally threatened bird species found at TIMU (NPS photos).

TIMU also supports 23 amphibian and 43 reptile species, including the state threatened gopher tortoise (*Gopherus polyphemus*) (NPS 2020d). The park has served as a research and monitoring location for the Carolina diamondback terrapin (*Malaclemys terrapin centrata*; Figure 7), a species that was previously under-studied (Butler 2002, Kolluri 2014). Diamondback terrapin numbers declined in the 19th and early 20th centuries as a result of overharvest and have not recovered since, primarily due to continued human influence (e.g., habitat loss, bycatch in crab traps) (Castellon 2017). Additional research is needed to determine if the entire species, or some of the five subspecies that occur in Florida, may warrant protection as a state threatened species (Castellon 2017).

The marshes, tidal creeks, and rivers in and around the park support a diversity of fish and aquatic invertebrates, including some commercially important species. Oysters were historically important as a food source, but shellfish harvesting has been closed in Duval County since 1996 due to water quality concerns (NPS 2016c). Aquatic invertebrates have not been closely surveyed or studied in the park, despite their value to the food web as prey species. Macroinvertebrate taxa that are thought to be present at TIMU are listed in Appendix B.

Despite their small size, insects play a vital role in terrestrial and aquatic ecosystems (Losey and Vaughan 2006, Macadam and Stockan 2015). For example, pollinators are critical in producing food for both humans and wildlife, while decomposers (e.g., beetles, flies) are key in nutrient cycling (Losey and Vaughan 2006). However, insects are often under-studied, and relatively little is known about their diversity, abundance, and distribution on most NPS lands (NPS 2015a). Several research projects to help address these gaps have occurred at TIMU during the past decade.

Figure 7. A Carolina diamondback terrapin (*Malaclemys terrapin centrata*; North Florida Land Trust photo, left) and gopher tortoise (*Gopherus polyphemus*) with burrow (Jacksonville University photo, right).

In 2009, a nationwide study was initiated to document baseline mercury levels in dragonfly larvae (Eagles-Smith et al. 2020). As predators relatively high on the aquatic food chain, dragonfly larvae can serve as indicators of mercury contamination risk and overall ecosystem health (D'Amato 2015, Eagles-Smith et al. 2020). Three ponds at TIMU were sampled in 2014 as part of this study, and two additional sites were surveyed to generate a preliminary checklist of dragon and damselfly species (Order Odonata) for the park (D'Amato 2015) (Appendix C). One site, Spanish Pond, was also sampled annually from 2016–2019 as part of the Dragonfly Mercury Project (Eagles-Smith et al. 2018). Based on 2014 results, mercury levels in TIMU dragonfly larvae were lower than those at the other 33 parks sampled (Figure 8). At Spanish Pond, mean mercury levels in dragonfly larvae have varied from 19.2 ppb to 113.7 ppb between 2014 and 2019 with no clear trend, but have stayed well below 300 ppb, the level that may cause toxicological risk to organisms that consume the larvae (Eagles-Smith et al. 2018, NPS 2020b).

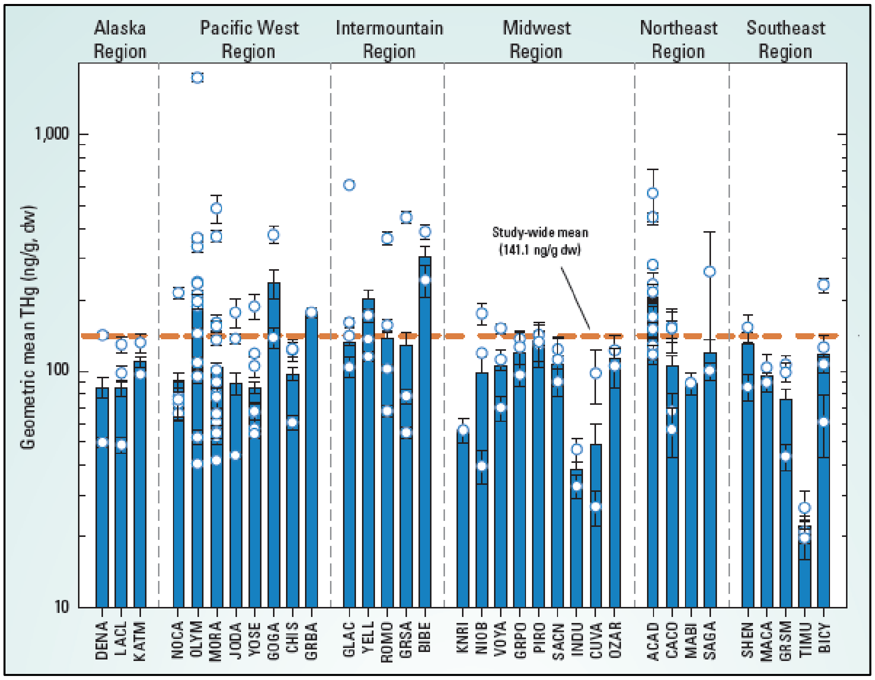

Figure 8. Geometric mean of dragonfly larvae total mercury (THg) concentrations by park (bars) and by site within parks (dots), 2014 (reproduced from Eagles-Smith et al. 2016). Error bars represent standard error. TIMU is the second bar from the right.

In 2012–2013, bee species were sampled in vulnerable habitats at 48 NPS units, including TIMU's vegetated inland sand dunes (NPS 2015a). Twenty-four bee species were found at TIMU, including a rare sand-associated leafcutter bee (*Megachile pruina*) and a rare kleptoparasitic species (*Epeolus carolinus*). A full list of bee species documented during this study can be found in Appendix D. Although no research into other pollinators at TIMU has been published, the Kingsley Bird Club documented butterfly and moth species observed in 2006; this list is included as Appendix E.

Two bee species found at TIMU: *Megachile mendica*, a common leaf cutting bee (left) and *Agapostemon splendens*, a sand-associated sweat bee (right) (USGS photos).

2.2.3 Resource Issues Overview

Non-native Species

Non-native invasive species pose one of the greatest threats to biodiversity and ecosystem integrity worldwide, with the potential to impact ecological community composition, structure, and function (Mooney et al. 2005, Beard and App 2013). These species can compete with native plants and animals and disrupt ecosystem processes such as nutrient cycling and disturbance regimes (e.g., fire, flooding). Eighteen of the non-native plant species that have been documented at TIMU are considered invasive by the State of Florida (Table 3) (FLEPPC 2019). The park has coordinated with the NPS Florida and Caribbean Invasive Plant Management Team (FLC IPMT) to remove and control invasive plants at Kingsley Plantation, Thomas Creek and the Theodore Roosevelt/Fort Caroline Areas (NPS 2016c). Species targeted include Chinese tallow (*Triadica sebifera*), Chinese wisteria (*Wisteria sinensis*), camphortree (*Cinnamomum camphora*), and air potato (*Dioscorea bulbifera*) (NPS 2016d). Non-native animals occurring at TIMU that may negatively impact native plant and wildlife communities include feral hogs (*Sus scrofa*) and feral cats (*Felis catus*) (NPS 2020d). Feral hogs are found in every county in Florida, in habitats ranging from hardwood hammocks to salt marshes and pine flatwoods (FWC 2021b). Rooting by feral hogs disturbs soils and native vegetation, exposing them to erosion and non-native plant invasions (USDA 2013).

Table 3. Non-native, invasive plant species documented within TIMU (NPS 2020d) with Florida invasiveness category (FLEPPC 2019).

Scientific name	Common name	Invasiveness category [a]
Albizia julibrissin	silktree, mimosa	1
Alternanthera philoxeroides	alligatorweed	2
Ardisia crenata	coral ardisia	1
Asparagus aethiopicus	Sprenger’s asparagus fern	1
Cinnamomum camphora	camphortree	1
Dactyloctenium aegyptium	Durban crowsfoot grass	2
Dioscorea bulbifera	air potato	1
Eichhornia crassipes	water-hyacinth	1
Landoltia punctata	dotted duckmeat/duckweed	2
Lantana camara	largeleaf lantana	1
Ligustrum lucidum	glossy privet	1
Lonicera japonica	Japanese honeysuckle	1
Ludwigia peruviana	Peruvian primrose-willow	1
Lygodium japonicum	Japanese climbing fern	1

[a] Category 1 = Invasives that are altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives; Category 2 = Invasives that have increased in abundance or frequency but have not yet altered Florida plant communities to the extent shown by Category 1 species. These species may become Category 1 if ecological damage is demonstrated.

Table 3 (continued). Non-native, invasive plant species documented within TIMU (NPS 2020d) with Florida invasiveness category (FLEPPC 2019).

Scientific name	Common name	Invasiveness category [a]
Melia azedarach	chinaberry	2
Pueraria montana	kudzu	1
Triadica sebifera	Chinese tallow	1
Wisteria sinensis	Chinese wisteria	2

[a] Category 1 = Invasives that are altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives; Category 2 = Invasives that have increased in abundance or frequency but have not yet altered Florida plant communities to the extent shown by Category 1 species. These species may become Category 1 if ecological damage is demonstrated.

Climate Change

Climate is a key driving factor in the ecological and physical processes influencing park ecosystems throughout the Southeast Coast Network (SECN) (Davey et al. 2007). As a result of global climate change, temperatures are projected to increase across the southeastern U.S. over the next century (Carter et al. 2014). Warmer air temperatures will increase evaporation rates and plant transpiration (i.e., plant water use), meaning that even if annual precipitation remains constant or slightly increases, overall conditions could still become drier in the future (Carter et al. 2014). Higher air temperatures will lead to higher water body temperatures, which will impact sensitive aquatic ecosystems (Hoegh-Guldberg and Bruno 2010). In the marine and estuarine environments, for example, many species are adapted to a particular temperature range and are negatively impacted if temperatures fluctuate too far or too frequently outside that range. Some organisms rely on temperature cues to initiate behaviors such as migration or reproduction; climate changes may disrupt the timing of these vital processes (Hawkes et al. 2009, Hoegh-Guldberg and Bruno 2010). Warmer waters also hold less dissolved oxygen, which is necessary for most aquatic organisms, than cooler waters (USGS 2016b). In addition, warmer ocean waters can intensify storm impacts, including hurricanes (Hoegh-Guldberg and Bruno 2010, IPCC 2013).

Warming temperatures will trigger sea level rise (SLR), due to both the thermal expansion of water and the melting of continental ice (IPCC 2013). Between 1993 and 2010, global SLR averaged 3.2 mm/year (0.13 in/year) (IPCC 2013). At Mayport, FL, SLR has averaged 2.72 mm/year (0.11 in/yr) from 1928–2019, which is equivalent to a rise of approximately 27.1 cm (0.9 ft) over 100 years (Figure 9). The SLR rate is expected to increase over the remainder of this century, so that total SLR by 2100 will be between 0.28–0.98 m (0.9–3.2 ft) (IPCC 2013). Sea level rise results in the loss of coastal lands, as rising waters inundate additional areas along the shore. In some cases, accretion (sediment accumulation) may keep up with the rate of SLR, but models project that higher rates of SLR (~1 m [3.3 ft] by 2100) may result in the conversion of tidal wetlands to open water (Schupp 2015, Alizad et al. 2016a).

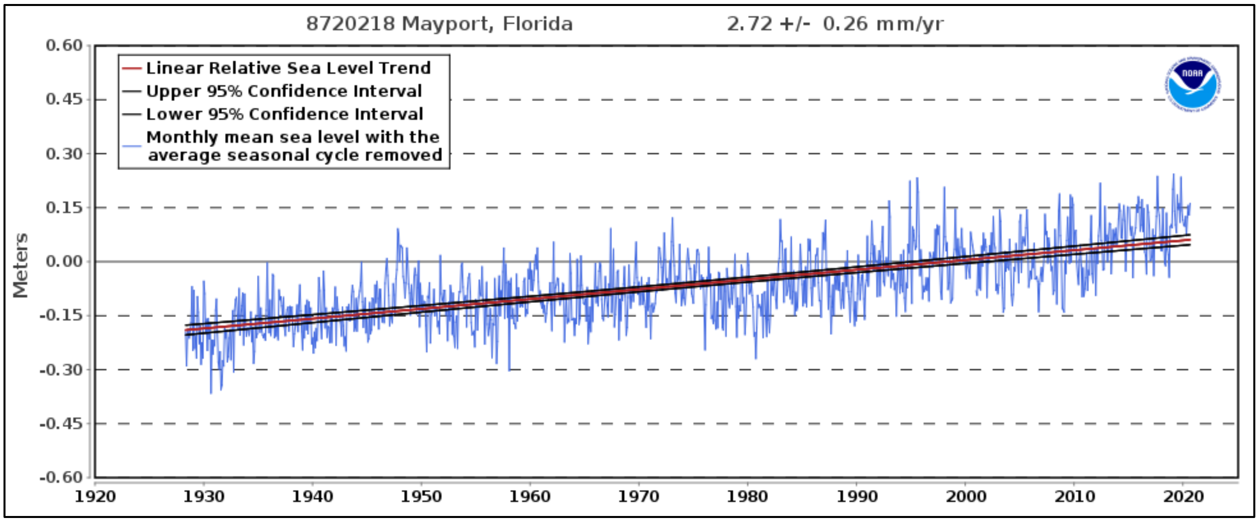

Figure 9. Mean sea level trend for Mayport, FL (NOAA 2020).

Development

Duval County, where TIMU is located, has been among the fastest growing counties in Florida, and the City of Jacksonville has experienced one of the highest overall population increases in the country (U.S. Census Bureau 2019). Between 2010 and 2019, Jacksonville's population increased by nearly 11%, from approximately 822,000 to 911,500 (U.S. Census Bureau 2020). Development and urban expansion (Figure 10), which typically accompany population growth, can increase air and water population, contribute to habitat loss and fragmentation, and increase exposure to invasive species (Byrd 2007, NPS 2016c, UNF and JU 2019). For example, the increase in impervious surfaces associated with development (e.g., roads, driveways, parking lots) has intensified storm runoff, which often carries contaminants from developed areas into wetlands and waterways (Anderson 2005, Shehane et al. 2005). This includes excess nutrients such as nitrogen and phosphorous that contribute to eutrophication, which can decrease dissolved oxygen levels in surface waters and trigger harmful algal blooms (USGS 2016a, 2017a).

Human modification of rivers and estuarine systems often threaten salt marshes and aquatic wildlife. Dredging to maintain shipping channels has impacted river and coastal hydrology across northeast Florida by altering water levels, salinity, and sediment dispersal/accretion (Kennish 2001, Dix et al. 2017, UNF and JU 2019). Dredging is likely to continue on the St. Johns River in the future to maintain depth and channel stability for commercial and naval shipping (UNF and JU 2019).

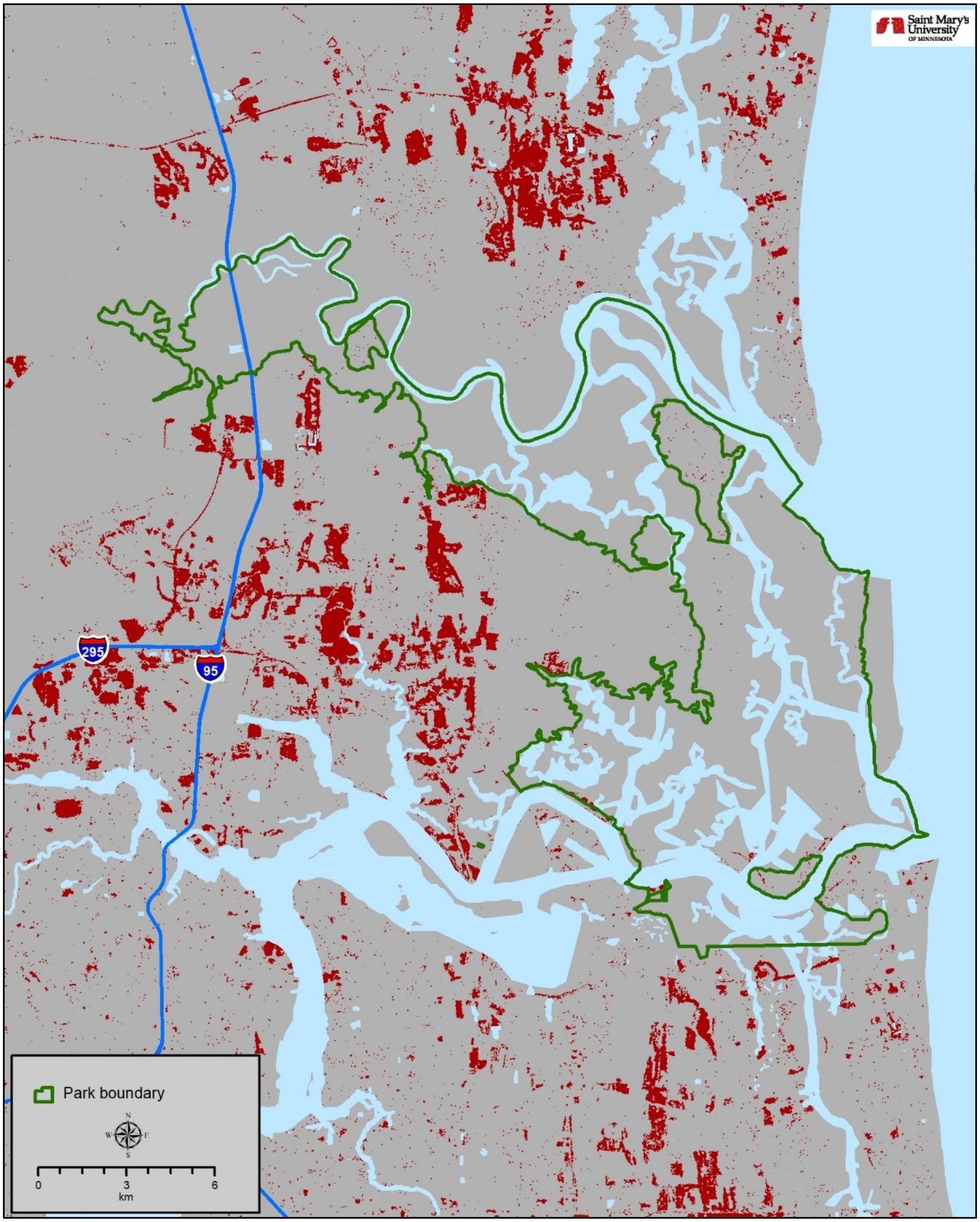

Figure 10. Areas in red above experienced landcover change from undeveloped to developed, or from lower intensity to higher intensity development, between 2001 and 2019, according to the National Land Cover Database (NLCD) (USGS 2021).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

According to TIMU's original General Management Plan, land use management will be "through a process of cooperation among landowners, regulatory authorities, and others with jurisdiction or an interest in the preserve" (NPS 1995). The objective of park management is

> *... promoting environmental awareness and sound land stewardship practices, while providing for visitor understanding and appreciation of preserve resources and stories* (NPS 1995)

As water and aquatic resources are vital to TIMU, park managers strive to "perpetuate surface and ground waters as integral components of park aquatic and terrestrial ecosystems" and "maintain the natural quality of surface and ground waters in accordance with all applicable federal, state, and local laws and regulations" (NPS 1996). Specific management objectives related to water resources include:

- To achieve and maintain Florida Class II (edible shellfish) water quality standards within the preserve in order to promote biodiversity and to protect the estuarine ecosystem;
- To coordinate with agencies responsible for regulating the development of uplands within the preserve to ensure that current and future uses di nit impair significant natural habitats, water quality, or a healthy estuarine ecosystem;
- To strenuously foster no net loss of wetlands in the preserve;
- To preserve the natural dynamics of the surface water and tidal hydrologic regimes which are critical to the biological systems of the preserve;
- To manage, in cooperation with other agencies, boating, boating-related activities, fishing and hunting to allow the public to experience the various water-based resources and values of the preserve in a manner which will not… impair the integrity of this relatively undeveloped and undisturbed estuarine system;
- To educate the general population and visitors about the impacts and relationships between human use and natural resources, and the wetlands and upland dynamics of a saltwater estuary complex; and
- To ensure the provision of land and water-based access to allow visitors to have a visual and sensory understanding of the wetlands ecology (NPS 1996).

2.3.2 Status of Supporting Science

The SECN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2008, the SECN completed and released a Vital Signs Monitoring Plan (DeVivo et al. 2008); Table 4 shows the SECN Vital Signs selected for monitoring in TIMU.

Table 4. SECN Vital Signs selected for monitoring in TIMU (DeVivo et al. 2008).

Category	SECN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]
Air and Climate	Ozone	–	X	–
	Wet and Dry Deposition	–	X	–
	Visibility and Particulate Matter	–	X	–
	Air Contaminants	–	X	–
	Weather and Climate	–	X	–
Geology and Soils	Coastal Shoreline Change	X	–	–
	Salt Marsh Elevation	X	–	–
Water	Groundwater Dynamics	–	X	–
	Surface Water Dynamics	–	x	–
	Water Chemistry	X	–	–
Biological Integrity	Invasive/Exotic Plants	X	–	–
	Marine Invertebrates	–	–	X
	Fish Communities	–	–	X
	Amphibians	X	–	–
	Breeding Forest Birds	X	–	–
	Small Mammals	–	–	X
	Plant Communities	X	–	–
	Shorebirds (T&E species)	–	–	X
	T&E Species	–	X	–
Human Use	Fisheries Take	–	X	–
	Visitor Use	–	X	–
Landscapes (Ecosystem Patterns and Processes)	Fire and Fuel Dynamics	X	–	–
	Land Cover and Use	X	–	–

[a] **Category 1** represents Vital Signs for which the network will develop protocols and implement monitoring.

[b] **Category 2** represents Vital Signs that are monitored by the park, another NPS program, or by another federal or state agency using other funding.

[c] **Category 3** represents priority Vital Signs for which monitoring has been deferred.

Since 2008, the University of North Florida (UNF) and Jacksonville University (JU) have collaborated to produce an annual State of the Lower St. Johns River Basin report for the City of Jacksonville's Environmental Protection Board (UNF & JU 2008, 2019). Each report addresses the condition of resources such as fisheries, wetlands, aquatic invertebrates, non-native species, water chemistry, and contaminants (metals, hydrocarbons, pesticides, etc.). These reports provide some insight into the condition of aquatic resources within the St. Johns Basin portion of TIMU (See Figure 5). The City of Jacksonville collects water quality data from 12 locations within or near TIMU approximately every 2 months (Hynds and Starkey 2019). These data are a useful supplement to the

NPS water quality monitoring and have been included in SECN monitoring reports (Wright et al. 2012, Wright and Mockus 2015, Hynds and Starkey 2019).

3. Study Scoping and Design

This NRCA is a collaborative project between the NPS and SMUMN GSS. Project stakeholders include the TIMU resource management team, and SECN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held on 21–23 January 2020. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the TIMU NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to TIMU managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component; and
- Resource focus and priorities are primarily driven by TIMU resource management.

This condition assessment provides a “snapshot-in-time” evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid TIMU resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding
- resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these; and
- Report program performance (e.g., Department of Interior Strategic Plan “land health” goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including TIMU resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project;
- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point;
- Clearly identify “management critical” data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process;

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually; and
- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any physical, biological, or chemical agent that induces adverse changes within a component (EPA 2016a). These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation.

During the TIMU NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in TIMU. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were adapted from the TIMU State of the Park Report (NPS 2016c). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized by the end of February 2020 following review and acceptance from NPS resource staff. The framework contains a total of eight components (Table 5) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 5. Timucuan Ecological and Historic Preserve natural resource condition assessment framework.

Category	**Component**	**Measures (Significance Level)**	**Stressors**	**Reference Condition**
Biotic Composition/ Ecological Communities	Upland Hardwood Hammocks	Acreage (3), species richness (2), invasive species presence/absence (3), redbay presence/persistence (2)	Palm bronzing, redbay disease, invasive species, development, climate change and range expansion of non-natives, storm events (surge, winds, etc.)	Use current veg map as a point of comparison for future assessments. No loss or degradation from current condition (e.g., no increase in number of invasive species).
	Salt marshes	Extent (acreage) of estuarine/brackish wetlands (3), plant species richness of estuarine/brackish wetlands (3), elevation of saltwater marshes, using sediment elevation tables (3), water quality (3)	Mangrove migration north, armored surfaces on private inholdings preventing marsh migration, climate change related sea level rise, boat wakes, storm events, dredging and related spoil island creation, siltation and changes in hydrologic flows	Use current veg map as a point of comparison for future assessments for extent. Could use comparable salt marshes to north (CUIS) and south (GTM) for species richness. State standards for water quality.
Biotic Composition/ Wildlife	Herpetofauna	Amphibian species richness (3), reptile species richness (3), number of gopher tortoise burrows (3), diamondback terrapin nesting numbers (2)	Chytrid fungus, development and habitat loss/fragmentation, traffic strikes, climate change, predation, air quality/pollution	Tuberville (2005) for species richness. Baseline for terrapins and tortoises will be current data.
	Birds	Species richness (3), species abundance (3), species distribution (3), wading bird nesting numbers (3)	Climate change, development, feral cats, boat traffic (wake issues)	Byrne et al. (2011)
	Saltwater Fish Community	Species richness (3), indices of abundance for age classes (3)	Water quality degradation, loss of nursery habitat as a result of development and hardened/armored surfaces, climate change, possible overharvest	No further deterioration or loss in community
	Oysters	Change in oyster bed extent (3), recruitment (3), contaminant levels (3)	Boat wakes, channel manipulation, climate change/sea level rise, water quality changes	No net loss (extent, recruitment); NOAA Mussel Watch's "low" contaminant ranges for oysters

Table 5 (continued). Timucuan Ecological and Historic Preserve natural resource condition assessment framework.

Category	Component	Measures (Significance Level)	Stressors	Reference Condition
Environmental Quality	Water Quality	DO (3), salinity (3), total nitrogen (3), total phosphorus (3), indicator bacteria (3), water clarity (3), chlorophyll a (3), total organic carbon in sediment (3), sediment contaminant rating (3)	Wastewater/septic discharge, agricultural runoff, dredging projects, adjacent land development (including fertilizer runoff from residential areas), gas/oil spills from recreational boats/marinas	Criteria used by the SECN water quality monitoring program; salinity reference is undefined
	Air Quality	Atmospheric deposition of sulfur/nitrogen (3), Ozone (3), atmospheric deposition of mercury (3), visibility (3)	Development, vehicle traffic, local power plant, wildfires, rural trash burning, possibly operations at Naval Station Mayport	NPS ARD established standards

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time TIMU staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff or downloaded from IRMA. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from TIMU and the SECN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1–3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 6. This categorization allows measures that are more important for determining condition of a component (higher significance level) to be more heavily weighted in calculating an overall condition. If a measure is given a Significance Level of 1, it is thought to be of low importance when determining the overall condition of the component. For this reason, measures with a Significance Level of 1 are not discussed in detail in the Current Condition and Trends section of a component’s chapter. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 6. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0–3 integer scale (Table 7). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 7. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	**GOOD CONDITION**. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **SIGNIFICANT** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\,of\,measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\,of\,measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: resource is in good condition (WCS = 0.0 to 0.33); condition warrants moderate concern (WCS = 0.34 to 0.66); and condition warrants significant concern (WCS = 0.67 to 1.00). Tables 8 and **9** display and describe the symbology used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern, and green circles are in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there was currently insufficient data to make a statement about the condition of a component. The border of the circles represents SMUMN GSS's confidence in the assessment of current condition; bold borders indicate high confidence, normal borders indicate medium confidence, and a dashed-border indicates low confidence. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5–10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. An arrow that points to the left and right indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. An empty circle with no arrow is reserved for situations in which the trend of the component's condition is currently unknown.

Table 8. Description of symbology used for individual component assessments.

Condition Status		**Trend in Condition**		**Confidence in Assessment**	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
🟢	Resource is in Good Condition	⇧	Condition is Improving	⭘	High
🟡	Resource warrants Moderate Concern	⇔	Condition is Unchanging	◯	Medium
🔴	Resource warrants Significant Concern	⇩	Condition is Deteriorating	◌	Low

Table 9. Example indicator symbols and descriptions of how to interpret them in WCS tables.

Symbol Example	**Verbal Description**
🟢⇧	Resource is in good condition; its condition is improving; high confidence in the assessment.
🟡⇔	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
🔴	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
◌	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts, and TIMU and SECN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used, and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by TIMU resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend

This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors

This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps

This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component. Sources are listed alphabetically by last name.

4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the eight key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise

The order of components follows the project framework (Table 5):

4.1 Upland Hardwood Hammocks
4.2 Salt Marshes
4.3 Herpetofauna
4.4 Birds
4.5 Saltwater Fish Community
4.6 Oysters
4.7 Water Quality
4.8 Air Quality

4.1 Upland Hardwood Hammocks

4.1.1 Description

Upland hardwood hammocks are a wooded coastal community type with xeric (dry) to mesic (moderate) soils, dominated by oaks and other hardwood trees and shrubs (McClung 2004, Zomlefer et al. 2007). Forested hammocks are considered a late stage of succession, occurring in landscapes that have not recently experienced serious disturbances such as fires and flooding (Byrd 2007, Zomlefer et al. 2007). Most hammocks have dense tree or shrub canopies (80–100%), with tree branches supporting epiphytes such as Spanish moss and resurrection fern (*Pleopeltis polypodioides*) (Zomlefer et al. 2007, Cotten et al. 2019). Florida's hardwood hammocks provide food and shelter for wildlife, particularly for migrating birds after transoceanic or trans-gulf flights (Bezanilla 2002).

A maritime hardwood hammock at TIMU (NPS photo by R. Rasmussen).

At TIMU, upland hardwood hammocks are common at Cedar Point, Fort George Island, Talbot Island, and the Theodore Roosevelt Area (TRA) (Zomlefer et al. 2007, O'Hare et al. 2020). In these areas, dominant woody species include live oak (*Quercus virginiana*), sand live oak (*Q. geminata*), southern redcedar (*Juniperus virginiana* var. *silicicola*), and cabbage palmetto (City of Jacksonville 1998, Bezanilla 2002, Zomlefer et al. 2007). For the purposes of this NRCA, eight land cover classes (as mapped by O'Hare et al. 2020) will be included as hardwood hammock vegetation communities. These classes, along with their common tree and shrub species, are presented in Table 10.

Table 10. Hardwood hammock vegetation types at TIMU and their common plant species, as described by O'Hare et al. (2020).

Land cover class	**Common tree/shrub species**
Maritime Live Oak Hammock	Live oak (*Quercus virginiana*), pignut hickory (*Carya glabra*), southern redcedar (*Juniperus virginiana* var. *silicicola*), southern magnolia (*Magnolia grandiflora*), Darlington oak (*Q. hemisphaerica*), cabbage palmetto (*Sabal palmetto*), redbay (*Persea borbonia*), yaupon (*Ilex vomitoria*)
Cedar - Live Oak - Cabbage Palmetto Marsh Hammock	Southern redcedar, live oak, cabbage palmetto, sugar hackberry (*Celtis laevigata*)
Southeastern Florida Maritime Hammock	Sand live oak (*Q. geminata*), slash pine (*Pinus elliottii*), water oak (*Q. nigra*), Darlington oak, myrtle oak (*Q. myrtifolia*), saw palmetto (*Serenoa repens*), blueberries (*Vaccinium* spp.)
Palmetto - Live Oak Hydric Hammock	Live oak, cabbage palmetto, red maple (*Acer rubrum*), slash pine (*Pinus elliottii*), loblolly pine (*P. taeda*), laurel oak (*Q. laurifolia*)
Cabbage Palmetto Hydric Hammock	Cabbage palmetto, live oak, red maple, sweetgum (*Liquidambar styraciflua*), water oak (*Q. nigra*)
Temperate Hydric Hammock	Red maple, sweetgum, southern magnolia, live oak, cabbage palmetto
Northeast Florida Coastal Scrub	Sand live oak, myrtle oak, saw palmetto, redbay
Xeric Oak Shrubland	Sand live oak, myrtle oak, Chapman's oak (*Q. chapmanii*), redbay, devilwood (*Osmanthus americanus*)

4.1.2 Measures

- Acreage
- Species richness
- Invasive plant species presence/absence
- Redbay presence/persistence

4.1.3 Reference Condition/Values

There is no appropriate historical reference condition available for this resource at TIMU. Park management's goal is to see no loss or degradation from the current condition for the selected measures in this assessment. Thus, the information presented in this component could be used as a reference point for future assessments.

4.1.4 Data and Methods

Duever (1996) conducted a rare plant survey of TIMU, concentrating on several areas considered undersurveyed by the NPS: Cedar Point, the Broward Islands, and Burton Island. The author also described the vegetation communities observed and noted invasive plant presence. Field surveys were conducted on 12–13 June 1995.

Other known early surveys of hardwood hammocks within TIMU's current boundaries are baseline surveys or mapping efforts of smaller areas on Cedar Point (City of Jacksonville 1998) and Halfmoon Island (Bezanilla 2002) (Figure 11). The City of Jacksonville (1998) conducted vegetation and wildlife surveys at Cedar Point between January 1995 and March 1996. Methodology for vegetation surveys was adapted from the Army Corps of Engineers Wetland Delineation Manual (USACE 1987). Bezanilla (2002) used aerial photos and field surveys to map and describe the vegetation communities of Halfmoon Island. The report noted the major plant species present, dominant over- and understory species, canopy cover, and tree heights. Community type determinations were based on the Guide to the Natural Communities of Florida (FNAI 1990).

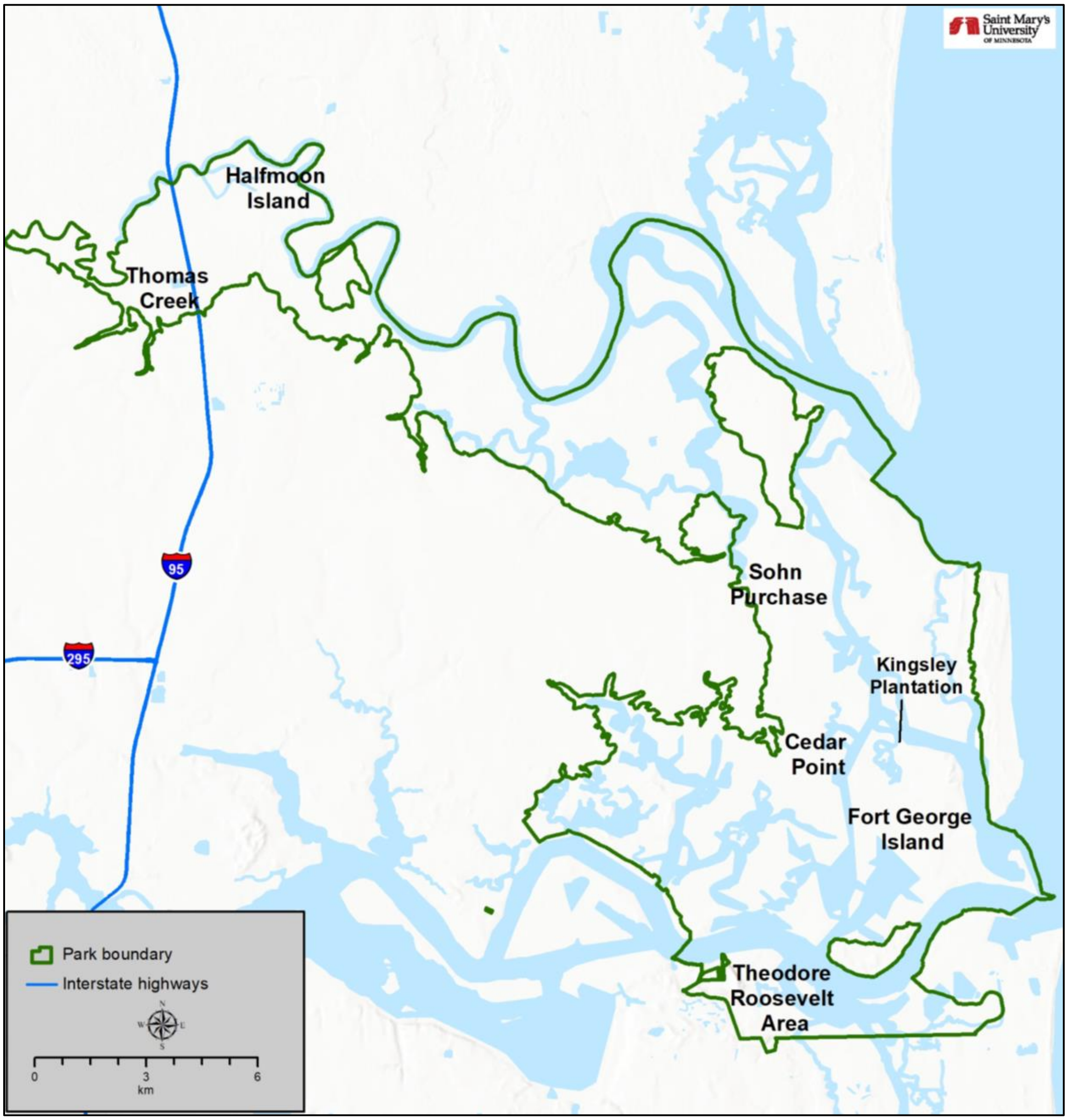

Figure 11. Approximate locations of hardwood hammock study areas within TIMU.

McClung (2004) conducted a resource assessment of marsh islands in the TIMU area owned by the NPS and The Nature Conservancy (TNC) (Appendix F). Field inventories, including vegetation surveys, were conducted between May 2003 and January 2004. Islands under 2 ha (5 ac) in size were completely inventoried, while larger islands were surveyed with line transects at approximately 10-m (33 ft) intervals (McClung 2004). All common plant species (i.e., those comprising at least 10% of total species composition) were recorded. Maritime hammock was the most common vegetation community on both TNC and NPS-owned islands.

Zomlefer et al. (2007) completed an intensive floristic survey within selected areas of TIMU, resulting in an annotated plant species list with information on general community type (i.e., habitat) and relative abundance. Surveys were conducted in April, June, and September–October of 2005. The research team focused on five NPS-owned areas of the park: Thomas Creek, Cedar Point, Fort Caroline National Memorial/Theodore Roosevelt Area, Kingsley Plantation, and Sohn Purchase (Zomlefer et al. 2007) (Figure 11).

Fraedrich et al. (2008) assessed redbay (*Persea borbonia*) mortality rates in a hardwood hammock area on Fort George Island within TIMU. In July 2005, five 0.08-ha (0.2 ac) circular plots were established along a 1.1 km (0.7 mi) stretch of park road with dead and wilting redbays. All redbays within each plot (132 total trees with diameter at breast height [DBH] >2.5 cm [1 in]) were rated for crown condition every 3 months through December 2006 (Fraedrich et al. 2008).

In 2009, the SECN initiated an interim vegetation monitoring project at TIMU as part of the Vital Signs monitoring program (Byrne et al. 2012b). Data collected include species composition, canopy cover, herbaceous cover, and canopy-species seedling frequency. Of the 26 plots sampled at TIMU, nine were within hardwood hammock communities. In 2019, the SECN modified the vegetation monitoring protocol, established new sampling locations, and collected baseline data for those plots. The primary objective of the updated protocol is to "detect meaningful changes in species composition and vegetation structure within natural and semi-natural vegetation communities of SECN parks… and determine whether these changes are correlated with trends in key stressors" (Boyle et al. 2019, p. 15). Generalized random-tessellation stratified (GRTS) sampling methodology (Stevens and Olsen 2004) was used to create a spatially-balanced, random set of monitoring sites for each park; plots are resampled every 4 years. Of 23 monitoring plots at TIMU, ten fell within hardwood hammocks; six within the TRA, and four at Cedar Point (Boyle and Rico 2021).

With NPS support, the University of Georgia's Center for Geospatial Research mapped and described vegetation at TIMU using National Vegetation Classification System (NVCS) standards (O'Hare et al. 2020). Mapping was based on May 2012 color infrared aerial photography of the park at a 1:12,000 scale. Field verification was conducted from 2014–2016. Over 40 different vegetation associations were identified within park boundaries (O'Hare et al. 2020).

From 2008–15, the NPS Florida and Caribbean Invasive Plant Management Team (FLC IPMT) has been visiting TIMU annually to detect and treat infestations of selected invasive plant species within the park. GIS data for the treatment locations during these years by species was provided by the NPS for this assessment (NPS 2016d). These data points were overlaid with vegetation mapping data from O'Hare et al. (2020) to identify invasive species detected within hardwood hammock communities. More recently (2018), two Geoscientists-in-the-parks interns conducted informal surveys for targeted invasive plants in selected park areas (Tardona 2019).

4.1.5 Current Condition and Trend

Acreage

As mentioned previously, early vegetation surveys within TIMU boundaries focused on smaller, specific areas. For example, the City of Jacksonville (1998) identified 41.4 ha (102.2 ac) of coastal maritime hammock vegetation on Cedar Point as of 1995. Bezanilla (2002) mapped 5.7 ha (14.2 ac) of maritime hammock on Halfmoon Island in 2002. In McClung's (2004) assessment of TIMU's marsh islands, a total of 41.3 ha (102 ac) of maritime hammock habitat were identified: 23.8 ha (58.9 ac) on islands owned by NPS and 17.5 ha (43.3 ac) on TNC-owned islands.

More recent vegetation mapping in TIMU has been more detailed and has had broader coverage. O'Hare et al. (2020) classified 1,660.4 ha (4,102.9 ac) or 9.4% of TIMU as hardwood hammock vegetation (Figure 12, Figure 13). The majority of this vegetation (62%) was classified as Maritime Live Oak Hammock, with Cedar - Live Oak - Cabbage Palmetto Marsh Hammock (8%) a distant second (Table 11). According to a 1991 delineation by the Florida Game and Fresh Water Fish Commission, 4.7% of the park was hardwood hammock at that time (NPS 2018). While it is uncertain whether the difference in percent coverage of hardwood hammock between 1991 and 2012 represents an actual increase in hammock communities or differences in mapping and classification methodologies, given the lack of fire and other major disturbances in these areas, it is likely that hardwood hammock acreage has at least remained stable and has possibly increased.

Table 11. Extent/acreage of hardwood hammock vegetation types at TIMU based on 2012 aerial imagery. As reported in O'Hare et al. (2020).

Land cover class	Area in ha (ac)	% of park area
Maritime Live Oak Hammock	1,030.7 (2,546.9)	5.8
Cedar - Live Oak - Cabbage Palmetto Marsh Hammock	138.2 (341.5)	0.8
Southeastern Florida Maritime Hammock	67.0 (165.6)	0.4
Palmetto - Live Oak Hydric Hammock	105.4 (260.4)	0.6
Cabbage Palmetto Hydric Hammock	73.4 (181.4)	0.4
Temperate Hydric Hammock	24.0 (59.3)	0.1
Northeast Florida Coastal Scrub	104.7 (258.7)	0.6
Xeric Oak Shrubland	117.0 (289.1)	0.7
Total	**1,660.4 (4,102.9)**	**9.4**

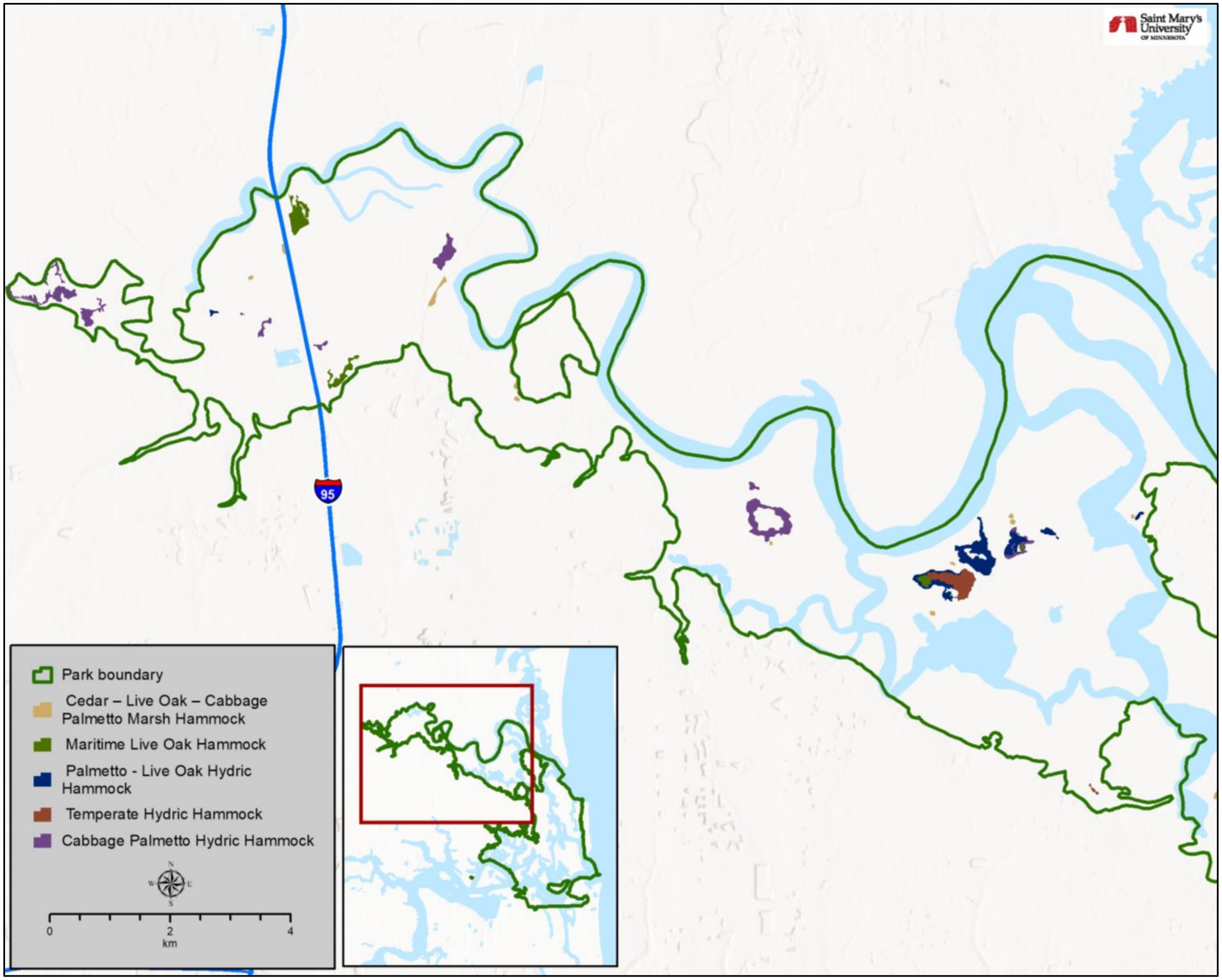

Figure 12. Extent of hardwood hammock communities in the northern portion of TIMU, as mapped by O'Hare et al. (2020).

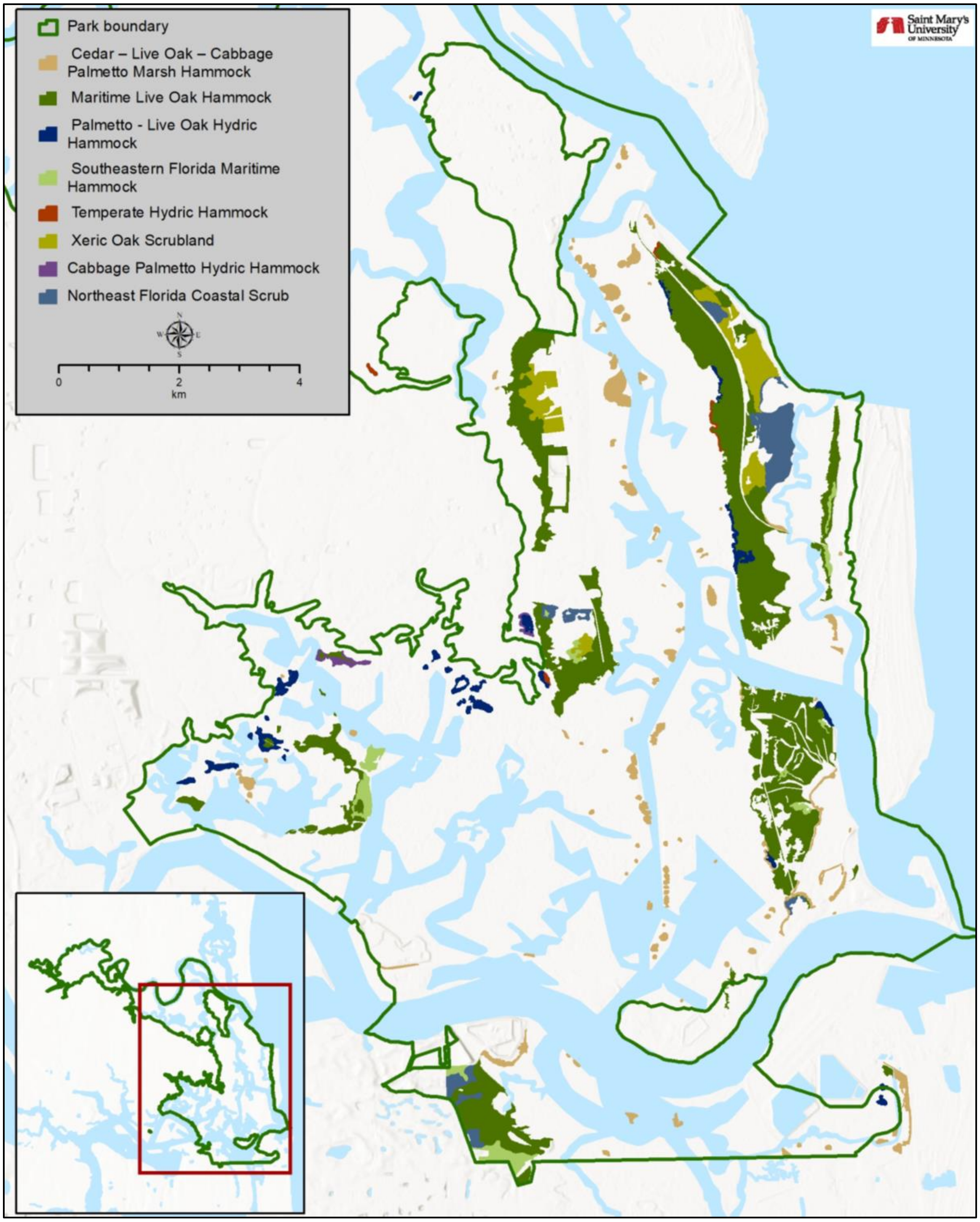

Figure 13. Extent of hardwood hammock communities in the southern portion of TIMU, as mapped by O'Hare et al. (2020).

<u>Plant Species Richness</u>

Various studies over time have documented 196 different taxa in TIMU's hardwood hammocks (Appendix G). Sixteen of these species (8%) are considered non-native. In their intensive floristic survey of selected areas within the park, Zomlefer et al. (2007) identified 100 plant species in maritime hammock communities. For comparison, in similar floristic surveys of the nearby Cumberland Island National Seashore (CUIS) and Fort Matanzas National Monument (FOMA), Zomlefer et al. (2004, 2008) documented 57 and 45 plant species, respectively, in comparable maritime vegetation communities. However, it should be noted that FOMA is a very small park, and is only 1% of the size of TIMU.

During 2009 SECN vegetation community monitoring, Byrne et al. (2012a, 2012b) documented 56 plant species in nine hardwood hammock plots at TIMU, and 69 species in 16 oak maritime plots at CUIS. These richness numbers are relatively similar, and the lower number for TIMU could be partly due to the smaller number of sampling plots (9 vs. 16). Most recently, 2019 SECN monitoring at TIMU documented 114 plant taxa across the ten new hardwood hammock plots (NPS 2020f).

Invasive Plant Species Presence/Absence

Non-native invasive species pose one of the greatest threats to biodiversity and ecosystem integrity, as they can compete with native plants and disrupt ecosystem processes such as nutrient cycling and disturbance regimes (Mooney et al. 2005, Beard and App 2013). While there has not been a comprehensive invasive plant survey of TIMU, some information can be gleaned from various vegetation surveys over time. For example, McClung (2004) did not detect any invasive plants on NPS-owned maritime hammock islands, but did report three invasive plants on one TNC-owned island (TNC58 – Little Marsh Island): Japanese honeysuckle (*Lonicera japonica*), lantana (*Lantana camara*), and mimosa (*Albizia julibrissin*; one tree, removed by survey team).

Duever (1996) had noted Japanese honeysuckle in several of TIMU's maritime hammocks in 1995, including on Sugarberry Island. Zomlefer et al. (2007) did not report Japanese honeysuckle in their maritime hammock study areas, but did observe Japanese climbing fern (*Lygodium japonicum*) in the Theodore Roosevelt/Fort Caroline area. Byrne et al. (2012b) and 2019 SECN monitoring efforts (NPS 2020f) did not report any invasive plants in hammock sampling plots.

According to FLC IPMT data for the park, ten invasive plant species were identified in hardwood hammock habitats (as mapped by O'Hare et al. 2020) across six locations within TIMU between 2008 and 2013 (NPS 2016d) (Table 12). No invasive plant species were noted in the hardwood hammock areas visited in 2015. In 2018, NPS interns documented sword fern (*Nephrolepis cordifolia*) and air potato (*Dioscorea bulbifera*) on Fort George Island near Kingsley Plantation (Tardona 2019).

Table 12. Invasive plant species treated by FLC IPMT, by year and location (NPS 2016d).

Location	Species Name	2008	2010	2011	2012	2013	2015
Theodore Roosevelt Area	*Triadica sebifera*	–	–	–	–	x	–
Northern Fort George Island	*Dioscorea bulbifera*	–	x	–	–	–	–
	Nephrolepis cordifolia	–	x	x	x	x	–
	Wisteria sinensis	–	–	–	x	x	–
	Cinnamomum camphora	–	–	–	x	x	–
	Lonicera japonica	–	–	–	–	x	–
	Hedera helix	x	x	–	x	x	–
Cedar Point	*Albizia julibrissin*	–	x	–	–	–	–
	Hedera helix	–	–	–	x	–	–
	Wisteria sinensis	–	–	–	x	–	–
	Asparagus densiflorus	–	–	–	x	–	–
Sawpit Creek (off northern Talbot Island)	*Cinnamomum camphora*	–	–	–	x	–	–
Island between Sisters Creek and Mud River	*Lygodium japonicum*	x	–	–	–	–	–
Thomas Creek (hydric hammock)	*Triadica sebifera*	x	–	–	–	–	–

Redbay Presence/Persistence

Redbay is a key native component of hardwood hammocks and other wooded coastal vegetation communities that provides habitat for a variety of wildlife (Byrne et al. 2012b). The fruits are eaten by numerous birds and the plant serves as a primary host for the larva of the Palamedes swallowtail (*Papilio palamedes*) (Fraedrich et al. 2008). A decline in redbay along the southeastern Atlantic Coast was first noted in 2003 and was traced to laurel wilt disease (LWD), a lethal fungus (*Raffaelea lauricola*) spread by a non-native beetle (Shearman and Wang 2016). Redbay decline was first observed at TIMU on Fort George Island in 2004 and at Cedar Point in 2005 (Zomlefer et al. 2007, Fraedrich et al. 2008).

Comprehensive, park-wide surveys for redbay have not occurred at TIMU. However, some information can be gleaned from literature and SECN vegetation monitoring data. In a survey of TIMU islands, McClung (2004) noted redbay as a *primary* canopy species on 10 of 29 TNC-owned maritime hammock islands, and nine of 27 NPS-owned islands. During 2009 SECN monitoring, redbay was noted in the shrub and groundcover layers of two of the nine sampling plots in hardwood hammock communities but not in the canopy of any of those plots (Byrne et al. 2012b). Redbay trees were documented in other vegetation community plots (e.g., pine flatwoods) at TIMU in 2009, but 73% of those trees (43 of 59) were standing dead.

During 2019 SECN monitoring, redbay was present in all ten hardwood hammock sampling plots (NPS 2020f). However, only one plot at TRA contained a tree-sized (>10 cm [3.9 in] diameter) redbay. Redbay seedlings and/or saplings were recorded in nine of the ten hardwood hammock plots (Table 13). In three of the plots, redbay was represented by just a single individual in one size class.

Table 13. Presence of redbay seedlings and saplings in TIMU hardwood hammock sampling plots by size classes (height for seedlings, dbh for saplings) (NPS 2020f). No seedlings or saplings were documented in one Cedar Point sampling plot.

	Seedlings (height in cm)				**Saplings (dbh in cm)**			
Plot	**5–15**	**15–30**	**30–50**	**50–137**	**0–1**	**1–2.5**	**2.5–5**	**5–10**
Cedar Pt-7	–	–	–	–	x	–	–	x
Cedar Pt-12	–	–	–	–	x	x	–	–
Cedar Pt-16	–	–	–	x	–	–	–	–
TRA-2	x	–	–	–	–	–	–	–
TRA-3	–	–	–	–	–	x	–	–
TRA-4	x	x	x	–	x	–	–	–
TRA-6	–	–	–	–	x	x	–	–
TRA-7	–	–	–	–	x	x	x	–
TRA-8	x	–	–	x	x	x	x	–

In a study of redbay mortality on Fort George Island, Fraedrich et al. (2008) found a dramatic increase in mortality of trees from 2005 to 2006. Of the 132 redbay trees (>2.5 cm [1 in] diameter) monitored, mortality increased from 9.8% in July 2005 to 92.4% in October 2006 (Figure 14). By December of 2006, all redbay trees >10.3 cm (4 in) in diameter were dead. However, among 222 smaller redbay stems (<2.5 cm diameter) first surveyed in July 2006, only one had died by January of 2007 (Fraedrich et al. 2008).

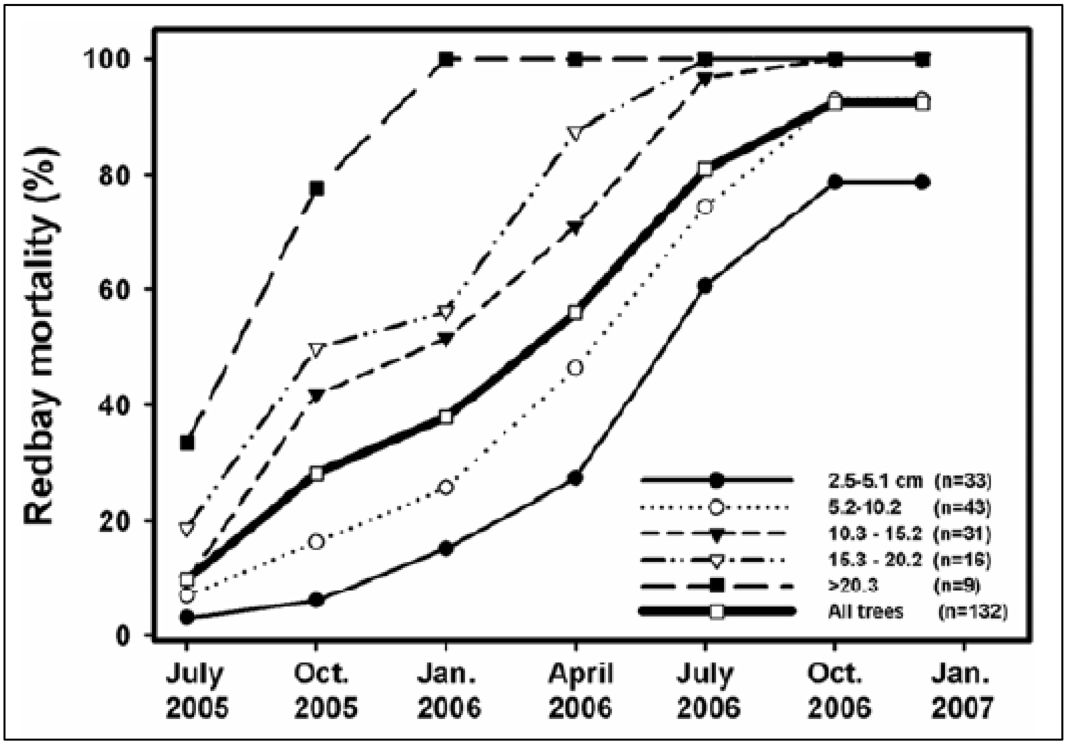

Figure 14. Cumulative percent redbay mortality by diameter class on Fort George Island at TIMU. Reproduced from Fraedrich et al. (2008).

Threats and Stressor Factors

Threats to TIMU's hardwood hammock communities include LWD, lethal bronzing disease (LBD) in palms, climate change, storm events, development, and invasive species (see discussion in "Invasive Plant Species Presence" section). As mentioned previously, redbay at TIMU has been severely impacted by LWD, a fungus transmitted by a non-native ambrosia beetle (*Xyleborus glabratus*). According to Fraedrich et al. (2008, p. 219), LWD was common "in urban, residential, and natural areas on a range of sites including swamps, mesic flatwoods, and xeric dune and upland coastal plain forests." The first sign of LWD is often wilting of branch tips or entire branches; this wilting then spreads throughout the entire crown and trees typically die soon after (Fraedrich et al. 2008). Larger trees are more likely to be affected than small trees, with Shearman and Wang (2016) finding a 5% increase in the likelihood of mortality with each 1-cm (0.4-in) increase in tree diameter.

At TIMU and across the southeastern coast, some re-sprouting has occurred from stumps of redbay trees killed by LWD (Fraedrich et al. 2008, Merten 2015). Some of the sprouts grow into the forest mid-story, but others succumb to herbivory, intense canopy shading (particularly by saw palmetto [*Serenoa repens*]), or renewed LWD infection (Figure 15) (Merten 2015). In LWD-impacted plots across Georgia and South Carolina, Shearman and Wang (2016) found that redbay regained much of the basal area lost to LWD mortality approximately 10 years after the initial infection. However, the stand structure had changed, with the majority of redbay stems in the 1–5 cm (0.4–2.0 in) diameter size class. This suggests that redbay may not be at immediate risk of extirpation, but it is unclear whether the species will ever fully recover from the disease (Shearman and Wang 2016).

Figure 15. The photo on the left shows redbay re-sprouting from the trunk of a tree killed by LWD infection. On the right, this re-sprout has wilted, indicating the continued presence of LWD (Merten 2015).

Along Florida’s coasts, several species of palms have been impacted by lethal bronzing disease (LBD), caused by a phytoplasma identified in the Tampa area in 2006 (Bahder and Helmick 2019). This phytoplasma lives in the phloem tissue of the plant, where sap is transported, and is spread between plants by piercing insects that feed on the sap, such as planthoppers and leafhoppers. Symptoms include premature fruit drop, rotting inflorescence, and collapse of the “spear leaf”, the central growth point of the plant (Figure 16) (Bahder and Helmick 2019). The disease is now confirmed in 31 Florida counties, with the Jacksonville area currently representing its northernmost extent. LBD has been found in 16 different palm species, only one of which (cabbage palmetto) occurs at TIMU. Once symptoms develop, the palm cannot recover and should be removed to reduce the risk of spread to other palms (Bahder and Helmick 2019).

Figure 16. The progression of lethal bronzing disease (LBD) from an earlier stage when only older leaves are discolored (left) to 3 months later when more leaves are discolored and the spear leaf has collapsed (right) (photos by Brian Bahder, University of Florida/IFAS).

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the SECN (Davey et al. 2007). Climate also affects the spread of invasive plant species and pests, which also threaten TIMU's hardwood hammocks (Davey et al. 2007). As a result of global climate change, temperatures are projected to increase across the southeast over the next century (Carter et al. 2018). Warming temperatures will likely allow invasive plants and forest pests to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). Temperature changes may also alter weather patterns, resulting in more storms with forest-damaging high winds (Carter et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014). In an effort to estimate the magnitude of potential change that forests on eastern national park lands may experience, Fisichelli et al. (2014) assessed the percentage of tree species expected to show large decreases or large increases in habitat suitability under climate change scenarios. Across 121 national park properties in the eastern U.S., estimated potential forest change ranged from 22–77%. The estimated forest change for TIMU (i.e., percent of tree species expected to experience large increases or decreases in habitat suitability) was 39% (Fisichelli et al. 2014). Habitat suitability projections for several of TIMU's key hardwood hammock tree species are shown in Table 14.

Table 14. Potential change in habitat suitability by 2100 for select TIMU hardwood hammock tree species based on two future climate scenarios (the “least change” scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the “major change” scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific name	Common name	Least change scenario	Major change scenario
Prunus serotina	black cherry	large decrease	large decrease
Quercus virginiana	live oak	small increase	large increase
Quercus laurifolia	laurel oak	no change	small increase
Pinus taeda	loblolly pine	small decrease	no change
Ilex opaca	American holly	large decrease	large increase
Diospyros virginiana	common persimmon	no change	large increase
Magnolia grandiflora	southern magnolia	small increase	small increase
Magnolia virginiana	sweetbay	no change	large increase
Ulmus alata	winged elm	new potential habitat	new potential habitat

Due to its location just off the Atlantic Ocean, TIMU is regularly impacted by tropical storms and hurricanes (NPS 2016c). While the effects of these storms on hardwood forest types are rarely catastrophic, they can influence forest structure and composition by creating “light gaps” in the tree canopy (Horvitz et al. 1995, Harcombe et al. 2009). While the creation of some canopy gaps is a natural forest process, large gaps may create opportunities for invasive plant species to become established (Horvitz et al. 1995). As a result of global warming, the intensity of hurricanes is projected to increase over the next century (Knutson et al. 2010), which may in turn increase storm impacts on vegetation communities near the coast.

In the early 2000s, the lands adjacent to TIMU experienced some of the most rapid development in the state of Florida (Byrne et al. 2012b). A 2003 North Jacksonville Vision and Master Plan by the city’s Planning and Zoning Department called for over 34,000 new single-family homes in the area between the Trout River, Nassau River, and the Atlantic Ocean (Miller Sellen Conner & Walsh 2003). This area of Jacksonville, just west of TIMU, is expected to be home to over 112,000 people by 2025. This increase in development and urbanization will expose park vegetation communities to additional internal stressors, such as habitat fragmentation, invasive species, hydrological alterations, and herbicide use (Byrd 2007).

Data Needs/Gaps

Additional information is needed regarding the presence and abundance of invasive plant species across TIMU’s hardwood hammock communities. Also, further research is needed to better understand LBD and its impacts on Florida’s vegetation communities. For example, specific vectors (i.e., transmitting insects) and alternative hosts for the phytoplasma and vectors have not been identified (Bahder et al. 2018). It is also unclear how LBD was introduced to Florida and what the current and potential rates of spread may be.

Overall Condition

Acreage

The project team assigned this measure a *Significance Level* of 3. Based on 2012 aerial photos, O'Hare et al. (2020) classified 1,660.4 ha (4,102.9 ac) or 9.4% of TIMU as hardwood hammock vegetation. Given the lack of historic park-wide vegetation mapping, it is unclear whether the extent of hardwood hammocks within TIMU has changed over time. However, given the lack of fire and other major disturbances in these areas, it is likely that hardwood hammock acreage has at least remained stable and has possibly increased. Therefore, this measure is assigned a *Condition Level* of 0, indicating no concern at this time.

Plant Species Richness

This measure was assigned a *Significance Level* of 2. Over time, 196 unique plant taxa have been documented in TIMU's hardwood hammocks, 16 of which are considered non-native (Appendix G). During 2009 SECN vegetation monitoring, Byrne et al. (2012a, 2012b) documented similar numbers of species in hardwood hammocks at TIMU (56) and in comparable habitat at CUIS (69). Zomlefer et al. (2007) identified more plant species in TIMU's maritime hammocks (100) than in comparable habitat at CUIS (57) and FOMA (45) (Zomlefer et al. 2004, Zomlefer et al. 2008). The plant species richness measure is assigned a *Condition Level* of 0 for no current concern.

Invasive Plant Species Presence/Absence

A *Significance Level* of 3 was assigned for this measure. While some information on invasive plant presence was available for selected areas of TIMU, a park-wide survey of invasive plants or of hardwood hammocks specifically has not been completed. Most of the available data is from more than 5 years ago. As a result, a *Condition Level* was not assigned for this measure at this time.

Redbay Presence/Persistence

A *Significance Level* of 2 was assigned for this measure. TIMU has experienced a significant decline in tree-sized redbays, with Fraedrich et al. (2008) reporting 100% mortality of redbays >10.3 cm (4 in) in diameter in their Fort George Island study area. However, the species appears to be persisting in smaller sizes classes (Fraedrich et al. 2008, Boyle and Rico 2021), suggesting it is not at immediate risk of extirpation, although impacts to stand structure may be significant. Therefore, this measure is assigned a *Condition Level* of 3 for high concern.

Weighted Condition Score

The Weighted Condition Score for hardwood hammocks at TIMU is 0.29, indicating good condition (Table 15). Given the limited available data for most measures, a trend was not assigned and a moderate confidence border was applied. Continued monitoring and additional invasive plant surveys should allow future assessments to assess trends and increase confidence.

Table 15. Current condition of hardwood hammocks at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = 0.29**
Acreage	3	0	–
Plant Species Richness	2	0	–
Invasive Species Presence/Absence	3	n/a	–
Redbay Presence/Persistence	2	3	–
Overall	**–**	**–**	🟢

4.1.6 Sources of Expertise

- Forbes Boyle, SECN Botanist

4.2 Salt Marshes

4.2.1 Description

Wetlands, including salt marshes, perform critical ecosystem functions, including nutrient cycling, pollutant filtration, shoreline stabilization, and flood control (UNF & JU 2008, 2019). In addition, salt marshes provide valuable feeding, breeding, and nursery habitat for birds, herpetofauna, fish, and invertebrates (UNF & JU 2019, O'Hare et al. 2020). The salt marshes at TIMU are part of the largest remaining estuarine marsh system on the east coast of Florida (NPS 1996, Dix et al. 2017). Estuarine systems have a connection to the ocean but also receive freshwater inputs (Gregory et al. 2011). This mixing of salt and fresh water often contributes to high biological productivity (Parman et al. 2012). Estuarine wetlands within TIMU below the mean tide line are claimed under sovereignty by the State of Florida, with the City of Jacksonville having jurisdiction over zoning and land use (Anderson 2005).

Salt marsh within the Theodore Roosevelt Area of TIMU (SMUMN GSS photo).

The vegetation in salt marshes must be adapted to salinity and regular tidal inundation (Zomlefer et al. 2007). At TIMU, marsh areas with higher salinity are often dominated by smooth cordgrass (*Spartina alterniflora*), while areas with lower salinity (often at slightly higher elevations) tend to be dominated by needlegrass rush (*Juncus roemerianus*). The major salt marsh vegetation types found at TIMU and the common plant species in each type are presented in Table 16.

Table 16. Salt marsh vegetation types at TIMU and their common plant species. As described by O'Hare et al. (2020).

Vegetation Class	Common Plant Species
Southern Atlantic Coast Salt Marsh	Smooth cordgrass (*Spartina alterniflora*), Carolina sealavender (*Limonium carolinianum*), chickenclaws (*Sarcocornia perennis*)
Needlerush High Marsh	Needlegrass rush (*Juncus roemerianus*), smooth cordgrass
Glasswort-Saltgrass-Saltmarsh	Chickenclaws, smooth cordgrass, turtleweed (*Batis maritima*), Carolina sealavender, saltgrass (*Distichlis spicata*)

4.2.2 Measures

- Extent of estuarine/brackish wetlands
- Plant species richness
- Elevation of saltwater marshes (using sediment elevation tables)
- Water quality

4.2.3 Reference Condition/Values

Similar to upland hardwood hammocks, there is no known appropriate historical reference condition available for salt marshes at TIMU. The recent park vegetation map (O'Hare et al. 2020) can serve as a point of comparison for future assessments of salt marsh extent. Comparisons to plant species richness at similar salt marshes in nearby parks may provide some insight regarding conditions at TIMU. Similarly, changes in marsh elevations at nearby areas may such as the Guana Tolomato Matanzas National Estuarine Research Reserve, south of TIMU in St. John's County, could be compared to elevation changes at TIMU in future assessments.

4.2.4 Data and Methods

Several of the data sources utilized for the Hardwood Hammock component in this NRCA were also used in this component, including Zomlefer et al. (2007) and vegetation mapping by O'Hare et al. (2020). Several baseline surveys or park reports provided additional information on the species composition of TIMU's salt marshes. The park's Water Resources Management Plan (NPS 1996) listed typical plant species found in TIMU's salt marshes in 1984. The City of Jacksonville (1998) conducted baseline vegetation and wildlife surveys at Cedar Point in 1995 that included salt marshes.

Fox and Montague (2003) compared aerial photos of a marsh study area within TIMU (Figure 17) from 1943 and 1999 to estimate marsh loss over time. Photos were scanned and georectified in a GIS, then 13 sample areas were converted to grids. The "Map Calculator" tool in Esri's ArcView program was used to calculate change in area over the time period (Fox and Montague 2003).

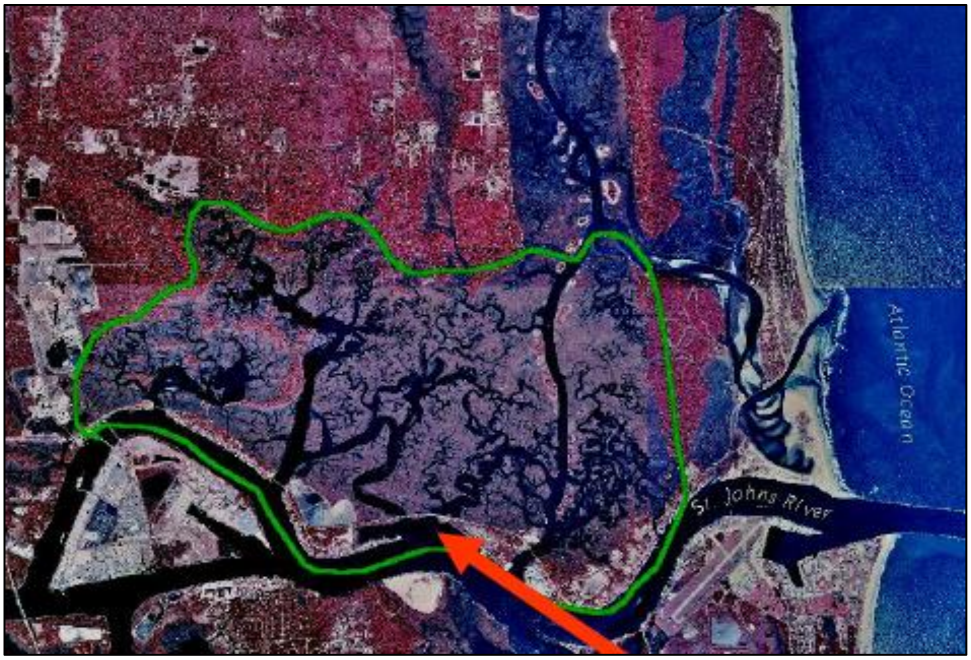

Figure 17. Fox and Montague (2003) marsh change study area. The orange arrow shows the location where construction of the Heckscher Drive causeway blocked tidal creek mouths.

Steinway-Rodkin and Montague (2004) conducted vegetation and soil sampling throughout TIMU salt marshes to better characterize these tidal wetlands and provide data for the park's vegetation database and maps. Eighty-one randomly selected sites were visited, with a focus on lower salinity and higher elevation marshes, as well as nearly monotypic stands (*Spartina alterniflora* or *Juncus roemerianus*). Plant species composition, height, and percent cover were documented along a 50 m x 1m (164 x 3 ft) belt transect at each site (Steinway-Rodkin and Montague 2004).

The NPS Water Resources Division (WRD) used GIS data and object-based image analysis to classify and quantify the types of salt marsh in TIMU (Cantor 2017). The primary focus was on the two most dominant types, smooth cordgrass-dominated marshes and needlegrass rush-dominated marshes, but seven other land cover classes were also mapped. The analysis utilized aerial imagery taken by the U.S. Geological Survey (USGS) in 2012 and elevation data (LiDAR) collected in 2007. Following mapping and classification, the results were compared to National Oceanic and Atmospheric Administration (NOAA) land cover data from 4 years (1996, 2001, 2006, 2010) to assess changes in marsh type over time (Cantor 2017).

The SECN initiated a saltwater marsh elevation monitoring program that includes six sampling locations with three replicate data-collection stations spread throughout TIMU (Figure 18) (DeVivo et al. 2015). The program utilizes a rod-surface elevation table (RSET) technique (Cahoon et al. 2002), which offers a non-destructive process to precisely measure sediment elevation over a long period of time relative to a fixed subsurface (Figure 19) (Asper and Curtis 2013). With repeated measurements over time, a rate of change can be calculated to detect any shifts or trends of concern. The sampling locations at TIMU were installed in 2014, and sampling occurred from 2015–2018

(NPS 2020e). At each station, measurements were taken in four directions (at right angles) around a central point using nine different measuring pins along the rod arm. At some TIMU stations, the same directions/angles could not be sampled during each visit due to challenges in positioning the RSET equipment (Lisa Cowart Baron, SECN Coastal Ecologist, pers. comm., 12 January 2021). For the purpose of this assessment, SMUMN GSS analysts excluded any measurements taken at an angle that differed by ≥9° from the original sampling angle. Surface elevations may also be impacted or skewed by natural features or activities (e.g., holes, plant stems, crustacean "chimneys"). If pin measurements were influenced by these features, as noted in the SECN dataset, SMUMN GSS analysts excluded these measurements.

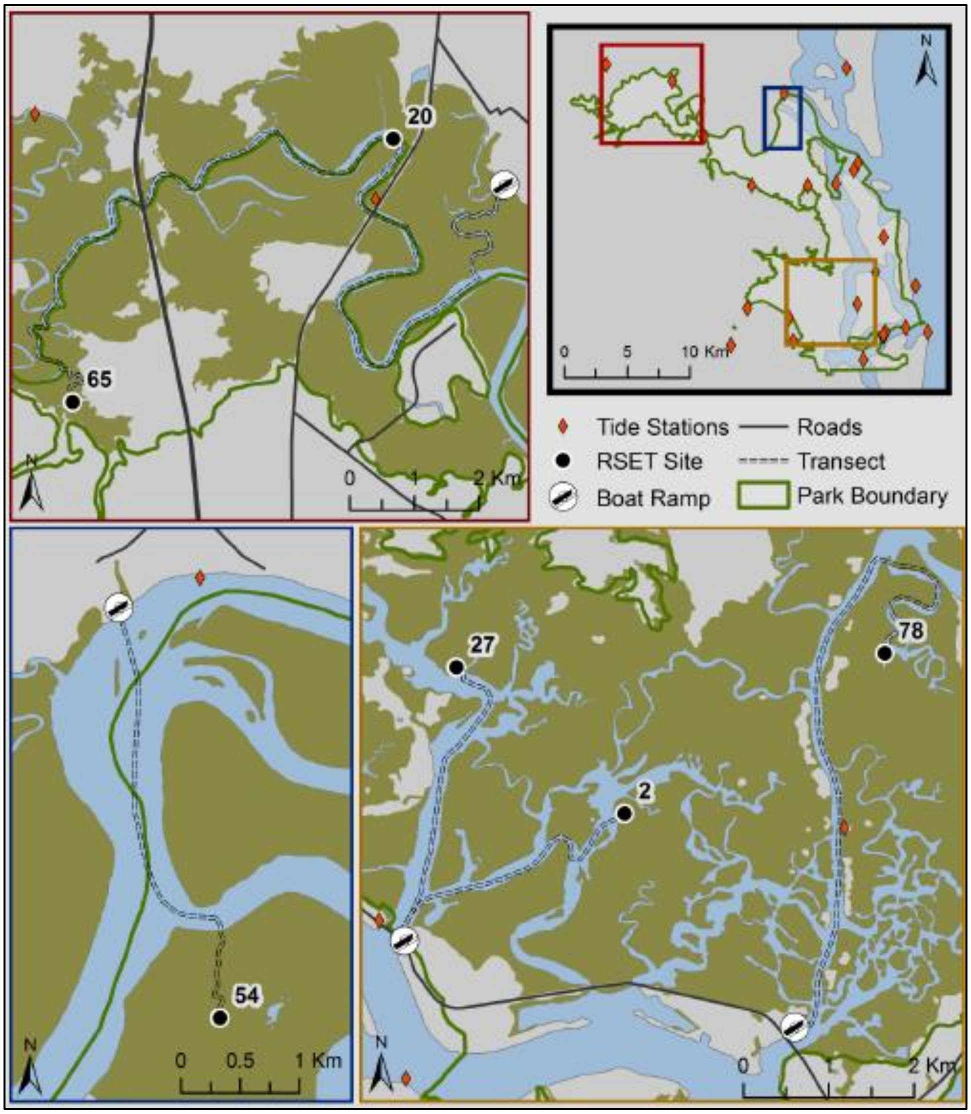

Figure 18. Sediment elevation table monitoring locations within TIMU (reproduced from DeVivo et al. 2015).

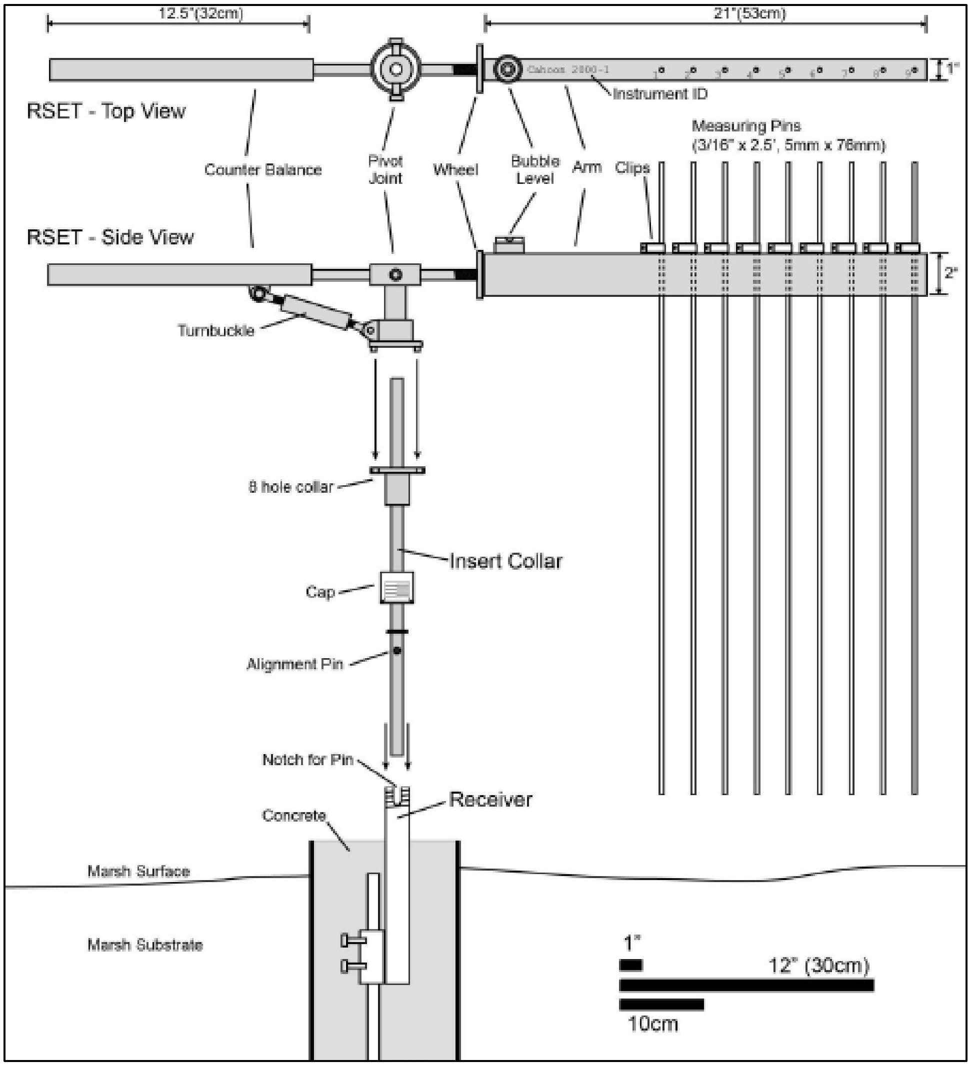

Figure 19. Detailed drawing of the rod-surface elevation table measuring equipment (reproduced from DeVivo et al. 2015).

4.2.5 Current Condition and Trend

<u>Extent of Estuarine/Brackish Wetlands</u>

Fox and Montague (2003) compared 1943 and 1999 aerial images of a marsh study area within TIMU, north of the St. Johns River and west of Fort George Island (see Figure 17). Over this time, approximately 12% of salt marsh area (~500 ha of the 4,700 ha study area) converted to open water. Marsh loss varied across the study area, with some sampling areas experiencing just 6–7% loss, while other areas declined up to 25% (Figure 20) (Fox and Montague 2003).

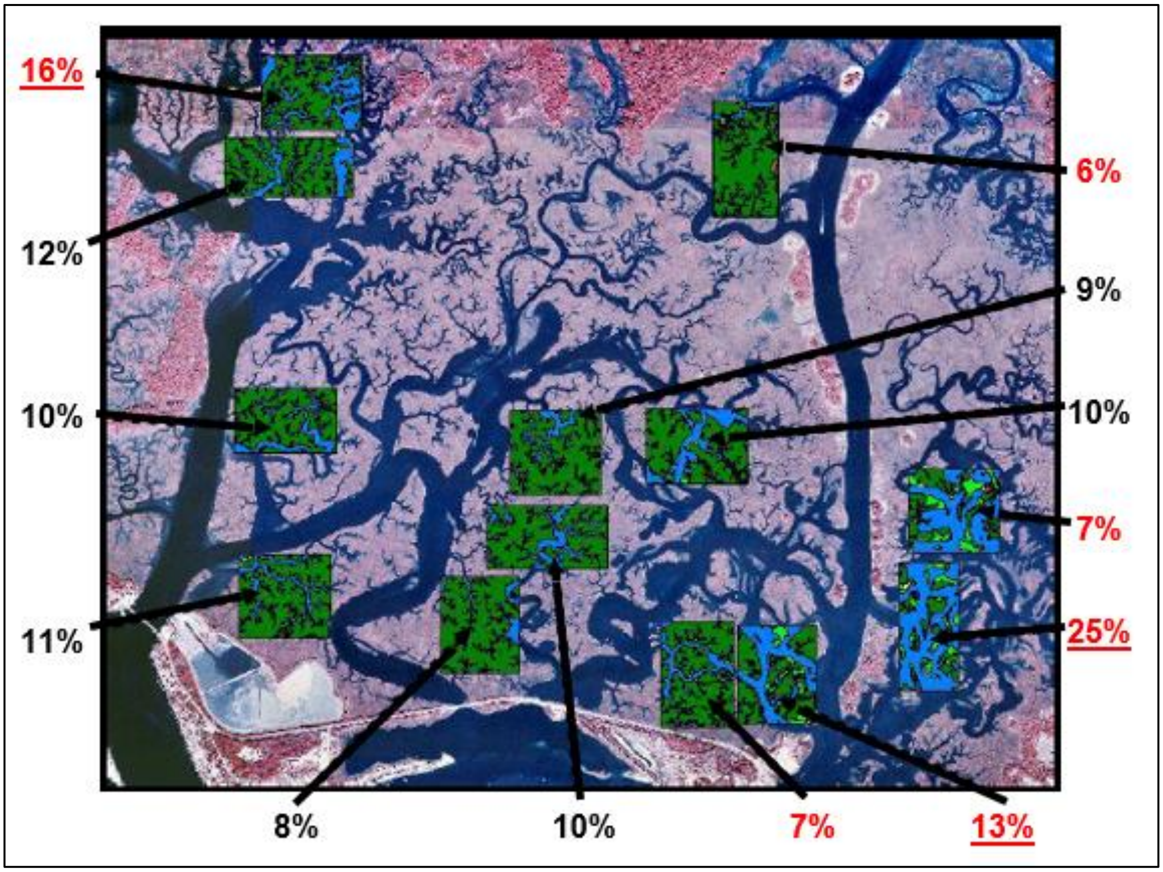

Figure 20. Marsh loss (%) between 1943 and 1999 in selected sample areas within Fox and Montague's (2003) study boundary. Red numbers indicate extreme high and low values, with the highest losses underlined.

Based on 2012 aerial imagery, the NPS WRD identified 7,850 ha (19,398 ac) of salt marsh: 4,701 ha (11,617 ac) of cordgrass-dominated marsh and 3,149 ha (7,781 ac) of needlegrass rush marsh (Cantor 2017). This accounted for 42.4% of the park area at the time. When compared to land cover maps from 1996 and 2010, the authors observed very little change in cover over time and no notable loss of salt marshes (Cantor 2017).

According to the TIMU vegetation mapping report (O'Hare et al. 2020), estuarine/brackish wetlands (i.e., salt marshes) cover 8,878 ha (21,938 ac) of the park, which accounts for approximately 48% of the park's total area (Table 17). The vast majority of this area is split between Southern Atlantic Coast Salt Marsh (50%) and Needlerush High Marsh (42%). These were the two most prevalent vegetation classes in the park (O'Hare et al. 2020). The extent of salt marsh communities at TIMU is shown in Figure 21 and Figure 22.

Table 17. Extent of salt marsh vegetation types at TIMU based on 2012 aerial imagery, as reported in O'Hare et al. (2020).

Vegetation Class	Area in ha (ac)
Southern Atlantic Coast Salt Marsh	4,417.2 (10,915.1)
Needlerush High Marsh	3,742.4 (9,247.7)
Glasswort-Saltgrass-Saltmarsh	718.5 (1,775.5)
Total	**8,878.1 (21,938.3)**

Plant Species Richness

Over time, various surveys of TIMU have documented 43 different plant species across the park's salt marshes (Appendix H). Only two of these species (4.7%) are considered non-native (Mexican tea [*Dysphania ambrosioides*] and New Zealand spinach [*Tetragonia tetragonioides*]). Due to differences in methodology (e.g., opportunistic observations vs. scientific sampling) and survey locations (e.g., smaller study area vs. park-wide), the various studies over time cannot be accurately compared to determine if there are any trends in species richness. In an intensive floristic survey within selected areas of TIMU (Thomas Creek, Cedar Point, Fort Caroline National Memorial/Theodore Roosevelt Area, Kingsley Plantation, and Sohn Purchase), Zomlefer et al. (2007) documented 24 plant species in salt marshes. For comparison, in similar floristic surveys of the nearby Cumberland Island National Seashore (CUIS) Zomlefer et al. (2008, 2011) documented 26 plant species in comparable salt marsh communities.

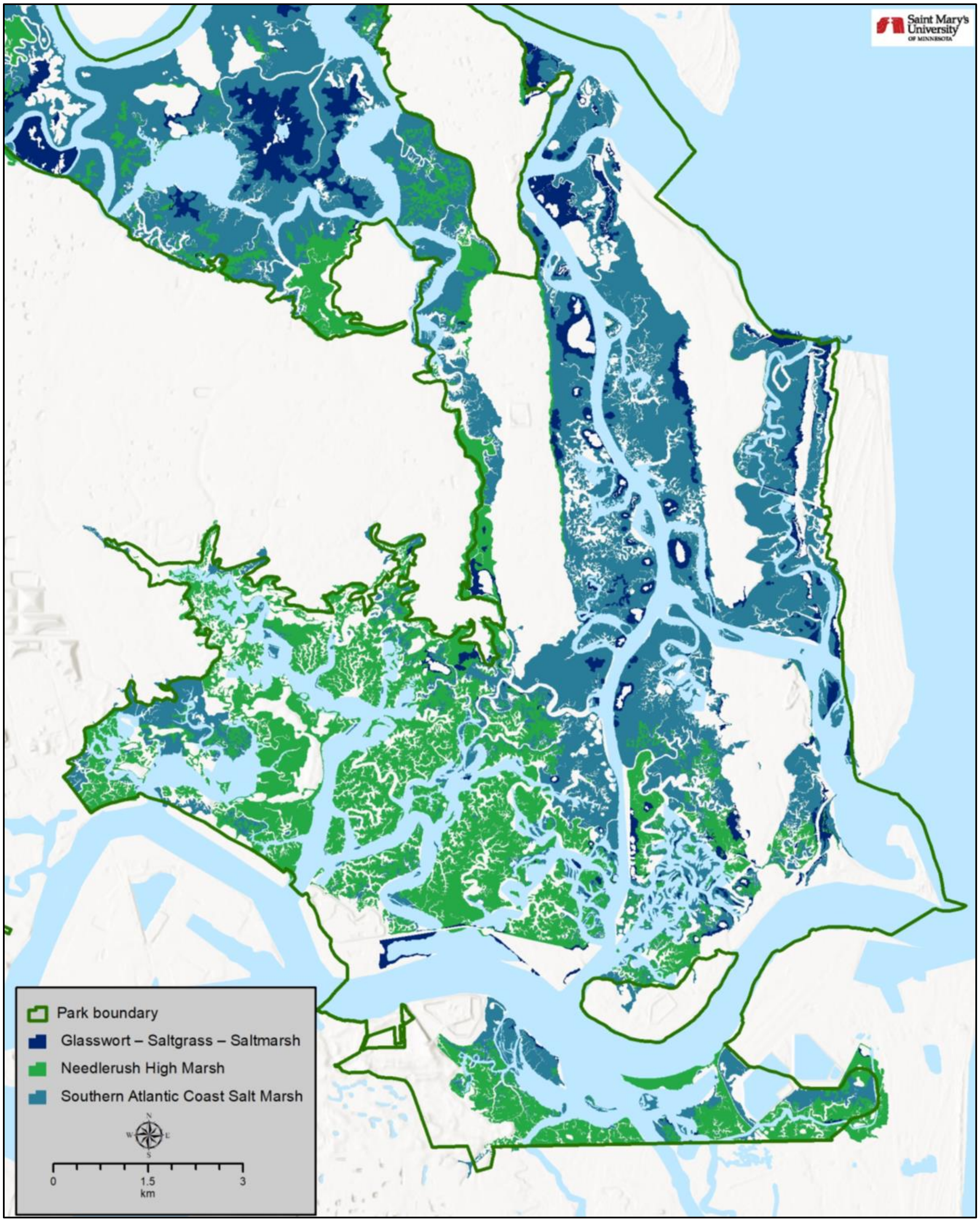

Figure 21. Extent of salt marsh communities in the southern portion of TIMU, as mapped by O'Hare et al. (2020).

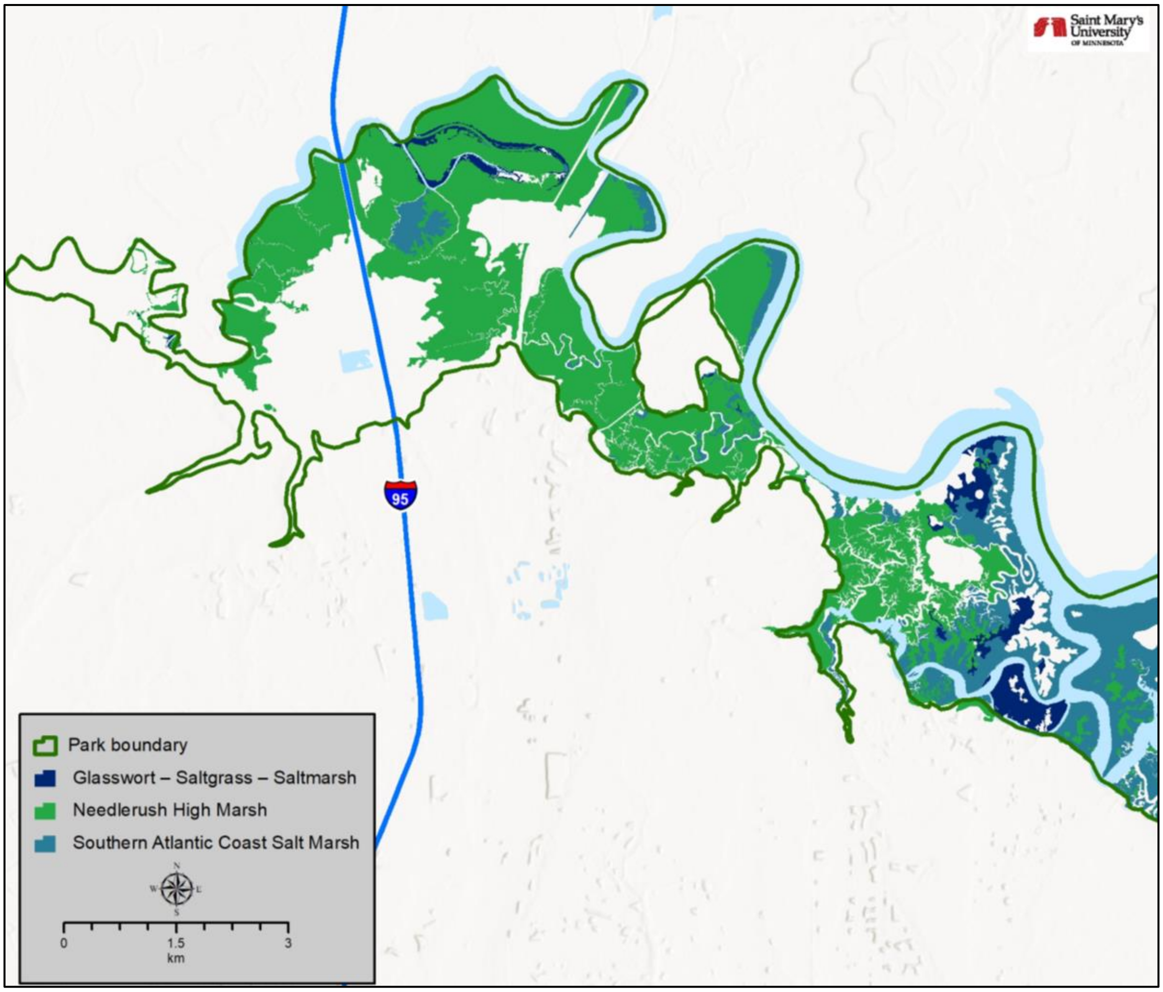

Figure 22. Extent of salt marsh communities in the northern portion of TIMU, as mapped by O'Hare et al. (2020).

Elevation of Saltwater Marshes (Using Sediment Elevation Tables)

Surface elevation is a key factor in determining the presence, density, and composition of vegetation in estuarine environments (Cooper and Waits 1973, Hagen et al. 2013, Cahoon et al. 2019). Sea level rise and subsidence reduce saltmarsh elevation while sediment accretion increases elevation (NPS 2017b). If accretion rates do not match or exceed sea level rise, a marsh becomes submerged and may eventually transition from a vegetated wetland to a mud flat or shallow open water (NPS 2017b). In Atlantic coastal marshes, cordgrass often dominates estuarine wetlands at lower elevations, while needlegrass rush dominates at slightly higher elevations (McManamay 2017, O'Hare et al. 2020).

Data were collected at six sampling locations with three replicate RSET stations between 2015 and 2018; these data have not been reviewed or quality-checked, and are therefore considered provisional (NPS 2020e). To estimate surface elevation change, the change (in mm) across all nine pins at each angle/direction can be averaged, and the mean for each of the four directions can be averaged for an overall station mean. Across the six TIMU locations, some sampling stations showed a loss in elevation between 2015 and 2018 while others showed a gain (Figure 23, Appendix I). The greatest elevation loss was 7 mm (0.3 in) and the greatest gain was 50.8 mm (2 in). Two locations (TIMU54 and TIMU78) experienced elevation gain at all three sites, with gains from 5.5–43.6 mm (0.2–1.7 in) (NPS 2020e). Due to the low number of sampling periods, large gaps between sampling periods, and inconsistent sampling (see Appendix I), it is not recommended that the change in elevation data shown in Figure 24 be used for planning purposes. Further, because of the time between last sampling and this report, the calculated elevation change may not reflect the current elevation change for TIMU at the time of this report (William "Ches" Vervaeke, USGS Ecologist, written communication, March 2021).

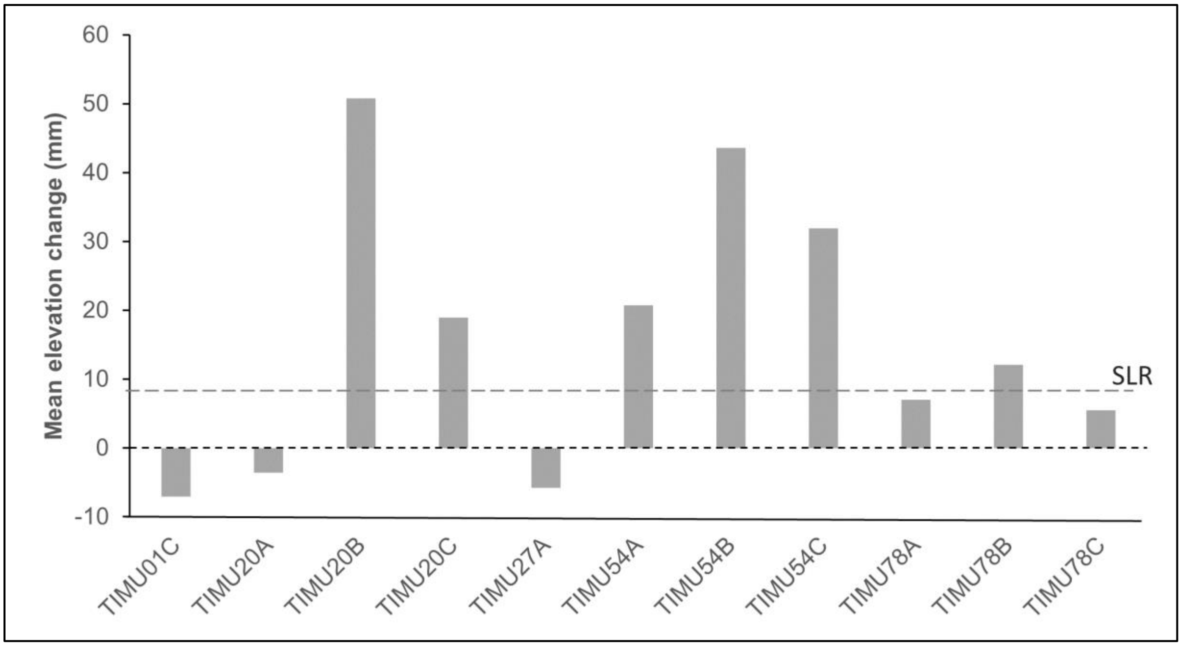

Figure 23. Mean change in sediment elevation table, 2015–2018, at TIMU salt marsh sampling locations (NPS 2020e). The gray dashed line represents three years of average sea level rise (8.1 mm). Note that TIMU65 is not included because it was only sampled in 2015 and 2016.

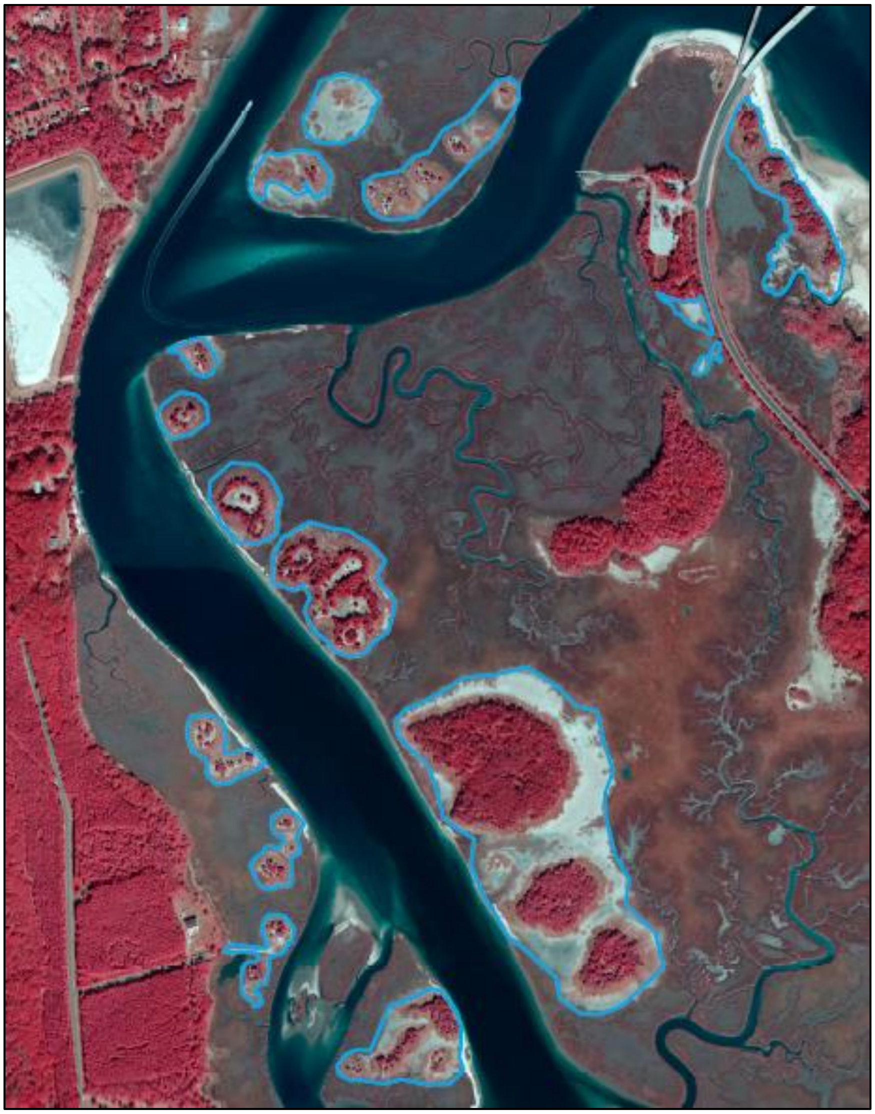

Figure 24. Spoil islands (outlined in blue) created from dredged material along northern Clapboard Creek, part of the Intracoastal Waterway (reproduced from SJRWMD 2012).

Water Quality

Water quality influences the vegetation and aquatic organisms present within a wetland (UNEP 2008). Degraded water quality could reduce the biodiversity and productivity of wetlands, which can impact their ability to perform ecosystem services. Important parameters include dissolved oxygen, nutrients, salinity, clarity, and contaminants. Available information on the water quality of TIMU's wetlands is discussed in detail in Chapter 4.7 of this assessment. In general, most water quality parameters (dissolved oxygen, nitrogen, phosphorus) were found to be in good or moderate condition in the majority of the park, although water clarity has recently become a concern in some areas of TIMU (Starkey et al. 2019). During 2018 monitoring, the areas of highest concern were on the Nassau River in the northern portion of TIMU (Starkey et al. 2019).

Threats and Stressor Factors

Threats to the park's salt marshes include climate change-related sea level rise (SLR), storm events, mangrove migration, boat wakes, dredging and related spoil island creation, armored surfaces on private inholdings, and siltation or other impacts from hydrologic flow alteration.

As discussed in Chapter 2 of this NRCA, temperatures are projected to increase across the southeastern United States over the next century as a result of global climate change (Carter et al. 2014). Sea level rise is occurring around TIMU, averaging 2.7 mm/yr (0.1 in/yr) from 1928–2019 (see Figure 9 in Chapter 2) (NOAA 2020). As a result of global climate change, the rate of SLR is expected to increase during the remainder of the 21st century, with an overall rise between 0.28–0.98 m (0.9–3.2 ft) by 2100 (IPCC 2013). Salt marshes can naturally gain elevation through accretion of sediment and plant matter, but if accretion rates do not keep up with accelerating SLR, tidal salt marshes may become permanently inundated, killing off the wetland vegetation (Hagen et al. 2013, Linhoss et al. 2015). Modeling suggests that SLR will have more of an impact on mean high water levels (i.e., "high tide") than mean low water levels in TIMU's tidal wetlands (Table 18) (Alizad et al. 2016b). These high water levels would trigger a loss in biomass (e.g., plants) density, particularly along the edges of tidal creeks (Alizad et al. 2016b).

Table 18. Estimated increase in mean low and high water levels within a TIMU marsh study area under two modeled SLR scenarios (Alizad et al. 2016b).

Projected SLR	Est. increase in mean low water	Est. increase in mean high water
15 cm	6 (±5) cm	19 (±1) cm
30 cm	17 (±9) cm	32 (±2) cm

Warming ocean temperatures due to climate change are projected to increase the intensity of Atlantic hurricanes, with more precipitation and higher wind speeds (Karl et al. 2009). For every 1°C (1.8°F) increase in ocean surface temperatures, hurricane rainfall amounts are likely to increase by 8–16%, along with wind speed increases of 1–8% (Gutowski et al. 2008). Flooding and increased wave energy from hurricanes can contribute to salt marsh erosion and shoreline modification (Howes et al. 2010, Dix et al. 2017).

The northeastern Florida coast is an ecotone or transition zone between grass-dominated salt marshes, common north of Florida, and mangrove forests to the south (Stevens et al. 2006, McGinley et al. 2016). However, these forests have been migrating north as a result of milder winters with fewer freezes and extreme cold events (days colder than −4°C [25°F]) (Stevens et al. 2006, Rodriguez et al. 2016). Between 1984 and 2011, mangrove forests expanded greatly, doubling in area at the northern end of their range in Florida (Rodriguez et al. 2016). Observations suggest black mangrove (*Avicennia germinans*) may be migrating north along Florida's Atlantic coast at rates up to 4.5 km/yr (2.8 mi/yr) (Williams et al. 2014). In 2006, the northern extent of mangrove forests was between Cape Canaveral and St. Augustine, over 64 km (40 mi) south of TIMU (Stevens et al. 2006). As of 2019, the northernmost population was near Fort George Inlet, at the southern edge of TIMU (Cavanaugh et al. 2019). Salt marsh plant species cannot compete with the taller mangrove trees for light and will be shaded out if mangroves invade (Kangas and Lugo 1990, Stevens et al. 2006). This shift in habitat will impact wildlife communities in the area and may trigger changes in species composition (McGinley et al. 2016). If global warming continues as expected, mangrove migration is likely to continue and may even accelerate (Rodriguez et al. 2016, Cavanaugh et al. 2019). Based on current climate projections and species distribution models, mangrove forests could expand into Georgia and South Carolina by 2100 (Osland et al. 2013, Cavanaugh et al. 2019).

Waves generated by boat wakes can significantly disturb shorelines, sometimes contributing to the erosion and loss of salt marsh vegetation and oyster reefs (Herbert et al. 2018). Boat wakes may also re-suspend sediment, increasing turbidity and potentially transporting sediment out of the estuarine system, where it is needed for accretion to maintain marsh elevation (Herbert et al. 2018). Recreational boat traffic is increasing in estuaries worldwide and demand for waterfront access, including new marina construction, is high in Florida (Frazel 2009, Dix et al. 2017, Herbert et al. 2018).

Human modification of rivers and estuarine systems often threaten salt marshes, including those at TIMU. To stop or prevent shoreline erosion, landowners and managers may install bulkheads, seawalls, or other armored surfaces; however, these structures often just shift erosion to other areas and can prevent the natural upslope migration of salt marshes (Dix et al. 2017, Herbert et al. 2018). Dredging to maintain shipping channels has altered river and coastal hydrology in northeast Florida (Frazel 2009, Dix et al. 2017). Dredging can modify water levels, salinity, and sediment dispersal/accretion, threatening the survival of salt marsh vegetation (Kennish 2001, UNF and JU 2019). Historically, dredge spoil was sometimes used to create islands within the tidal salt marshes, essentially replacing wetlands with upland habitat (Figure 24) (Anderson 2005). Human development and activities can also reduce freshwater inflow to estuarine marshes; the loss of this input can elevate salinity levels, which may harm marsh vegetation (Durako et al. 1988, Alizad et al. 2016b).

Data Needs/Gaps

Additional monitoring data are needed to assess changes in the sediment elevation table of TIMU’s salt marshes. SECN scientists have found that current RSET monitoring stations at the park are not suitable for consistent and reliable long-term data collection (Lisa Cowart Baron, pers. comm., 12 January 2021). New stations were established in 2020 and data collection will begin in 2021 (Lisa Cowart Baron, pers. comm., February 2021). At least 5 years of data are recommended for analyzing trends in elevation change (Lynch et al. 2015). In addition, further study of river and creek hydrology within the park will help managers better understand the processes that maintain TIMU’s salt marshes (e.g., freshwater inflow, tidal regime, sedimentation/accretion) (NPS 1996, Dix et al. 2017).

McGinley et al. (2016) recommends monitoring of mangrove migration, as the advance is happening relatively quickly. At TIMU, this could consist of an “early detection” approach, similar to that taken for exotic invasive species. This will allow managers to determine when and where mangroves first arrive at TIMU and whether any management action should be taken.

Overall Condition

Extent of Estuarine/Brackish Wetlands

The project team assigned this measure a *Significance Level* of 3. While evidence suggests that the extent of salt marsh within TIMU has declined since the 1940s (Fox and Montague 2003), marsh area has been relatively stable over the past two decades (Cantor 2017, O'Hare et al. 2020). As a result, this measure is assigned a *Condition Level* of 1 at this time, indicating low concern.

Plant Species Richness

This measure was also assigned a *Significance Level* of 3. Over time, 43 different plant species have been documented across the park's salt marshes, only two of which are non-native (Appendix H). In intensive floristic surveys, research teams documented 24 plant species in TIMU's salt marshes (Zomlefer et al. 2007) and 26 plant species in similar marshes at CUIS (Zomlefer et al. 2008, Zomlefer and Kruse 2011). Therefore, species richness is assigned a *Condition Level* of 1 for low concern.

Elevation of Saltwater Marshes (Using Sediment Elevation Tables)

A *Significance Level* of 3 was assigned for this measure. Limited RSET data from TIMU's salt marshes show mixed results; some locations gained elevation while others lost elevation. However, given the short timeframe for this dataset (2015–2018) and its provisional nature, no conclusions can be drawn regarding condition at this time and a *Condition Level* has not been assigned.

Water Quality

This measure was assigned a *Significance Level* of 3. As detailed in Chapter 4.7 of this report, estuarine water quality parameters are generally in good or moderate condition at TIMU, although some concern has arisen over water clarity during recent sampling. As a result, this measure is assigned a *Condition Level* of 1.

Weighted Condition Score

The Weighted Condition Score for TIMU's salt marshes is 0.33, at the upper threshold of the good condition range, but very close to the moderate concern condition range (Table 19). The current trend appears to be stable.

Table 19. Current condition of salt marshes at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Extent of Estuarine/Brackish Wetlands	3	1	–
Plant Species Richness	3	1	–
Elevation of Salt Marshes	3	n/a	–
Water Quality	3	1	–
Overall	**–**	**–**	⇔

4.2.6 Sources of Expertise

- Lisa Cowart Baron, SECN Coastal Ecologist
- William “Ches” Vervaeke, USGS Ecologist

4.3 Herpetofauna

4.3.1 Description

Herpetofauna (i.e., reptiles and amphibians) are vital components of ecosystems in the southeast; because they are often both predators and prey, herpetofauna serve as “critical trophic links” in these ecosystems (Tuberville et al. 2005, p. 538). Amphibians in particular are considered indicators of environmental quality, given their sensitivity to environmental change and degradation (Tuberville et al. 2005, Smrekar 2012). Consequently, amphibian communities have been identified as a priority for SECN monitoring efforts (Byrne et al. 2010).

To date, 43 reptile and 22 amphibian species have been confirmed as present at TIMU (NPS 2020d). These include several species of conservation concern, with the American alligator (*Alligator mississippiensis*) being federally-listed as threatened due to its similarity in appearance to the American crocodile (*Crocodylus acutus*), and the eastern indigo snake (*Drymarchon corais couperi*), which is a federally listed subspecies of the indigo snake (*D. corais*). Two additional species are listed by Florida as state threatened species (eastern pine snake [*Pituophis melanoleucus*], gopher tortoise [*Gopherus polyphemus*]) (FWCC 2018b).

Herpetofauna species of particular concern for additional monitoring in TIMU include the gopher tortoise and the Carolina diamondback terrapin (*Malaclemys terrapin centrata*) (Figure 25). The gopher tortoise has become a species of management interest due to its decline in the majority of its range, and its status as a state threatened species (Hoover and Clarke 2004, Henderson et al. 2018). Historically, gopher tortoises were found throughout longleaf pine communities along the southeast coastal plain; the loss and fragmentation of this habitat has likely contributed to a decline in tortoise populations of up to 80% during the 20th century (Jones and Dorr 2004). The burrows of this long-lived reptile provide habitat for numerous other species, including many species of conservation concern, from invertebrates and amphibians to snakes and lizards. As a result, the gopher tortoise is considered a keystone species of southeastern sandy upland ecosystems (Hoover and Clarke 2004, Henderson et al. 2018). As of 2019, TIMU boundaries contained an estimated 4,006 ha (9,900 ac) of suitable habitat for gopher tortoise conservation (Hoover and Clarke 2004, Kidd 2019).

Figure 25. A gopher tortoise (left, JU photo) and a Carolina diamondback terrapin hatchling (right, North Florida Land Trust photo).

The diamondback terrapin is the only North American turtle adapted to brackish water, and can be found in salt marsh and mangrove habitats from Massachusetts to the Texas coast (Hart et al. 2014, Castellon 2017). There are five known subspecies in Florida, but only the Carolina diamondback terrapin occurs in northeastern Florida (Butler 2002). Diamondback terrapin numbers declined significantly across their range in the 19th and early 20th centuries due to overharvest for human consumption (Castellon 2017, Parks 2019). While harvest has been greatly reduced, the species has not recovered, likely due to a combination of habitat loss, predation, and drowning in crab traps (Castellon 2017, FWC 2021a).

4.3.2 Measures

- Amphibian species richness
- Reptile species richness
- Number of gopher tortoise burrows
- Diamondback terrapin nesting numbers

4.3.3 Reference Condition/Values

The NPS requested unique reference conditions that will vary between measures. Tuberville et al. (2005), an intensive herpetofaunal survey, will serve as the reference condition for the amphibian species richness and reptile species richness measures. The reference condition for the number of gopher tortoise burrows measure and the diamondback terrapin nesting numbers measure will be represented by the most current data. Given the information on the area’s terrapin and tortoise populations, the current condition of these two measures will be useful for future assessments to serve as a baseline.

4.3.4 Data and Methods

In an effort to complete a baseline wildlife survey of Cedar Point, researchers (City of Jacksonville 1998) constructed a series of funnel traps and bucket traps that were then attached to drift fences in order to sample the amphibian and reptiles of the TIMU area between January 1995 and March 1996. Arrays of traps were located in three unique areas to sample a broad range of different habitat types.

Array 1 was located in a young hardwood hammock with sparse ground cover vegetation. Array 2 was located on a small island with a salt marsh that surrounded it. The vegetation of the island was predominantly southern redcedar and various *Ilex* spp. Array 3 was located in an area of mature oak and hickory hammocks that transitioned into saw palmetto/pine/cedar habitats.

Tuberville et al. (2005) conducted herpetofaunal surveys of the 16 SECN parks, including TIMU, from 2001 to 2003. Field surveys included a variety of sampling techniques such as terrestrial drift fences, coverboards, aquatic traps, aquatic dip netting, automated recording of anuran (i.e., frog and toad) calls, road-cruising, and opportunistic visual searches. These results were supplemented with searches of museum records, literature accounts, and personal collections/reports (Tuberville et al. 2005).

In 2009, the SECN conducted a pilot amphibian community monitoring program at TIMU, with the objective to identify trends in species occupancy, distribution, diversity, and community composition (Byrne et al. 2010). The protocol incorporated two survey techniques: a time- and area-constrained visual encounter survey (VES) and automated-recording devices (ARDs) programmed to capture anuran calls (Byrne et al. 2013). Thirty locations were sampled in 2009; ARDs were deployed from 9–19 April and VESs conducted from 24 June through 29 July (Figure 26). ARDs were programmed to record for 1 minute every 10 minutes from dusk to dawn once every 3 days during deployment (Byrne et al. 2010). Monitoring for anurans (frogs and toads) with ARDs was repeated in 2015 and 2020 but data have not been fully processed and analyzed (Michael Parrish, SECN Wildlife Biologist, written communication, 16 April 2021).

Hoover and Clarke (2004) completed a gopher tortoise burrow survey as part of their gopher tortoise management plan for TIMU. Gopher tortoise burrow surveys were completed in TIMU during the summer months (June to August) of 2003. Surveys focused on areas of known tortoise activity (based on communication with NPS staff) and areas that contained potentially suitable tortoise habitat based on aerial imagery and previously published soil surveys (Figure 27) (Hoover and Clarke 2004). When a burrow was discovered, researchers documented the location via GPS, classified the burrow as active or inactive, and recorded the height and width of the burrow entrance. The vegetation that surrounded each burrow was sampled by using a quadrat technique, and the percent cover, density, frequency, and relative importance value of each plant species was documented (Hoover and Clarke 2004).

Gopher tortoise burrow surveys were also conducted in 2013, 2017, and 2018. The 2013 results were not published but were incorporated into the 2017 and 2018 reports (Tardona et al. 2017, Henderson et al. 2018). In 2017, surveys were conducted at four locations: TIMU headquarters, Kingsley Plantation, Fort Caroline (FOCA) and Ribault Column, and American Beach (Tardona et al. 2017). Due to the small size of each location, surveyors were able to walk each entire site searching for burrows, rather than sampling along transects. In 2018, Henderson et al. (2018) conducted burrow surveys in the same locations as Tardona et al. (2017) and at four additional sites: Cedar Point, the Bennett House property near Cedar Point, Crabtree House near Kingsley Plantation, and the northern portion of the Theodore Roosevelt Area (TRA) (Figure 28). Each site was visited at least three times between June and August, typically in the morning. Entire sites were searched again, with the exception of Cedar Point, where surveys were conducted along trails and fire lines from a slow-moving vehicle, due to the large area to be covered and low number of tortoises (Henderson et al. 2018). A burrow camera was used to determine occupancy, either by tortoises or other species.

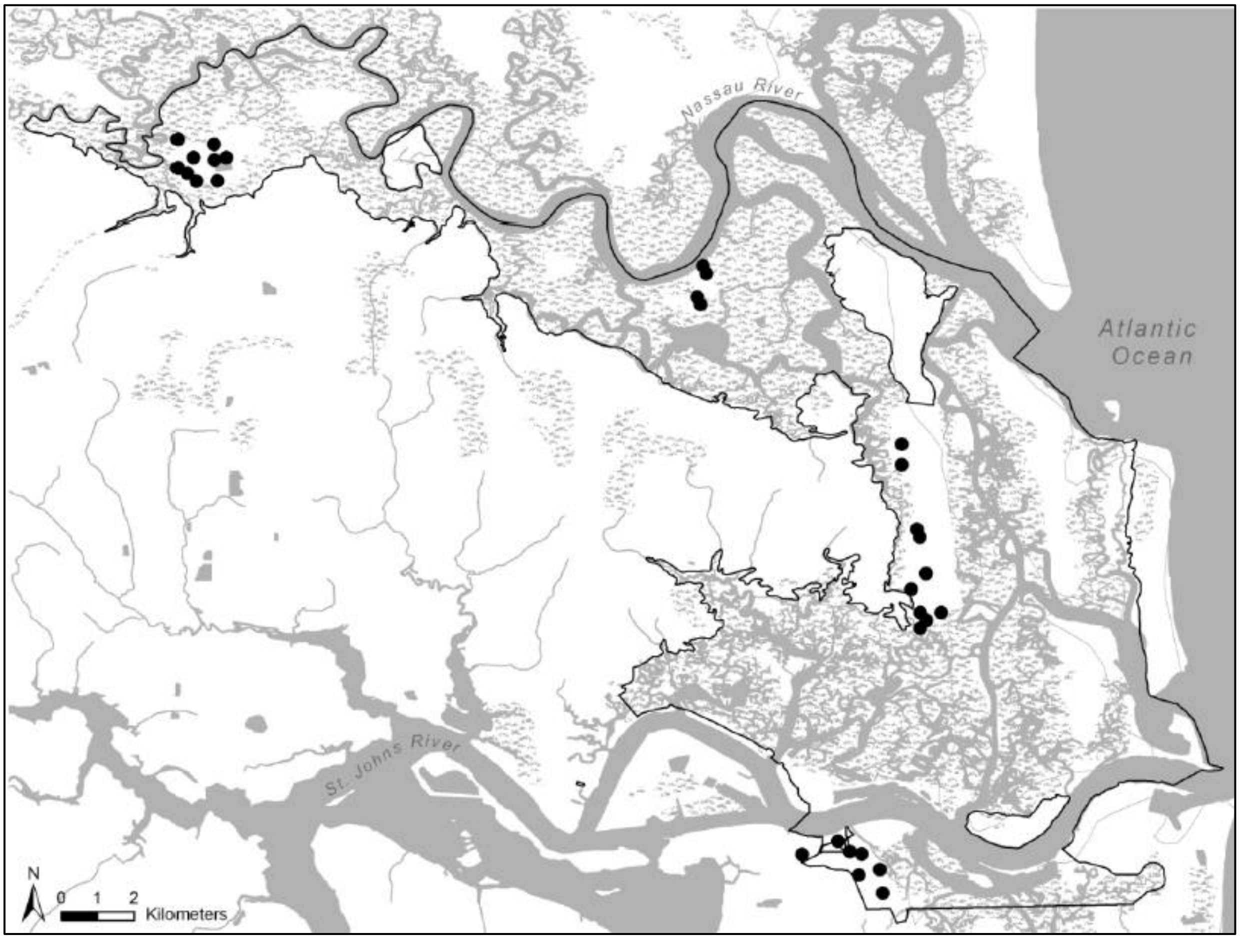

Figure 26. 2009 herpetofauna sampling locations at TIMU/FOCA (reproduced from Byrne et al. 2010).

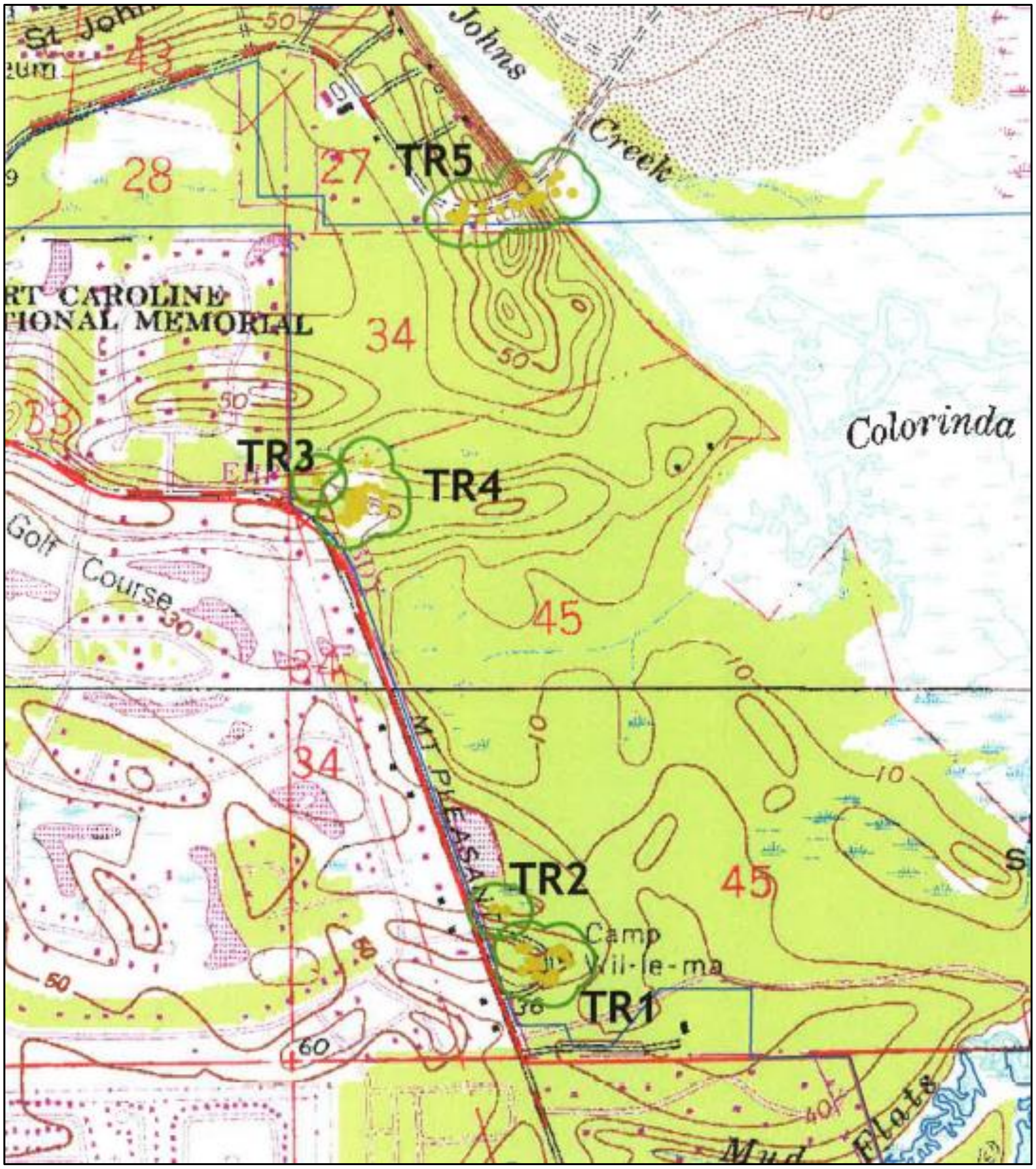

Figure 27. 2003 burrow survey locations (green outlines around yellow dots) within TRA (reproduced from Hoover and Clarke 2004). TR1 is the park headquarters area. Surveys were also conducted at Kingsley Plantation and on Cedar Point.

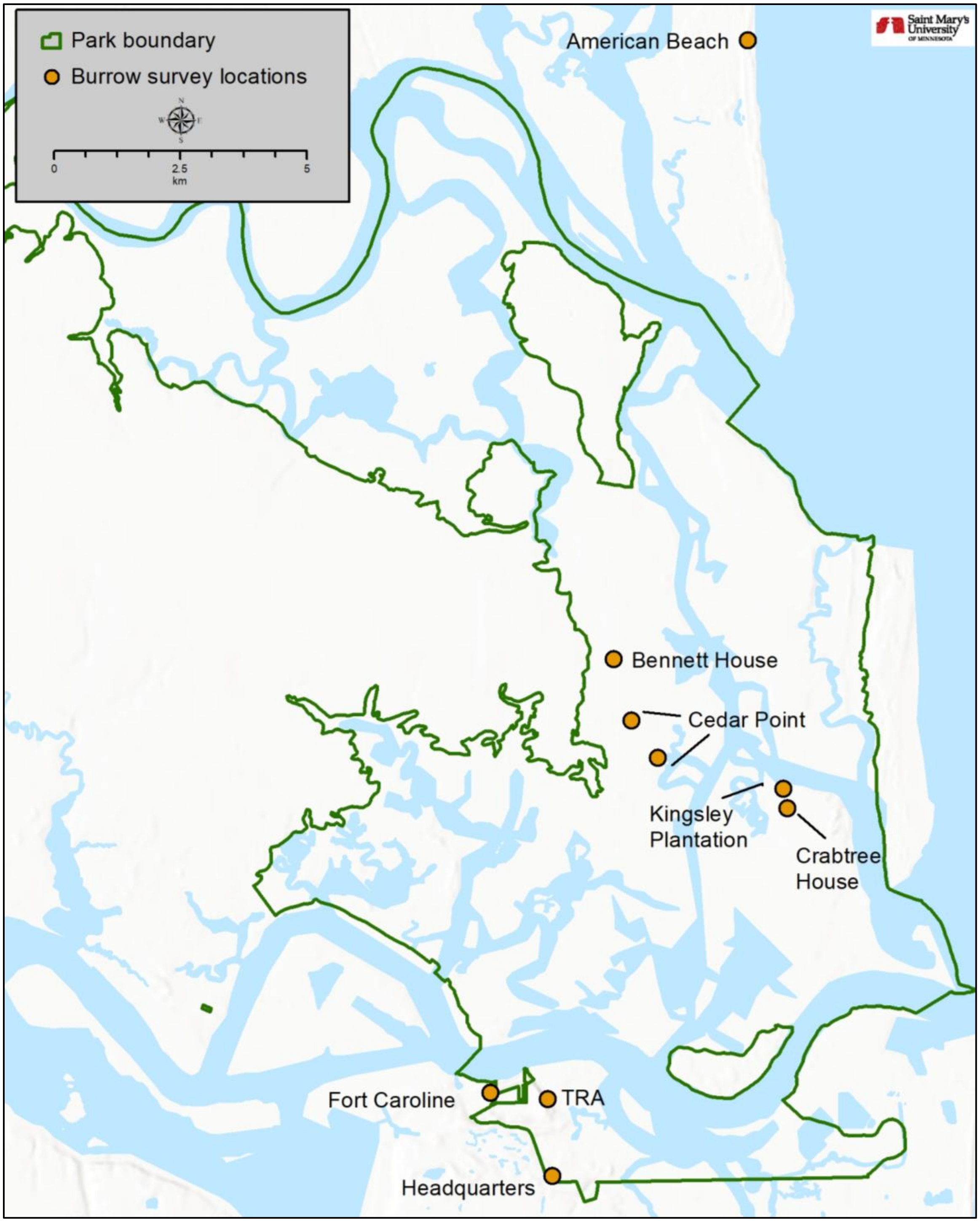

Figure 28. Gopher tortoise burrow survey locations (Tardona et al. 2017, Henderson et al. 2018).

Montgomery et al. (2015) used burrow cameras and remote game cameras to estimate the population size and study activity patterns of gopher tortoises at two TIMU locations: American Beach and TRA. At each location, there was a human-impacted site and a more isolated site. Burrow counts and occupancy searches with burrow cameras were conducted in early summer and again in December

(Montgomery et al. 2015). Game cameras were deployed from June to September to record activity at active burrows.

An expansion of the work completed by Butler (2000), Butler (2002) completed both a mark-recapture study, and a general survey of diamondback terrapins that took place almost entirely in the TIMU area (Figure 29). The objectives of the survey were to estimate the population levels and sex ratios of diamondback terrapins in northeast Florida, as well as to observe terrapin movement via radio transmitters attached to the animals. Sampling/surveying completed by Butler (2002) took place somewhat intermittently between 1997–2001; a two field season hiatus occurred from 1998–2000. Most terrapins were captured at nesting beaches; the methods used to capture included hand capture, modified crab pots, and cast netting. From May through October in 1997 and 2000, researchers monitored a nesting beach on Sawpit Island, counting “crawls” (i.e., terrapin tracks) and following those crawls to search for nests. When nests were found, they were marked and subsequently revisited to check for depredation or other damage and for hatchling emergence. If nests were depredated, efforts were made to identify the predator species using tracks or other signs (Butler 2002).

The North Florida Land Trust (NFLT), in partnership with the Florida Department of Environmental Protection (FLDEP), has conducted terrapin nest surveys on the Sawpit Island beach annually since 2009 (Simmons 2016, Dunn 2018). Surveys are conducted by a group of trained volunteers known as “Team Terrapin”, following the methods outlined by Butler (2002). Survey results for 2009–2017 were found in Dunn (2018) and more recent data (2018–2021) were provided by NFLT (2021).

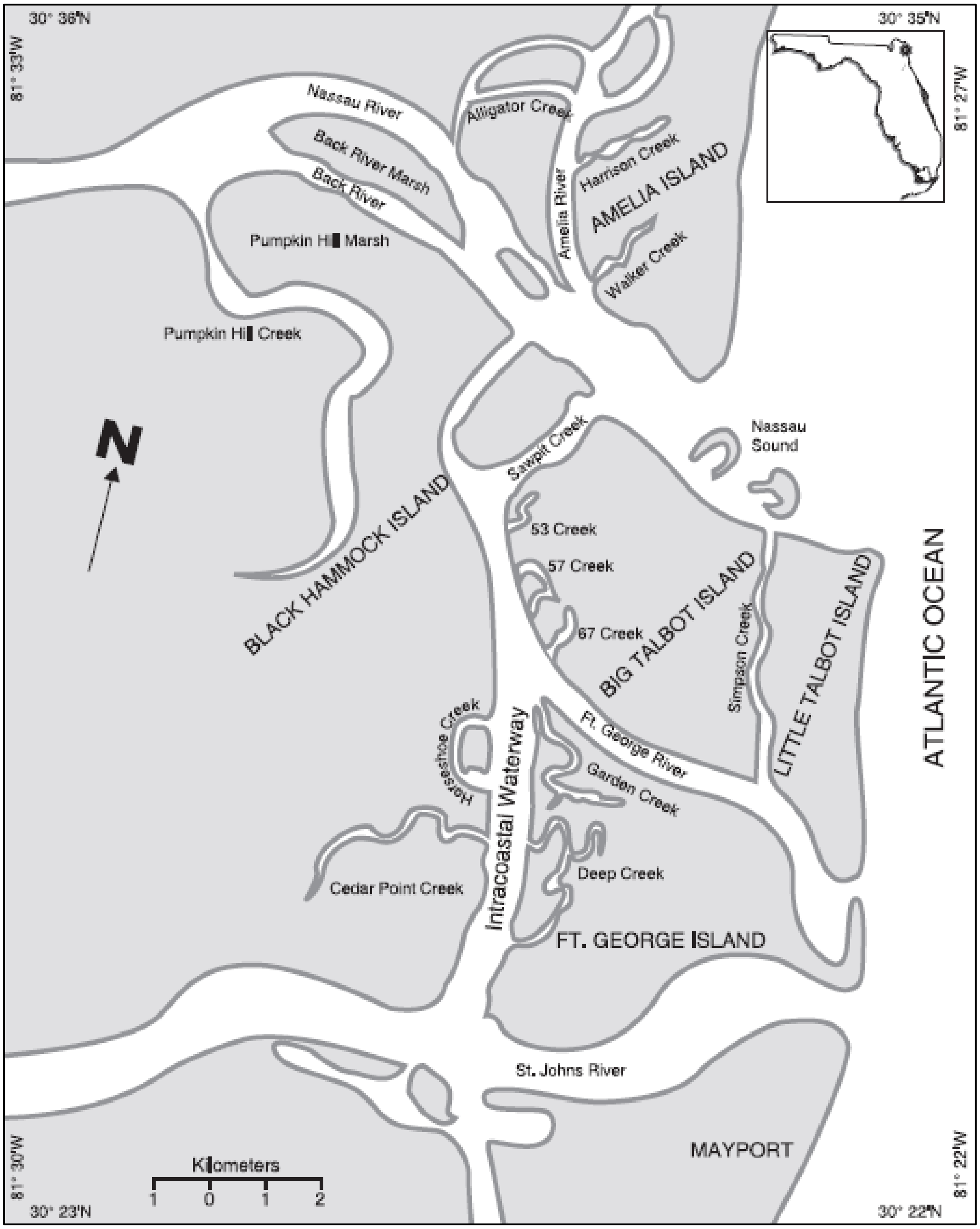

Figure 29. Diamondback terrapin study area of Butler (2002). Efforts primarily focused on Deep and Garden Creeks in the southern portion, as well as Pumpkin Hill and Back River marshes in the northern portion.

4.3.5 Current Condition and Trend

Amphibian Species Richness

The earliest known herpetofaunal survey at TIMU was on Cedar Point in 1995–1996 (City of Jacksonville 1998). These surveyors recorded eight amphibian species, all anurans. However, this included the Cope's gray treefrog (*Dryophytes chrysoscelis*), which has not been documented by subsequent surveys, and may have been a misidentification (Table 20). An extensive park-wide survey and museum/literature searches by Tuberville et al. (2005) from 2001 to 2003 identified 21 amphibian species occurring at TIMU. Sixteen of these were documented by a field survey, three by museum specimens only, and two by personal communication (e.g., anecdotal reports). One of the species documented during the field survey, the greenhouse frog (*Eleutherodactylus planirostris*), is considered non-native (Tuberville et al. 2005).

Table 20. Amphibian species documented at TIMU by various surveys over time. For Tuberville et al. (2005), S = documented by field survey, M = museum specimen, P = personal communication (P^1 = historical report, not found in contemporary surveys). For Byrne et al. (2010), A = audio recording, V = visual survey.

Order/Group	Scientific Name	Common Name	City of Jacksonville (1998)	Tuberville et al. (2005)	Byrne et al. (2010)
Anurans (frogs & toads)	*Acris gryllus*	southern cricket frog	x	S, M	A, V
	Anaxyrus quercicus	oak toad	–	–	V
	Anaxyrus terrestris	southern toad	x	S, M	V
	Dryophytes chrysoscelis	Cope’s gray treefrog	x	–	–
	Dryophytes cinerea	green treefrog	x	S, M	A, V
	Dryophytes femoralis	pine woods treefrog	–	S	A, V
	Dryophytes gratiosa	barking treefrog	–	P	–
	Dryophytes squirella	squirrel treefrog	x	S	A, V
	Eleutherodactylus planirostris [a]	greenhouse frog	–	S	V
	Gastrophryne carolinensis	eastern narrowmouth toad	–	S, M	V
	Lithobates capito	gopher frog	–	M	–
	Lithobates catesbeianus	American bullfrog	–	S	V
	Lithobates clamitans [b]	green frog	–	S	A, V
	Lithobates grylio	pig frog	–	S	A, V
	Lithobates sphenocephalus	southern leopard frog	x	S	A, V
	Pseudacris crucifer	spring peeper	–	S	A, V

[a] non-native species

[b] Records for the bronze frog (formerly *Lithobates clamitans clamitans*) from Byrne et al. (2010) have been combined with the green frog (*Lithobates clamitans*), as the bronze frog is no longer recognized as a distinct subspecies.

Table 20 (continued). Amphibian species documented at TIMU by various surveys over time. For Tuberville et al. (2005), S = documented by field survey, M = museum specimen, P = personal communication (P^1 = historical report, not found in contemporary surveys). For Byrne et al. (2010), A = audio recording, V = visual survey.

Order/Group	Scientific Name	Common Name	City of Jacksonville (1998)	Tuberville et al. (2005)	Byrne et al. (2010)
Anurans (frogs & toads) (continued)	*Pseudacris ocularis*	little grass frog	x	S, M	A, V
	Scaphiopus holbrookii	eastern spadefoot	x	M	V
Salamanders	*Ambystoma talpoideum*	mole salamander	–	S, P	–
	Eurycea quadridigitata	dwarf salamander	–	S	V
	Notophthalmus perstriatus	striped newt	–	P^1	–
	Notophthalmus viridescens	eastern newt	–	S, P	–
	Plethodon grobmani	southeastern slimy salamander	–	M	–

[a] non-native species

[b] Records for the bronze frog (formerly *Lithobates clamitans clamitans*) from Byrne et al. (2010) have been combined with the green frog (*Lithobates clamitans*), as the bronze frog is no longer recognized as a distinct subspecies.

Byrne et al. (2010) documented 16 amphibian species at TIMU; nine were observed both visually and through audio recordings while seven were only observed visually (Table 20). Species visually observed included the non-native greenhouse frog. The most frequent visually observed species were the squirrel treefrog (*Dryophytes squirella*), green treefrog (*Dryophytes cinerea*), and the eastern spadefoot (*Scaphiopus holbrookii*) (Parrish, written communication, November 2021) (Figure 30).

Figure 30. Three of the most common amphibian species in TIMU were (left to right) the squirrel treefrog, southern leopard frog, and eastern spadefoot (NPS photos).

Reptile Species Richness

The City of Jacksonville (1998) survey of Cedar Point documented 11 reptile species: four snakes, four lizards, and three turtles (Table 21). The survey and museum/literature search by Tuberville et al. (2005) identified 43 amphibian species occurring at TIMU. Twenty-eight of these were documented by a field survey, and 15 by museum specimens and/or personal communications only. Two of the species observed during surveys (brown anole [*Anolis sagrei*] and pond slider [*Trachemys scripta*]), as well as one museum specimen (Texas horned lizard [*Phrynosoma cornutum*]), are considered non-native (Table 21).

Table 21. Reptile species documented at TIMU by various surveys over time. For Tuberville et al. (2005), S = documented by field survey, M = museum specimen, P = personal communication (P1 = historical report, not found in contemporary surveys). For Byrne et al. (2010), V = visual survey.

Order/Group	Scientific Name	Common Name	City of Jacksonville (1998)	Tuberville et al. (2005)	Byrne et al. (2010)
Crocodilians	*Alligator mississippiensis*	American alligator	–	S	–
Snakes	*Agkistrodon piscivorus*	cottonmouth	x	P^{1}	V
	Cemophora coccinea	scarlet snake	–	S, M	–
	Coluber constrictor	racer	x	S	–
	Crotalus adamanteus	eastern diamondback rattlesnake	–	S, M	V
	Diadophis punctatus	ring-necked snake	–	S	–
	Drymarchon corais	indigo snake	–	P^{1}	–
	Haldea striatula	rough earth snake	–	S	–
	Lampropeltis getula	common kingsnake	–	P^{1}	–
	Lampropeltis triangulum	milk snake	–	M, P	–
	Liodytes pygaea	black swamp snake	–	S	–
	Nerodia fasciata	southern water snake	–	S, M	–
	Opheodrys aestivus	rough green snake	x	S	V
	Pantherophis guttatus	corn snake	x	M	V
	Pantherophis obsoletus	Texas ratsnake	–	S	V
	Pituophis melanoleucus	eastern pine snake	–	P^{1}	–
	Rhadinaea flavilata	pine woods snake	–	S	–

[a] non-native species

Table 21 (continued). Reptile species documented at TIMU by various surveys over time. For Tuberville et al. (2005), S = documented by field survey, M = museum specimen, P = personal communication (P1 = historical report, not found in contemporary surveys). For Byrne et al. (2010), V = visual survey.

Order/Group	Scientific Name	Common Name	City of Jacksonville (1998)	Tuberville et al. (2005)	Byrne et al. (2010)
Snakes (continued)	*Sistrurus miliarius*	pygmy rattlesnake	–	P[1]	–
	Storeria dekayi	brown snake	–	P[1]	V
	Storeria occipitomaculata	red-bellied snake	–	S	–
	Thamnophis saurita	eastern ribbon snake	–	M, P	–
	Thamnophis sirtalis	common garter snake	–	S, P	–
Lizards	*Anolis carolinensis*	green anole	x	S, M	V
	Anolis sagrei [a]	brown anole	–	S	V
	Cnemidophorus sexlineatus	six-lined racerunner	–	S, M	V
	Eumeces inexpectatus	southeastern five-lined skink	x	S	V
	Eumeces laticeps	broadhead skink	x	S	V
	Ophisaurus attenuatus	slender glass lizard	–	P[1]	–
	Ophisaurus ventralis	eastern glass lizard	–	S, M	V
	Phrynosoma cornutum [a]	Texas horned lizard	–	M	–
	Sceloporus undulatus	eastern fence lizard	–	S	–
	Scincella lateralis	ground skink	x	S	V
Turtles & Tortoises	*Apalone ferox*	Florida softshell turtle	–	S	–
	Chelydra serpentina	common snapping turtle	x	S	–
	Gopherus polyphemus	gopher tortoise	–	S, P	–
	Kinosternon baurii	striped mud turtle	x	M	–
	Malaclemys terrapin	diamondback terrapin	–	M, P	–
	Pseudemys nelsoni	Florida red-bellied cooter	–	S	–
	Pseudemys peninsularis	peninsula cooter	–	S	–

[a] non-native species

Table 21 (continued). Reptile species documented at TIMU by various surveys over time. For Tuberville et al. (2005), S = documented by field survey, M = museum specimen, P = personal communication (P1 = historical report, not found in contemporary surveys). For Byrne et al. (2010), V = visual survey.

Order/Group	Scientific Name	Common Name	City of Jacksonville (1998)	Tuberville et al. (2005)	Byrne et al. (2010)
Turtles & Tortoises (continued)	*Sternotherus minor*	loggerhead musk turtle	–	M	–
	Sternotherus odoratus	common musk turtle	–	S	–
	Terrapene carolina	common box turtle	x	M	V
	Trachemys scripta [a]	pond slider	–	S	–

[a] non-native species

Byrne et al. (2010) documented 14 reptile species during visual surveys at TIMU: seven lizards (including the non-native brown anole), six snakes, and one turtle species (Table 21). The most numerous species were the green anole (*Anolis carolinensis*), ground skink (*Scincella lateralis*), and southeastern five-lined skink (*Eumeces inexpectatus*) (Figure 31). The green anole was also the most frequently encountered species (Byrne et al. 2010).

Figure 31. Common reptiles at TIMU include (clockwise from top left): green anole, ground skink, and southeastern five-lined skink (NPS photos).

Gopher Tortoise Burrow Numbers

Gopher tortoises dig burrows to provide refuge during daily inactive and seasonal dormancy periods (Jones and Dorr 2004). Burrows can be up to 13.7 m (45 ft) long and 3.6 m (12 ft) deep, with size and shape varying with the size of the tortoise occupying them (Hoover and Clarke 2004, Henderson et al. 2018). Tortoises may utilize more than one burrow, and on rare occasions, more than one tortoise has been observed in a single burrow (Montgomery et al. 2015, Tardona et al. 2017). Therefore, burrow numbers are not necessarily equivalent to population size.

In the earliest known TIMU gopher tortoise burrow survey by Hoover and Clarke (2004), 77 burrows were documented across TRA, Kingsley Plantation, and Cedar Point (Table 22). The majority of these burrows (77%) were found at five locations within TRA (TR1-TR5), and 66% of these TRA burrows were considered active. Across all sites, adult-sized burrows were most common (38 total) and juvenile burrows were least common (10 total) (Hoover and Clarke 2004).

Table 22. TIMU Gopher tortoise burrow survey results, 2003 (Hoover and Clarke 2004). See Figure 27 for sampling area locations within the Theodore Roosevelt Area (TRA).

Location	Total burrows	Active burrows	Burrow size distribution
TRA (total)	59	39	26 adult, 10 subadult, 9 juvenile
TR1	17	10	11 adult, 3 subadult, 2 juvenile
TR2	2	1	1 adult, 1 subadult
TR3	2	0	–
TR4	20	14	5 adult, 2 subadult, 7 juvenile
TR5	18	14	9 adult, 4 subadult
Kingsley Plantation	12	7	6 adult, 3 subadult, 1 juvenile
Cedar Point	6	6	6 adult

Montgomery et al. (2015) documented 33 total burrows (18 occupied) at TRA and 53 burrows at American Beach (34 occupied) (Table 23). Occupancy, as determined by burrow camera, was 60% or higher at three sites, with only the TRA woodland location showing a lower occupancy of 38%. At TRA headquarters, two burrows were found to contain two tortoises, an adult and a juvenile. While at American Beach, two burrows contained both a male and a female tortoise (Montgomery et al. 2015).

Table 23. Gopher tortoise burrow survey results for the Theodore Roosevelt Area (TRA) and American Beach, 2014 (Montgomery et al. 2015). The TRA woodland and American Beach dune sites were more isolated while the TRA headquarters and American Beach ocean sites are impacted by humans.

Location	Total burrows	Occupied burrows	Tortoise age distribution
TRA woodland	8	3	3 adults
TRA headquarters	25	15	9 adults, 3 subadults, 2 juveniles
American Beach dune	28	19	15 adults, 2 subadults, 4 juveniles
American Beach ocean	25	15	9 adults, 3 subadults, 5 juveniles

Gopher tortoise burrows were surveyed at TIMU by NPS staff and/or interns in 2013, 2017, and 2018 (Tardona et al. 2017, Henderson et al. 2018). Four locations were visited in all three surveys: Headquarters, FOCA and Ribault Column, Kingsley Plantation, and American Beach. Total burrow numbers across these four locations were 81 in 2013, 117 in 2017, and 214 in 2018. In 2018, four additional locations were searched, yielding 76 more burrows, for a park-wide total of 290 burrows (Henderson et al. 2018). American Beach has consistently had the highest number of burrows, increasing from 30 in 2013 to 136 in 2018 (Figure 32). Headquarters had the second highest number of burrows, consistently increasing across surveys to a total of 40 burrows in 2018. Among 2018's newly sampled sites, northern TRA had the most burrows with 34, followed by Bennett House (near Cedar Point) with 24, Cedar Point with 13, and Crabtree House (near Kingsley Plantation) with five burrows (Henderson et al. 2018).

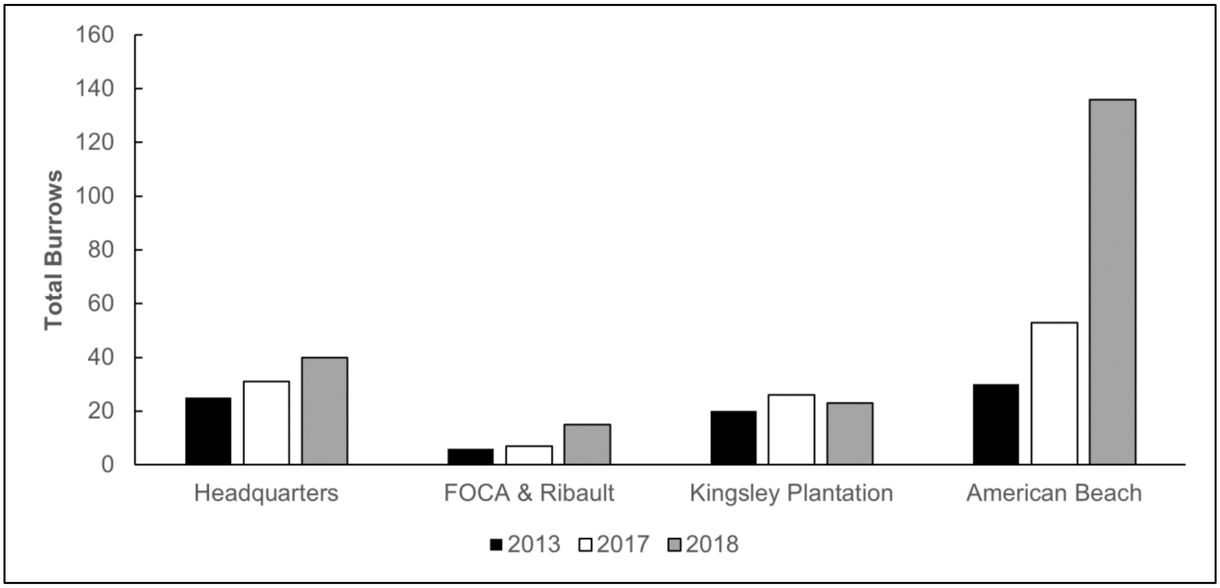

Figure 32. Total gopher tortoise burrows at four TIMU locations in 2013, 2017, and 2018 (Tardona et al. 2017, Henderson et al. 2018).

From 2017 to 2018, the number of active burrows increased at all four locations visited in both years, and nearly all of the burrows at the new locations were active (Table 24) (Tardona et al. 2017, Henderson et al. 2018). In 2018, occupancy (i.e., a tortoise found in the burrow) ranged from 13% at FOCA and Ribault Column to 77% at Cedar Point. At most sites, the greatest proportion of burrows were adult-sized, with subadult-sized burrows in the majority at two locations (FOCA and Ribault Column, Bennett House) (Figure 33). Burrow size was nearly evenly distributed at Headquarters and American Beach (Henderson et al. 2018).

Table 24. TIMU gopher tortoise burrow survey results, 2017 and 2018 (Tardona et al. 2017, Henderson et al. 2018). 2018 occupancy rates were determined by burrow camera.

Location	2017 Burrows		2018 Burrows			
	Total	**Active**	**Total**	**Active**	**Occupancy Rate**	**Burrow size distribution**
Headquarters	31	17	40	24	18%	34% adult, 31% subadult, 34% juvenile
FOCA & Ribault Column	7	2	15	5	13%	9% adult, 73% subadult, 18% juvenile
Kingsley Plantation	26	16	23	17	39%	58% adult, 37% subadult, 5% juvenile
American Beach	53	50	136	95	40%	33% adult, 31% subadult, 36% juvenile
Bennett House	–	–	24	24	50%	29% adult, 50% subadult, 21% juvenile
Cedar Point	–	–	13	12	77%	69% adult, 31% subadult
Crabtree House	–	–	5	4	40%	60% adult, 20% subadult, 20% juvenile
Northern TRA	–	–	34	34	53%	61% adult, 24% subadult, 15% juvenile

Examples of an active burrow (left, note the half-circle shape) and two inactive burrows, one partially covered by spider webs and litter and another that has been rounded due to use by a different animal (armadillo, fox, etc.) (NPS photos).

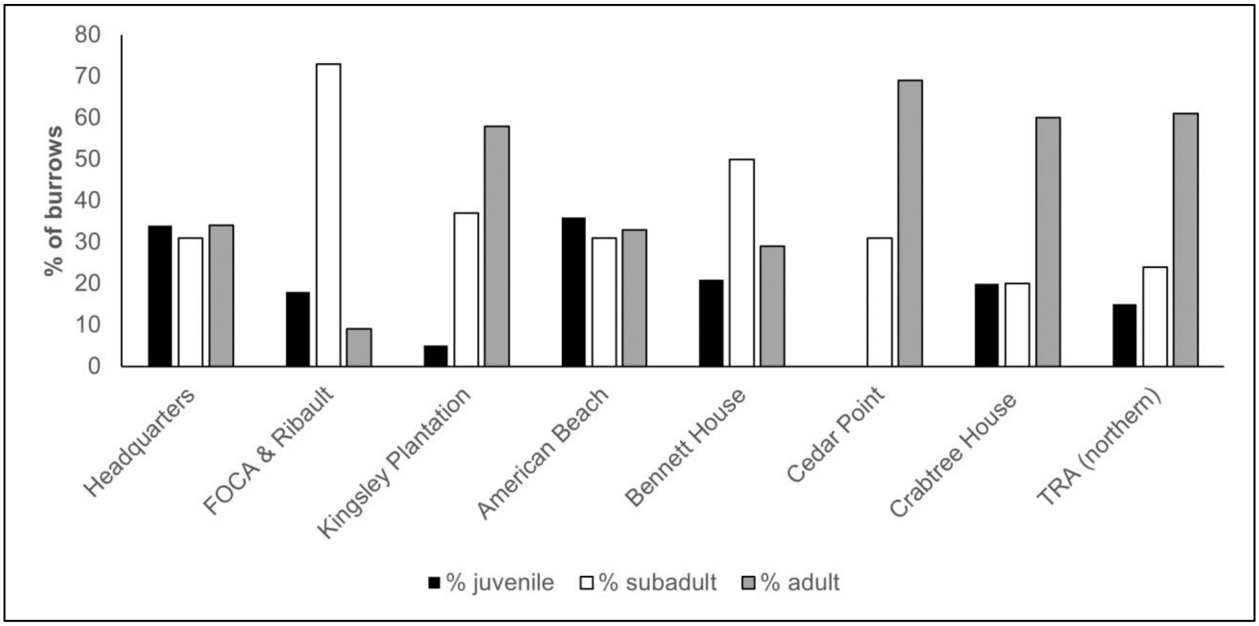

Figure 33. Burrow size distribution across TIMU locations in 2018 (Henderson et al. 2018).

Diamondback Terrapin Nesting Numbers

The first survey of the diamondback terrapin nesting beach at Sawpit Island in 1997 found and marked 114 nests (Butler 2002). A total of 372 depredated nests were documented, including 40 of the marked nests. The 2000 survey marked 112 nests; 411 depredated nests were documented, including 57 of the marked nests. The majority of nests were laid during May and June, with depredation primarily occurring in June and July. Each year, in addition to depredation, approximately a dozen nests were washed away by storms or high tides (Butler 2002).

Since 2009, terrapin nest numbers on Sawpit Island ranged from 194 in 2010 to 588 in 2018 (Figure 34) (Dunn 2018, NFLT 2021). However, through August of 2021, 683 nests had already been recorded. Annual nest numbers were lowest (below 250) from 2010–2015 but have remained above 300 since 2016. The number of nests depredated each year since 2009 ranged from 136 to 467, with an annual average of around 235 nests depredated (Dunn 2018, NFLT 2021).

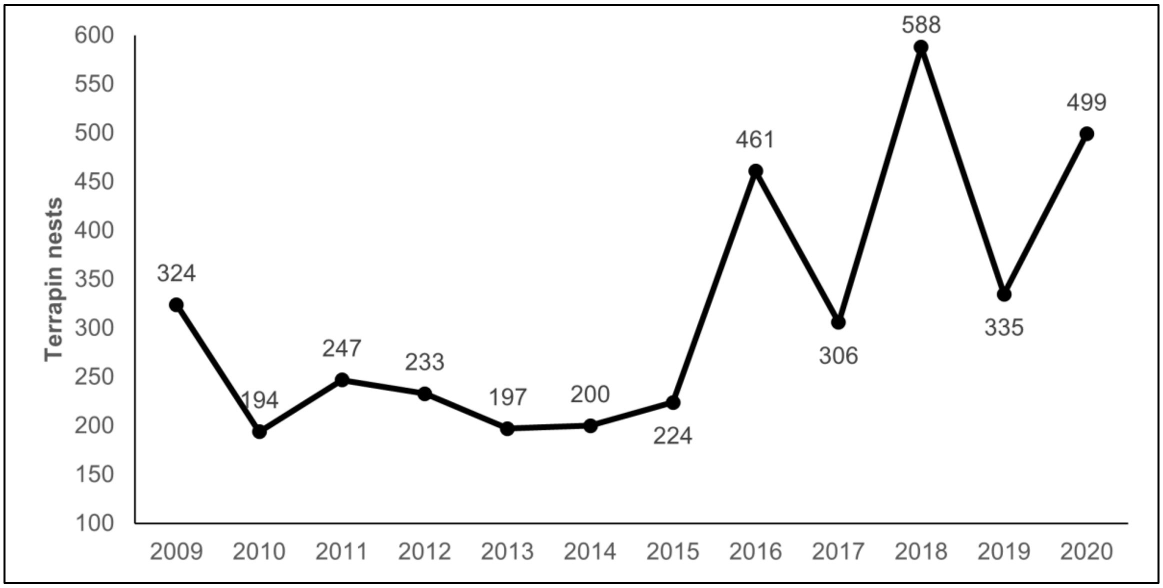

Figure 34. Total number of terrapin nests laid on Sawpit Island beach, 2009–2021 (Dunn 2018, NFLT 2021).

Threats and Stressor Factors

Threats to TIMU's herpetofauna include habitat loss and fragmentation, predation, climate change, traffic strikes, and chytrid fungus. Diamondback terrapins are also vulnerable to drowning in crab pots (Butler and Heinrich 2007).

Habitat loss, fragmentation, and degradation are considered a primary threat to herpetofauna populations (Hoover and Clarke 2004, Cushman 2006). In North America, losses in area of freshwater wetlands have been substantial (Dahl 2000). A reduction in these important aquatic habitats, along with an increase in landscape fragmentation, have been implicated in declining trends in aquatic biodiversity, particularly aquatic reptile and amphibian taxa (Bates et al. 2008). Habitat fragmentation by roads or other development has particularly impacted amphibians by creating barriers to juvenile dispersal (Cushman 2006). Habitat reduction and fragmentation can also expose herpetofauna to increased predation (Innes 2009, Munscher et al. 2012). Among reptiles, habitat loss and degradation is a primary threat to the gopher tortoise, as their habitat has been destroyed for human development, altered by the timber industry (e.g., densely-planted pine plantations), or lost to natural succession due to fire suppression (Hoover and Clarke 2004, Jones and Dorr 2004, Innes 2009). While prescribed burning can be a valuable tool for maintaining and improving tortoise habitat, controlled burning is typically not feasible at TIMU due to its proximity to the high-density human developments surrounding Jacksonville (Hoover and Clarke 2004, Henderson et al. 2018).

Traffic strikes (i.e., road-kill) can be a major source of mortality for herpetofaunal species (Dodd Jr. et al. 2004, Glista et al. 2008, Moore 2016). Along a single 3.2-km (2-mi) stretch of highway through a central Florida state preserve, a total of 833 frogs, 623 snakes, 187 turtles, and 12 alligators were struck and killed in a single year (Smith and Dodd Jr. 2003). After the construction of a barrier wall-culvert system to reduce wildlife mortality along this stretch of highway, herpetofauna mortality was still high, including 1,647 frogs, 149 snakes, and seven turtles (Dodd Jr. et al. 2004). Roadkill is a leading cause of mortality for gopher tortoises, who may be attracted to open roadside areas to forage, and also impacts diamondback terrapins (Enge et al. 2006, Crawford et al. 2013, Moore 2016). Over a 4-year study, 613 adult female terrapins were struck and killed along a single coastal Georgia causeway (Crawford et al. 2013). Gibbs and Shriver (2002) concluded that road mortality may be a "key limiting factor" in land turtle population recovery efforts. Roadkill can disproportionately impact female turtles, as they migrate for nesting and roadsides can be attractive nesting habitat (Steen et al. 2006).

Nest and hatchling predation are major threats to both gopher tortoises and diamondback terrapins in the TIMU area and throughout their range (Butler and Sowell 1996, Butler 2002, Munscher et al. 2012). Several studies have found that less than 10% of gopher tortoise hatchlings survive their first year, with predation being the primary source of mortality (Alford 1980, Landers et al. 1980). In a study of tortoise predation on the UNF campus in Jacksonville, none of the 20 monitored hatchlings survived longer than 21 months, and the majority died within a year (Butler and Sowell 1996). Predation was confirmed as the cause of death for 80% of hatchlings, with raccoons alone responsible for 58% of mortality. Other known gopher tortoise predators include armadillos (*Dasypus novemcinctus*), opossums, coyotes (*Canis latrans*), bobcats (*Lynx rufus*), snakes, and feral cats (Butler and Sowell 1996, Montgomery et al. 2015, Moore 2016).

Predation of diamondback terrapin nests is known to be high on Sawpit Island within TIMU; over half of nests are depredated in most years, with depredation occasionally reaching over 85% between 2009 and 2012 (Simmons 2016, NFLT 2021). Butler (2002) found that most nests were depredated within 24 hours of being laid, and that raccoons were the primary predator. Other nest predators included armadillos and crows (*Corvus* spp.), while ghost crabs (*Ocypode quadrata*) and fire ants (*Solenopsis invicta*) were found to prey on hatchlings (Butler 2002, Munscher et al. 2012). Raccoons are also known to prey upon adult terrapins (Seigel 1980, Feinberg and Burke 2003). Munscher et al. (2012) found that removing raccoons from Sawpit Island beaches decreased terrapin nest predation, but only for one season. Human activity, such as urban and suburban sprawl, have been shown to increase raccoon populations (Prange et al. 2003, Munscher et al. 2012), which could in turn increase predation on both diamondback terrapins and gopher tortoises.

With many of TIMU's herpetofaunal species dependent on aquatic habitat at some stage in their life cycles, drought is a major threat to these populations. Climate change has been implicated in widespread drought events, which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and occasional flooding that have damaged riparian areas and other important aquatic habitats, as well as degrading water quality (Bates et al. 2008). An overall increase in global temperatures associated with climate change, which contributes to extended periods of drought, will have a combined effect on biota by causing temperature and water stress (Bates et al. 2008). In addition, sea level rise related to climate change is a significant threat to diamondback terrapin nesting habitat (Hunter et al. 2015, Castellon 2017, Woodland et al. 2017). Warming temperatures associated with climate change may also impact reptile species with temperature-dependent sex determination (Janzen 1994, Mitchell and Janzen 2010). The temperature of the nest environment determines the sex of alligators and some terrestrial turtle hatchlings, including gopher tortoise and diamondback terrapin (Innes 2009, Simmons 2016). Warmer ambient temperatures may unnaturally skew the sex ratio in these species.

Chytrid fungus, specifically *Batrachochytrium dendrobatidis*, is a pathogen of amphibians that could potentially affect amphibian populations at TIMU. The pathogen has been identified as the cause of severe population declines on several continents, including North America (Piotrowski et al. 2004, Skerratt et al. 2007). Amphibians infected by *B. dendrobatidis* develop chytridiomycosis, an infectious non-hyphal zoosporic fungus that causes roughening and reddening of the skin, convulsions, ulcers and hemorrhages, and sporadic death. Not all amphibians infected with *B. dendrobatidis* develop chytridiomycosis or die; environmental factors, such as pH of the environment, drought, and temperature at time of infection, may affect mortality rates. Some research indicates that the fungus growth is inhibited by high temperatures (28°C [82°F]) and exposure of infected individuals to high temperatures may kill the fungus (Woodhams et al. 2003, Raffel et al. 2015). If this is the case, the warm summer temperatures at TIMU may somewhat alleviate the threat of chytrid to the park's amphibians. Chytrid fungus infections have not been detected at TIMU to date (Byrne and Moore 2011), but they may greatly impact amphibian populations if the diseases reach the park.

It has long been known that diamondback terrapins are incidentally caught and drowned by crab pots (Davis 1942, Bishop 1983). During a 2004 terrapin biology workshop, researchers and state biologists ranked crab pot bycatch as the greatest threat to terrapins range-wide (Butler et al. 2006). Terrapin mortality estimates due to crab pots vary widely, for example, ranging from 15–78% of the population per year in Chesapeake Bay (Roosenburg et al. 1997). Lost or abandoned pots, called "ghost pots", can be particularly fatal. In Chesapeake Bay, Roosenburg et al. (1997) found a ghost pot containing 49 dead terrapins, and Grosse et al. (2009) discovered a ghost pot in a Georgia tidal marsh containing 94 terrapin carcasses. Scientists have recommended the use of bycatch reduction devices (BRDs) on crab pots to reduce terrapin mortality (Butler and Heinrich 2007, Center for Biological Diversity 2020). These devices, consisting of a wire or plastic rectangle attached to the funnel entrance of the pot, prevent the entrance of larger turtles without impeding crab capture. In a study of BRD efficacy along Florida's coast, found that 4.5 x 12 cm BRDs would have prevented 73% of terrapin captures in commercial crab pots without significantly reducing the catch of legal-sized crabs (Butler and Heinrich 2007). In December 2020, the FWC proposed a draft rule to require 5 x 15 cm BRDs on blue crab traps (Schneider 2020). While commercial crabbers objected, arguing that the requirement would destroy the blue crabbing industry, the FWC voted to move the proposal forward. If the proposed rule passes, Florida would join New York, New Jersey, Delaware, and Maryland in requiring BRDs on commercial and/or recreational crab pots (Center for Biological Diversity 2020).

Data Needs/Gaps

The most recent survey data available for amphibians and reptiles (with the exception of the gopher tortoise and diamondback terrapin) is now over a decade old. While anuran monitoring using ARDs was conducted at TIMU in 2015 and 2020, these recordings have not yet been fully processed and analyzed. Results from the 2020 monitoring are expected to be published in 2022 (Parrish, written communication, 16 April 2021) and will be helpful in identifying any changes in anuran populations over time. This monitoring is currently scheduled to be repeated at TIMU in 2023.

The SECN monitoring protocol focuses on vocal anurans and only observes and documents reptile species and non-anuran amphibians opportunistically (Byrne et al. 2010). A park-wide reptile survey would help managers better understand the current condition of these populations and could update the park's NPSpecies list. Several reptiles on the current species list were documented by Tuberville et al. (2005) through "a reliable personal communication" and as "reported historically, not found in contemporary surveys" (see Table 21). Future surveys could focus on determining whether these species still occur at TIMU or if they should be considered historically present only.

Hoover and Clarke (2004) recommended studying recruitment rates of young and movement of tortoises between the populations within TIMU, as well as with populations in adjacent areas. For example, it is unclear whether there is interaction between the various tortoises at TRA or whether the populations are reproductively isolated. If these populations are isolated, it may be helpful to study the possibility of creating habitat corridors to connect them, in order to promote gene flow and to increase the overall available habitat for the species (Hoover and Clarke 2004). Continued monitoring of TIMU's gopher tortoise population will be important to detect any changes or threats to this keystone species over time. Henderson et al. (2018) recommends watching the following areas:

- The high-density population at American Beach, to see whether the habitat can continue to support a high number of tortoises.
- Older populations, such as at Cedar Point and Kingsley Plantation, to see how they fare as current tortoises continue to age.
- The population at Bennett House, which currently includes grassy areas but is likely to experience natural succession to a brushier, less open habitat.

Burrow surveys were planned for the summer of 2020 but were cancelled due to Covid-19 pandemic restrictions (Steven Kidd, TIMU Chief of Science and Resource Management, written communication, 7 September 2021).

Butler (2002) recommended long-term monitoring of diamondback terrapins to identify and address any population declines. Since observation and study is easier at nesting beaches, it may be helpful to search for and monitor additional nesting beaches within TIMU boundaries (Butler 2002). For example, a field inventory of islands in the TIMU area by McClung (2004) discovered a terrapin nest and egg shells on a spoil island along southern Sisters Creek, which could be investigated further. In addition, further study of predator impacts on terrapins could help managers determine whether predator control is needed to stabilize certain terrapin populations (Butler 2002). Research into the effects of crabbing and potential climate change impacts on diamondback terrapins in the TIMU area may help managers better understand the species' local population dynamics.

Overall Condition

Amphibian Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3. Across various surveys over time, 22 total amphibian species have been documented at TIMU (Tuberville et al. 2005, Byrne et al. 2010). The most recent survey by Byrne et al. (2010) confirmed the presence of 17 of these species. Although SECN monitoring was repeated in 2015 and 2020, those data have not yet been processed and published; therefore, it is unknown whether amphibian species richness has changed over the past decade. As a result, a *Condition Level* was not assigned for this measure at this time.

Reptile Species Richness

This measure was also assigned a *Significance Level* of 3. Over time, 43 different reptile species have been documented at TIMU, including species of conservation concern (Tuberville et al. 2005, Byrne et al. 2010). However, the most recent survey was during 2009 SECN monitoring, when reptile observations were opportunistic rather than systematic. Since no more recent information is available, a *Condition Level* was not assigned for reptile species richness.

Gopher Tortoise Burrow Numbers

A *Significance Level* of 3 was assigned for this measure. Gopher tortoise burrows were first surveyed at TIMU in 2003, and again in 2013, 2017, and 2018 (Hoover and Clarke 2004, Henderson et al. 2018). Burrow numbers have increased in recent years, but it is uncertain whether this represents an actual population increase or is partly due to increased survey efforts (Henderson et al. 2018). However, at this time the population appears to be at least stable with no immediate cause for concern. Therefore, a *Condition Level* of 1 is assigned, indicating low concern.

Diamondback Terrapin Nesting Numbers

This measure was assigned a *Significance Level* of 2. Nesting surveys have been conducted on a single beach within TIMU, on Sawpit Island (Dunn 2018). Since 2009, nesting numbers have fluctuated widely, but were consistently below 250 from 2010–2015 and remained above 300 from 2016–2020, peaking at 588 nests in 2018 (Figure 35). However, a large percentage of terrapin nests are lost to depredation each year (Butler 2002, Dunn 2018). Because nesting surveys have been conducted on only one beach and nothing is known about terrapin nesting in other areas of TIMU, the *Condition Level* for this measure is currently considered unknown.

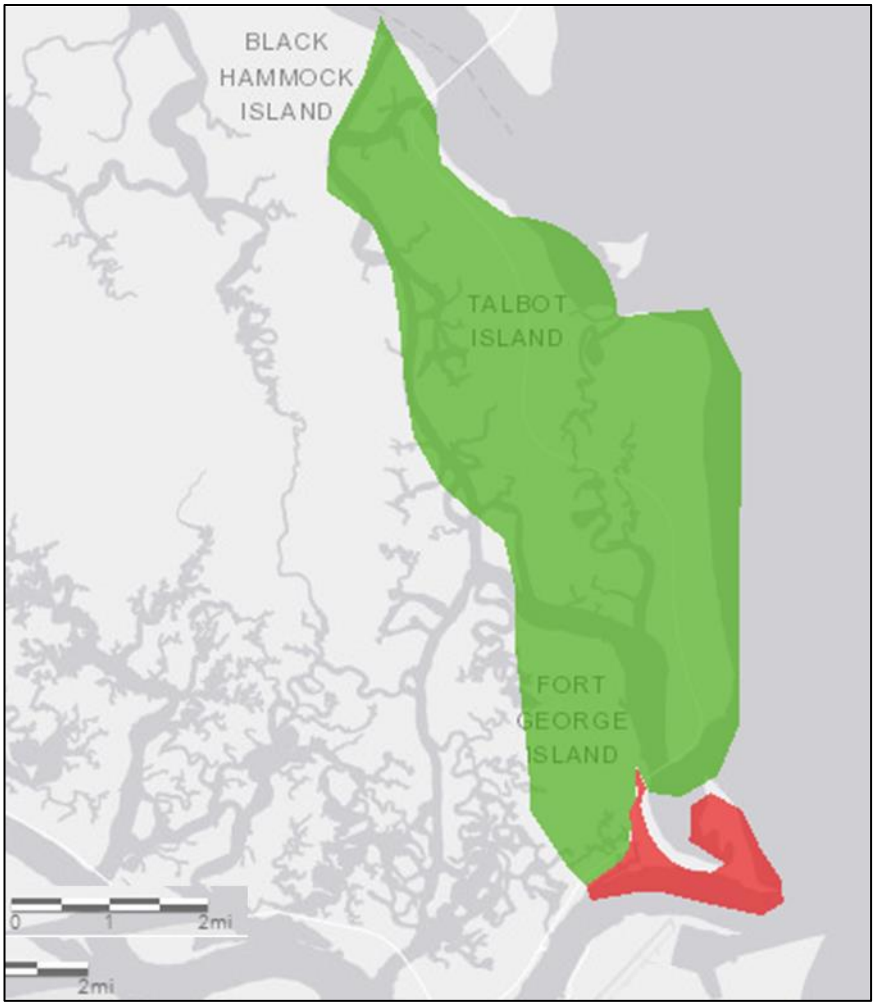

Figure 35. The Huguenot Park-Nassau Sound Globally Important Bird Area (red) and Fort George and Talbot Islands State Important Bird Area (green). Boundaries are approximate and do not accurately align with the provided basemap (reproduced from NAS 2020).

Weighted Condition Score

A *Weighted Condition Score* was not calculated for TIMU’s herpetofauna, primarily due to a lack of current data or park-wide information (Table 25). Updated information will be needed in order to determine the current condition of and any trends in the park’s amphibian and reptile populations.

Table 25. Current condition of herpetofauna at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Amphibian species richness	3	n/a	–
Reptile species richness	3	n/a	–
Gopher tortoise burrow numbers	3	1	–
Diamondback terrapin nesting numbers	2	n/a	–
Overall	**–**	**–**	◌

4.3.6 Sources of Expertise

- Steven Kidd, TIMU Chief of Science and Resource Management
- Michael Parrish, SECN Wildlife Biologist

4.4 Birds

4.4.1 Description

Situated in high ecological positions in most food webs, bird populations represent potential indicators of their ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009, Byrne et al. 2011). Birds are often highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Avian populations may respond negatively to disturbances in their critical habitats (e.g., stopover, wintering, and/or breeding areas), thus adverse changes observed in either migratory or non-migratory species may indicate a need to assess ecological conditions in one or more locations (Hilty and Merenlender 2000, Zöckler 2005).

The unique ecosystems and physical formations in TIMU provide bird species with ideal nesting, stopover, and overwintering habitat; for many northern bird species, TIMU represents the southern-most breeding limit (Tardona et al. 2003). The salt marshes, coastal dunes, and upland hardwood hammocks, combined with the many salt, fresh, and brackish waters provide ample habitat for the many bird species that utilize the area (Tardona et al. 2003). In fact, several avian species of conservation concern, such as the Piping Plover (*Charadrius melodus*), Red Knot (*Calidris canutus rufa*), and Wood Stork (*Mycteria americana*), utilize a variety of habitats in TIMU throughout the year. The greater TIMU area represents a critical area for breeding and roosting shorebirds and gulls, and also hosts large numbers of migratory falcon species in the fall (NAS 2020). Accordingly, the National Audubon Society has designated two areas within TIMU's administrative boundary as Important Bird Areas: Huguenot Park-Nassau Sound (Globally Important Bird Area), and Fort George and Talbot Islands (State Important Bird Area) (Figure 35) (NAS 2020).

TIMU has confirmed the presence of more than 300 species of birds, many of which are migratory species (NPS 2020d). Additionally, TIMU has confirmed the presence of 16 bird species that are either federally listed as threatened or endangered, or identified by the Florida Fish and Wildlife Conservation Commission (FWC) as state-threatened, or endangered (Table 26).

Table 26. State and federal bird species of conservation concern that have been documented in TIMU (FWCC 2018b).

Common Name	Federal Status	Florida Status
American Oystercatcher	–	T
Black Skimmer	–	T
Burrowing Owl	–	T
Florida Scrub-Jay	T	T
Least Tern	–	T
Little Blue Heron	–	T
Piping Plover	T	T
Red Knot	T (*rufa* ssp)	–
Red-cockaded Woodpecker	E	T
Reddish Egret	–	T

Table 26 (continued). State and federal bird species of conservation concern that have been documented in TIMU (FWCC 2018b).

Common Name	Federal Status	Florida Status
Roseate Spoonbill	–	T
Sandhill Crane	–	T
Seaside Sparrow	–	T
Snowy Plover	–	T
Tricolored Heron	–	T
Wood Stork	T	T

TIMU is also home to a large concentration of breeding Painted Bunting (*Passerina ciris*). The Painted Bunting occurs in two geographic breeding areas: a western range that extends across much of south central and southwestern U.S. and Mexico, and an eastern range that is limited to the coastal areas from North Carolina to North Florida (Lowther et al. 1999, Sykes and Holzman 2005, Delaney et al. 2013). The eastern breeding population also extends inland to limited areas of Georgia and South Carolina. While not designated by Florida or the Federal government as a threatened or endangered species, the Painted Bunting was historically listed as a high priority species for conservation action on the Partners in Flight Landbird Conservation Plan (Rich et al. 2004).

Analyses of Breeding Bird Surveys (BBS) in the eastern U.S. indicated that the decline of Painted Buntings in Florida was the most severe out of all states in the species' eastern range (Sauer et al. 2011). In the TIMU area, Painted Bunting breeding concentrations represent one of the largest concentrations in northeast Florida (Tardona et al. 1997), and many of the preserve's visitors come to the park for a chance to view this elusive and beautiful species (Figure 36).

Figure 36. A male Painted Bunting (*Passerina ciris*) (NPS Photo/ Roger Clark).

TIMU is located along the Atlantic Flyway, one of the major migration flyways in North America (Figure 37), and many species, such as the Red Knot, pass through the park or use the park as a stopover on their way from wintering grounds in the south to breeding grounds in the park or in the north. The park also acts as an important over-wintering area for several migratory species that spend the winter months in the various ecosystems of TIMU before returning to their breeding grounds in the spring.

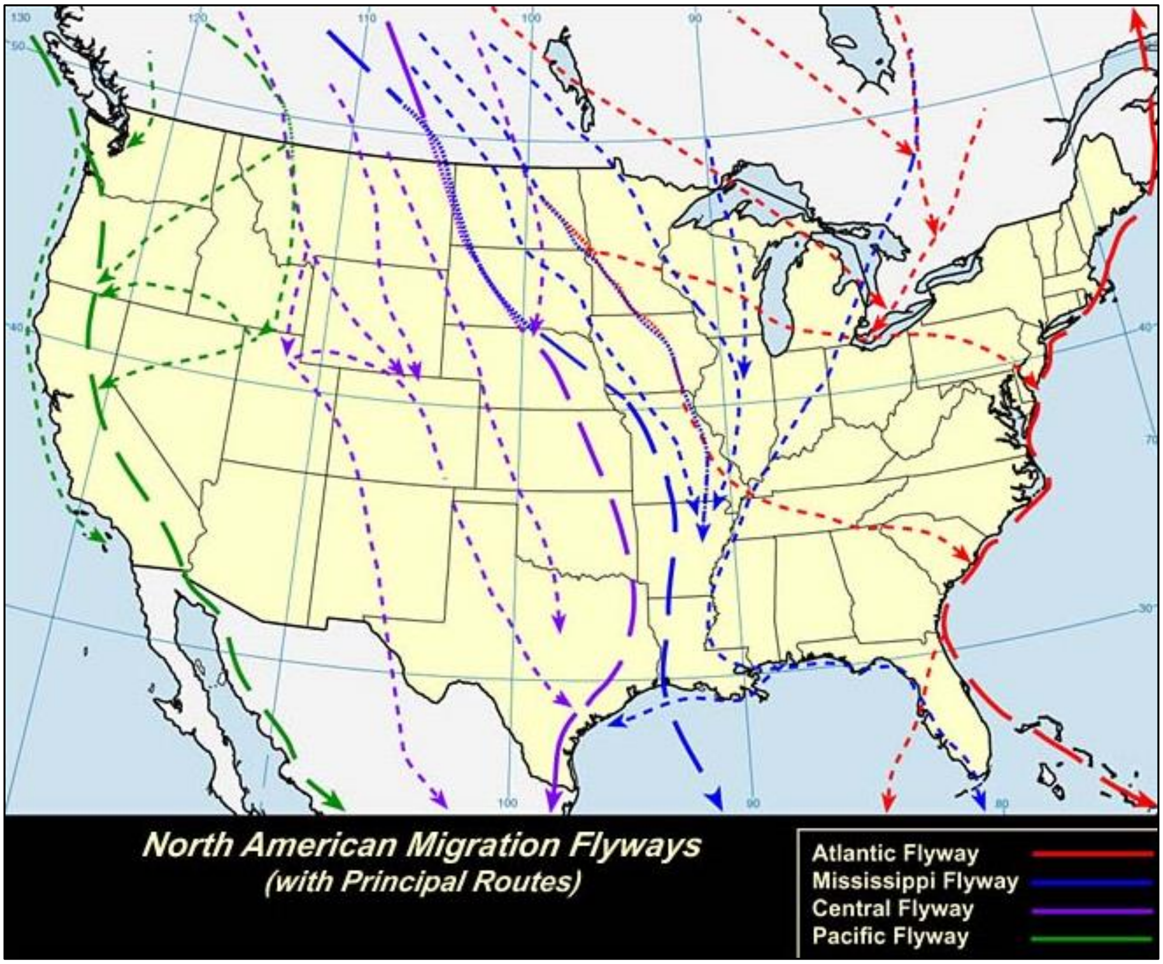

Figure 37. Major North American migratory flyways. TIMU is located along the principal route of the Atlantic Flyway, as well as secondary crossover route that heads to the Gulf of Mexico (NPS 2016b). Bolded, longer dashed lines indicate principal migratory routes, while shorter dashes indicate secondary and crossover migration routes.

4.4.2 Measures

- Species richness
- Species abundance
- Species distribution
- Wading bird nesting numbers

4.4.3 Reference Condition/Values

A historic reference condition was not assigned to this component during project scoping; instead, park managers requested to use the most recently published avifauna work by the SECN (Byrne et al. 2011). Byrne et al. (2011) represents the pilot stage of SECN landbird monitoring in the park, and by choosing this as a reference condition, researchers with TIMU and the SECN can compare future surveys to the original monitoring effort to establish potential trends in the park's landbird community. The SECN has completed additional landbird sampling in TIMU since Byrne et al. (2011), with sampling taking place in 2015 and again in 2020. The results of these sampling efforts have not been summarized or published to date, but when they are they may be compared to the reference condition of Byrne et al. (2011) where appropriate to identify potential short-term trends.

Byrne et al. (2011) documented richness, abundance, and distribution of landbirds in the park, but does not focus on wading bird nest numbers (i.e., active nest counts). For the wading bird nesting numbers measure in this assessment, the best professional judgement of identified subject matter experts and NPS staff will be used to assess current condition.

4.4.4 Data and Methods

The NPS Certified Bird Species List for TIMU (NPS 2020d) was used for this assessment, as this list represents all of the confirmed bird species present in the park. The list was populated by the various bird inventories and surveys that occurred in the park's area, and in the case of parks with limited bird work, will likely resemble the overall species list of the primary bird inventory efforts for the park. This source does not represent an on-the-ground inventory or survey, but rather a compilation of the various studies and reports in the park to create a list of species to be expected in TIMU.

TNC (1996) summarizes the results of bird censuses at Cedar Point (which was not yet part of TIMU). These censuses paid particular attention to species that were endangered, threatened, unique, rare, or otherwise notable as species of concern in Florida. Eleven surveys were completed during the spring migration (April–June) of 1995. These surveys took place in the early morning and all birds heard and visually observed were denoted. General survey methodology followed the standardized BBS, with surveys in forested areas along the extensive trail system of the area. Other areas sampled include the marshes and tidal channels that are associated with Horseshoe and Cedar Point Creeks.

Jones and Jones (1998) represents a relatively informal, unpublished census point count conducted at Cedar Point and the TRA by Betty and Ken Jones during the winter (January–February) of 1998. Twenty-four point count locations were utilized in Cedar Point, while 18 were used in the TRA. Specific methodology details such as count duration and route were not provided, and observers only documented the species that were detected rather than abundance or distribution/sites detected. The results of this census are provided in this assessment, as they provide valuable insight into the winter bird population of TIMU.

Landbirds were identified as a high-ranking Vital Sign by the SECN during the Vital Sign selection process (DeVivo et al. 2008). Consequently, the SECN began a landbird monitoring program in all network parks, with the specific objective of determining trends in landbird species occupancy, distribution, diversity, and community composition in network parks (Byrne et al. 2011). Monitoring began in TIMU in 2010, and was conducted as a "pilot" phase in order to develop and fine tune the sampling protocol that would later be published by Byrne et al. (2014). Thirty sites were chosen (Figure 38) using a random, spatially balanced algorithm, and each site was surveyed from April to June using a variation of the variable-circular plot (VCP) technique. Using this technique, observers were stationed at the center point of a 0.5 ha (1.2 ac) macroplot and recorded all species observed and heard during a 12-minute window. Birds that flew over the macroplot during sampling were recorded as flyover species. When possible, observers documented the time frame that the bird was recorded (e.g., 0–3 minutes after start, 3–6 minutes, etc.), and the distance of the bird from the observer. Distance was recorded in one of four intervals: 0–25 m (0–82 ft), 25–50 m (82–164 ft), 50–100 m (164–328 ft), and >100 m (328 ft).

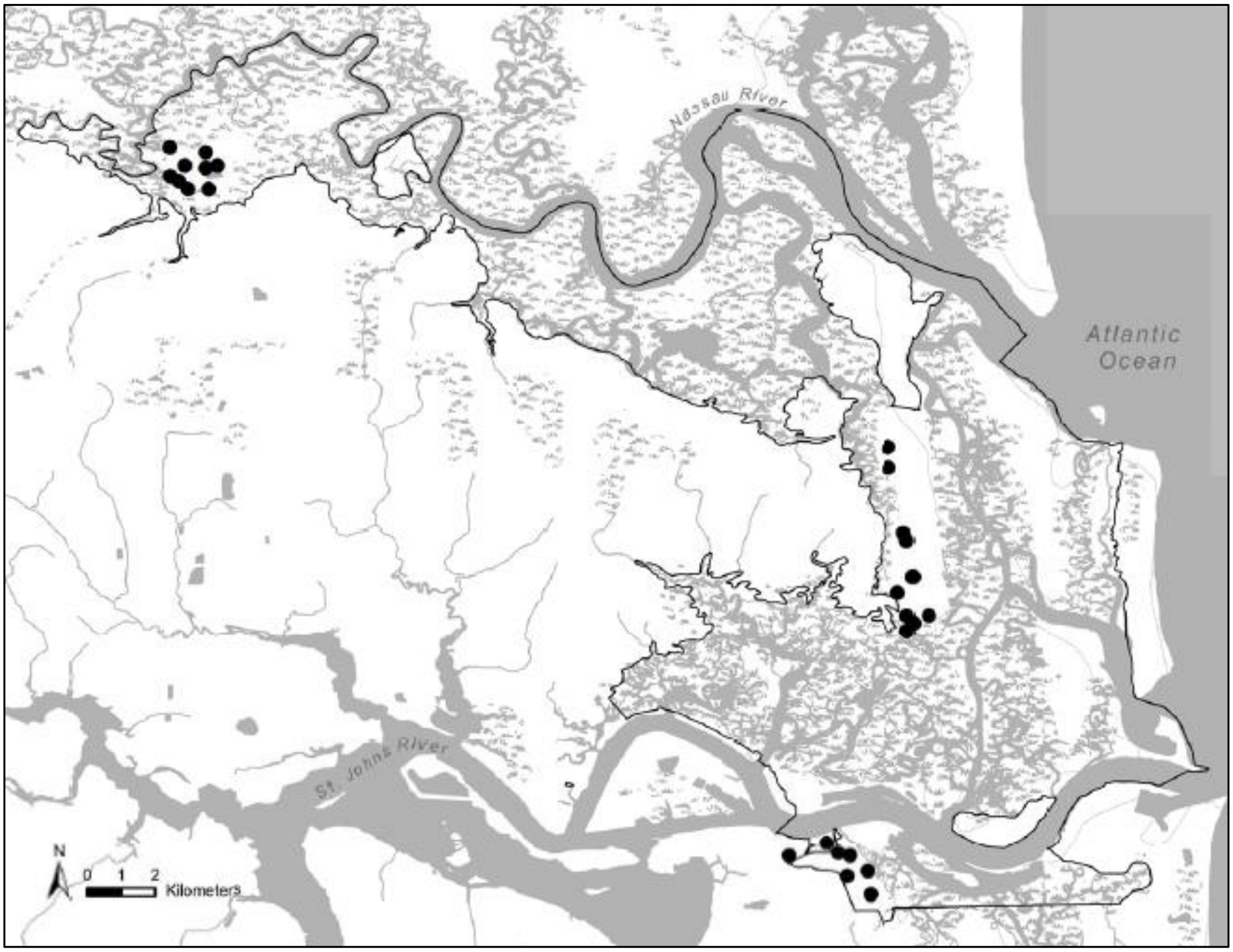

Figure 38. Landbird monitoring locations selected by the SECN for monitoring in the 2010 sampling season (Byrne et al. 2011).

The data from the 2010 "pilot" phase of the SECN landbird monitoring are currently the only available data from SECN-led monitoring. Monitoring of the park has not concluded, however, as visits have occurred in years prior but have not been summarize and published. The first official round of sampling using the Byrne et al. (2014) protocol occurred in 2015. This methodology differed from what was used in 2010, as instead of field observers conducting surveys, automatic recording devices (ARDs) were utilized. These devices were programmed to record audio for 12 minutes, once a day (08:00 hours) on an every-other-day basis. The devices were deployed at 30 locations across TIMU in 2015 (Michael Parrish, SECN Wildlife Biologist, written communication August 2020). Additional monitoring following the same protocol and sampling window was completed in 2020 (with 28 locations sampled), but have not been analyzed or published. Future sampling is planned in TIMU in 2023, with continued plans to sample the park on a 3-year rotation (Michael Parrish, pers. comm., 2020).

eBird is a citizen science data collection portal that is managed by the Cornell Lab of Ornithology. This application allows users to

> "*…document bird distribution, abundance, habitat use, and trends through checklist data collected within a simple, scientific framework. Birders enter when, where, and how they went birding, and then fill out a checklist of all the birds seen and heard during the outing (eBird 2020).*"

eBird allows users to input all species observed at any location worldwide, and these observations are then compiled to create regional checklists. Internal verification processes are utilized when unusual birds are entered for a region, and these entries are verified by regional experts during an external review. While these data are not part of a rigorous survey effort and do not follow any sort of methodology, they do prove useful when compiling expected species lists for an area, and are especially useful to document transient or vagrant species as they pass through regions. For this assessment, eBird regional checklists were downloaded for Kingsley Plantation, Cedar Point, the TRA, and Fort Caroline and are current through August 2020.

An annual CBC is centered just northwest of the City of Jacksonville, approximately 1.6 km (1 mi) north of Little Marsh Island (Figure 39) and has been completed annually since 1949, although there have been non-consecutive counts dating as far back as 1910. The count circle near TIMU is part of the International CBC, which started in 1900 and is coordinated by the Audubon Society. Multiple volunteers surveyed a 24-km (15-mi) diameter area on one day, typically between 14 December and 5 January, by foot, boat, or car. The center point of the 24-km (15-mi) diameter was 30.4152010ºN, −81.4877290ºW (Figure 39). Unlike surveys that occur during the breeding season (such as a breeding bird survey), the CBC surveys overwintering and resident birds that are not territorial and singing. The total number of species, individuals, and observers were recorded each year.

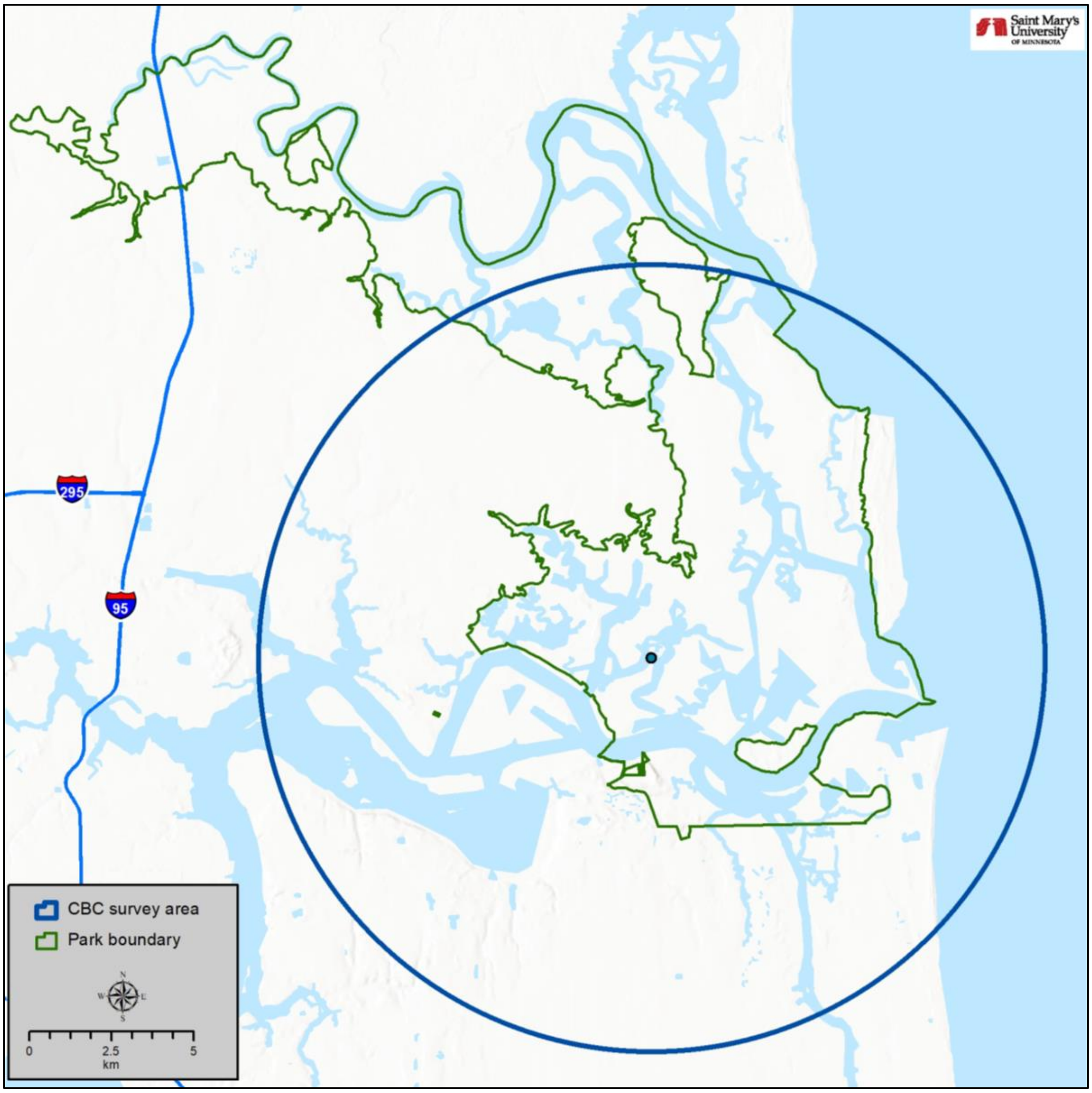

Figure 39. Christmas bird count survey area for the Jacksonville CBC. The Jacksonville CBC has been conducted annually since 1949, and dates back as far as 1910.

Data from the TIMU area CBC were obtained from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx and the following edits were made to the dataset:

- All incomplete species identifications were omitted (e.g., *Buteo* spp., *Vireo* spp., Greater/Lesser Scaup).
- Observations of American Green-winged Teal and Green-winged Teal were treated as one category as both refer to *Anas crecca*.
- Similarly, observations of American Barn Owl were treated as observations of the Barn Owl (*Tyto alba*).

- Aggregated observations of species artificially separated by color variations (e.g., white and blue form of *Ardea herodias,* or white-eyed/red-eyed Eastern Towhee) were not treated as unique species observations.
- CBC observations of Palm Warbler had been broken down into taxonomically correct subspecies: Western Palm Warbler (*Setophaga palmarum palmarum*), and Yellow Palm Warbler (*Setophaga palmarun hyphochrysea*). Because the western subspecies' range is of a great distance to the park and are unlikely to be vagrants to TIMU, all observations were grouped together to the higher species level and were treated as observations of Palm Warbler (*Setophaga palmarum*).
- CBC records had a category of observations listed as "Ridgway's/Mangrove/Clapper Rail". Of these three species, only the Clapper Rail (*Rallus longirostris*) is likely to occur in the TIMU area; these observations were merged together with the Clapper Rail observations.
- CBC records indicated observations of Sandwich Tern (Cabot's). These observations were adjusted to be records of Cabot's Tern (*Thalasseus acuflavidus*) which was formerly identified as a subspecies of the Sandwich Tern but has since been determined to be its own unique species (Efe et al. 2009).

4.4.5 Current Condition and Trend

Species Richness

Bird surveys often focus on different parameters, and accordingly will utilize varying methodologies. Because of this, it is difficult to compare the results of the studies to each other. The differing methodologies, focal species, and timing make trends and patterns observed in each study difficult to compare and the results are best analyzed individually. This assessment presents the results of each study, but does not compare the species richness values between any studies.

NPS Certified Species List (NPS 2020d)

The NPS Certified Bird Species List contains 312 species that are confirmed in the park (Appendix J). Unlike annual bird surveys, NPS (2020) is not well suited for an analysis of annual species richness, as no data are collected yearly. The NPS Certified Species List documents the presence (or historic presence) of the identified species and serves as a useful point of comparison to determine which species have been documented in the park.

eBird Results

Results from the eBird citizen science database for the Kingsley Plantation, Cedar Point, the TRA, and Fort Caroline areas indicated that 237 species have been observed in the TIMU area. The Kingsley Plantation checklist had the highest species richness estimate with 209 observed species, followed by Theodore Roosevelt, Cedar Point, and Fort Caroline, respectively (Appendix K).

TNC (1996) Rare Bird Survey of Cedar Point

TNC (1996) identified species richness as being the estimated combined number of species on each census date. However, the raw census date data are not available, and the estimated species richness values for these dates were presented only in graphs in the published report. Due to this, species richness will be simply reported as the total number of species observed for the study period (April–June 1995).

In total, 108 species were observed across the various habitats sampled in Cedar Point (Appendix J). TNC (1996) indicated that the species richness of the study area appeared to be relatively static, with an average of 55 different species being observed during each survey. Because this survey occurred during the breeding season, wintering species were likely absent from any estimate of species richness; TNC (1996) noted that most of the wintering species were absent from Cedar Point by 22 April 1996. Authors noted that species richness in the area was high, likely due to the wide range of habitat types in the area. Further, the avian communities of Cedar Point appeared to align with what had been previously observed at nearby Fort George Island and other nearby coastal areas (TNC 1996).

Jones and Jones (1998)

The point count surveys conducted by Jones and Jones (1998) occurred from January to February of 1998 in both Cedar Point and the Theodore Roosevelt Area of TIMU. The results of this survey are unique in that they are the result of focused survey and methodology that captured a snapshot of the wintering/resident population of birds in the park. Outside of the somewhat informal CBC efforts in some areas, the winter bird community of many parks has been under-sampled in many areas. In total, 50 avian species were identified across both studies areas. During the Cedar Point counts, 39 species were identified, and 28 species were identified in the Theodore Roosevelt Area (Appendix L).

Byrne et al. (2011)– SECN Landbird Monitoring

Observer-based surveys in 2010 documented the presence of 50 landbird species across 30 survey plots in TIMU (Byrne et al. 2011) (Appendix J). The House Finch (*Haemorhous mexicanus*) was the only non-native species observed during the study. When looking at the likelihood of detecting a species, Byrne et al. (2011) indicated that the Carolina Wren (*Thryothorus ludovicianus*), Northern Cardinal (*Cardinalis cardinalis*), and Tufted Titmouse (*Baeolophus bicolor*) were most frequently encountered species in the study area.

Jacksonville Christmas Bird Count (1910–11, 1924–25, 1929–32, 1936, 1940, 1944–45,1948–present)

The Jacksonville CBC survey area encompasses most of TIMU (Figure 40). Counts such as the CBC (or other index counts, e.g., breeding bird surveys) are neither censuses nor density estimates (Link and Sauer 1998). The overall usefulness of index count data is often limited by possible biases of count locations and the number of observers, and it is often not advisable to estimate overall population sizes from these data alone (Link and Sauer 1998). These biases may influence how many individuals are observed in a given year, and may potentially explain the annual variation observed in species each year. Results of the Jacksonville CBC should be interpreted with a degree of caution.

During the 83 years of semi-continuous CBC efforts for the entire Jacksonville count circle (not just within TIMU boundaries), 286 bird species have been observed (Appendix J). The highest number of species observed in a given year was 168 (2013; 40 observers), while the lowest number of species observed was 16 (1945; note that there was only one observer) (Figure 40). The average number of bird species observed during the Jacksonville CBC was 133 species, and the average number of observers per year was 32.

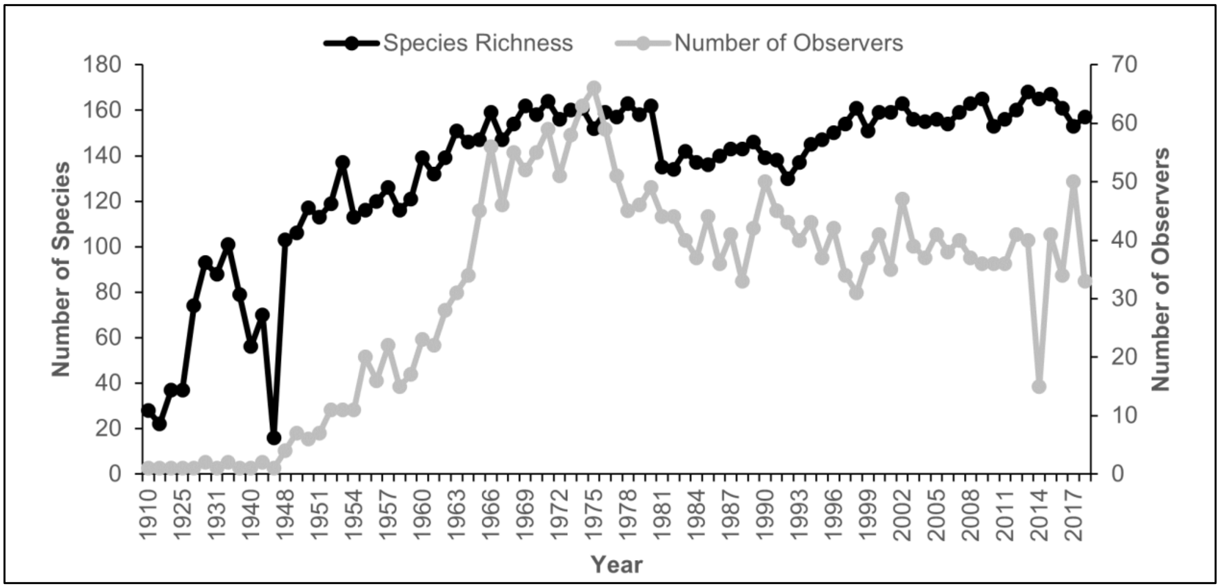

Figure 40. Number of bird species and observers during the Jacksonville CBC between 1910 and 2018. Note that data include all count circle results and are not specific to TIMU. Data retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Species Abundance

Avian species abundance refers to how many individuals are documented in a given survey/monitoring period. However, the various studies that have taken place in TIMU have used varying definitions of abundance. Some surveys report abundance by the summation of the total number of observations made for each species (Byrne et al. 2011), while others discuss abundance as the average number of individuals detected per study date (TNC 1996). It needs to be noted, however, that all species have different detection probabilities, and measures of abundance reported here should be considered "naïve" estimates, as they do not account for these variable detection probabilities.

TNC (1996) Rare Bird Survey of Cedar Point

Similar to the species richness measure in this assessment, the TNC (1996) report does not provide raw data for species abundance. Instead, abundance was reported using the percent of census dates where an individual was observed, as well as the average number of individuals observed per census date.

Several avian species were observed on every census date during TNC (1996), as 17 species were found during every census. The three most abundant species were Bobolink (*Dolichonyx oryzivorus*; 35 ind./census), Cedar Waxwing (*Bombycilla cedrorum*; 24.3 ind./census), and Common Yellowthroat (*Geothlypis trichas*; 16.6 ind./census) (Table 27). Other species detected in relatively high numbers included the Northern Parula (*Setophaga americana*), Red-winged Blackbird (*Agelaius phoeniceus*), and the Eastern Towhee (*Pipilo erythrophthalmus*).

Table 27. The ten species with the highest average number of individuals/census (ind./census) date during the TNC (1996) rare bird survey in the Theodore Roosevelt Area and Cedar Point area of TIMU.

Species	**Avg # of ind./census date**
Bobolink	35.0
Cedar Waxwing	24.3
Common Yellowthroat	16.6
Northern Parula	14.4
Red-winged Blackbird	12.4
Eastern Towhee	11.0
Gray Catbird	10.6
Northern Cardinal	10.5
White-eyed Vireo	10.5
Tufted Titmouse	9.9

Byrne et al. (2011) – SECN Landbird Monitoring

Byrne et al. (2011) reported abundance as the total number of detections across the entire study period. Results appeared to suggest a compositionally diverse landbird community, with Northern Cardinal, Laughing Gull (*Leucophaeus atricilla*), Tufted Titmouse, Carolina Wren, Eastern Towhee, and Northern Parula comprising over 50% of all observations (Table 28). Northern Cardinal and Laughing Gull had the highest number of detections, with both species being observed over 250 times during the survey. Little Blue Heron (*Egretta caerulea*), a state-threatened species, was detected two times during the survey; no other state or federally listed species were detected during the surveys (Byrne et al. 2011).

Table 28. Number of detections (sight and sound) collected during Byrne et al. (2011) sampling in TIMU in 2010.

Common Name	**Number of Detections**
Northern Cardinal	288
Laughing Gull	251
Tufted Titmouse	153
Carolina Wren	143
Eastern Towhee	120
Norther Parula	112
Yellow-throated Warbler	74
White-eyed Vireo	61
Mourning Dove	51

Table 28 (continued). Number of detections (sight and sound) collected during Byrne et al. (2011) sampling in TIMU in 2010.

Common Name	Number of Detections
Common Yellowthroat	47
Red-bellied Woodpecker	45
Red-eyed Vireo	44
Blue-gray Gnatcatcher	35
Chuck-will's-widow	33
Pine Warbler	33
Gray Catbird	31
Great Crested Flycatcher	28
American Crow	19
Red-winged Blackbird	19
Blue Jay	18
Blue Grosbeak	17
Common Grackle	15
Clapper Rail	13
Prairie Warbler	12
Downy Woodpecker	9
Barred Owl	8
White Ibis	8
Carolina Chickadee	7
Great Egret	7
Brown Thrasher	6
House Finch	6
Northern Mockingbird	6
Northern Bobwhite	5
Pileated Woodpecker	5
Snowy Egret	5
Acadian Flycatcher	4
Canada Goose	4
Common Moorhen	4
Great Blue Heron	4
Eastern Screech-owl	3
Fish Crow	3
Summer Tanager	3
Eastern Phoebe	2
Little Blue Heron	2
Osprey	2

Table 28 (continued). Number of detections (sight and sound) collected during Byrne et al. (2011) sampling in TIMU in 2010.

Common Name	Number of Detections
Ovenbird	2
Red-shouldered Hawk	1
Ruby-crowned Kinglet	1
Yellow-billed Cuckoo	1
Yellow-breasted Chat	1

Jacksonville Christmas Bird Count (1910–11, 1924–25, 1929–32, 1936, 1940, 1944–45,1948–present)

As discussed previously, the CBC takes place over the winter months when some migratory and breeding bird species are no longer present in the area; the abundance estimates and species observed during these counts may look very different when compared to breeding or migratory season surveys. As was done with the species richness measure, abundance estimates are discussed below for the CBC that takes place near TIMU. It is important to note that any perceived trends from CBC effort could be due to observer effort, untrained observers, or other variabilities that could be attributed to the lack of a rigorous, repeatable sampling methodology. Results of the CBC are presented here to allow for crude comparisons over a long period of record, but offer no conclusions regarding statistical significance or scientifically-supported trends. Statistics included here could provide managers with information to identify target areas of perceived concern in the future.

Yellow-rumped Warbler (*Setophaga coronata*) had the highest average number of individuals detected per year during the Jacksonville CBC, with 3,229 detections per year (Table 29). The maximum estimated number of Yellow-rumped Warblers observed during a count was 8,700 in 1968. Only one other species approached the numbers of the Yellow-rumped Warbler; estimated detections of Ring-billed Gull (*Larus delawarensis*) averaged 2,885 per count. Ring-billed Gull had an extremely high count in 1991, with 19,772 detections reported. Frequently detected, though slightly less abundant, species included the American Robin (*Turdus migratorius*), Herring Gull (*Larus argentatus*), Fish Crow (*Corvus ossifragus*), and Red-winged Blackbird (Table 29).

For the 10 most frequently detected species, abundance estimates during the Jacksonville CBC in the past 5 years have been variable (Table 30). Five species exhibited perceived declines in abundance in the past five years (Yellow-rumped Warbler, Ring-billed Gull, Herring Gull, Fish Crow, and Red-winged Blackbird), while the other five species exhibited perceived increases in abundance. Of the species identified in Table 30, no species exhibited as great a decline in perceived abundance as the Ring-billed Gull. The cumulative average abundance for this species across the duration of the CBC was 2,885 ind./year, but in the last 5 years the highest number of Ring-billed Gulls detected never exceeded 800. Conversely, the American Robin had a 5-year average of 3,813 ind./year from 2014–2018, which represented a perceived increase that was nearly double that from the cumulative CBC average of 1,560 ind./year.

Table 29. Average annual abundance for the 10 most frequently observed bird species during the Jacksonville CBC. Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Species	Average Number of Individuals/Year
Yellow-rumped Warbler	3,229
Ring-billed Gull	2,885
American Robin	1,560
Herring Gull	1,372
Fish Crow	1,367
Red-winged Blackbird	1,229
Laughing Gull	1,187
Tree Swallow	1,135
Double-crested Cormorant	1,011
Black Skimmer	956

Table 30. Average annual abundance estimates from 2014–2018 CBC efforts for the 10 species historically detected most frequently in the Jacksonville Count Circle. Negative values are also shaded in gray. Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx. NOTE: departure from average has not been tested for statistical significance, and represents only the difference between the 5-year average and the CBC Duration average.

Species	2014	2015	2016	2017	2018	5-Year Avg.	Departure from CBC Duration Average
Yellow-rumped Warbler	1,500	1,200	1,500	900	2,100	1,440	−1,789
Ring-billed Gull	800	400	400	400	700	540	−2,345
American Robin	2,100	790	2,100	7,323	6,753	3,813	2,253
Herring Gull	100	200	225	60	76	132	−1,240
Fish Crow	1,100	400	400	200	330	486	−881
Red-winged Blackbird	600	1,000	700	900	500	740	−489
Laughing Gull	1,100	1,600	1,700	1,200	1,000	1,320	133
Tree Swallow	100	4700	600	1,300	600	1,460	325
Double-crested Cormorant	1,300	900	1,000	1,100	1,000	1,060	49
Black Skimmer	3,400	1,100	900	2,464	1,792	1,931	976

Species Distribution

The species distribution measure in this assessment represents a data gap. Many of the studies that have taken place in the park have documented species richness, abundance, or diversity, but few have looked extensively at the distribution of birds across the landscape of the park. The SECN landbird monitoring represents the most useful dataset available, but the two most recent surveys (2015, 2020) remain unsummarized and not yet published. Future assessments of condition will benefit greatly from those publications and will be able to describe the condition and distribution of birds more accurately across the entirety of TIMU.

The 2010 SECN monitoring is summarized briefly below, with distribution largely represented by the proportion of sites (Figure 38) where a species was observed. Appendix C and Appendix D in Byrne et al. (2011) provide additional visual examples of where species were detected in relation to study sites.

Byrne et al. (2011) – SECN Landbird Monitoring

Byrne et al. (2011) reported species composition and distribution by calculating the proportion of sites where a species was detected at least once. Naïve occupancy estimates, which indicate the likelihood of an observer encountering a species, suggested that the Carolina Wren (detected at 96% of sites), Northern Cardinal (detected at 92% of sites), and the Tufted Titmouse (detected at 92% of sites) were the most frequently detected and broadly distributed species during sampling. A breakdown of species composition by sampling sites is provided in Table 31.

Table 31. Proportion of sites where each bird species was detected at TIMU during 2010 monitoring by Byrne et al. (2011).

Common Name	Proportion of Sites Where Observed
Carolina Wren	0.96
Northern Cardinal	0.92
Tufted Titmouse	0.92
Eastern Towhee	0.62
Northern Parula	0.62
White-eyed Vireo	0.54
Yellow-throated Warbler	0.54
Blue-gray Gnatcatcher	0.50
Common Yellowthroat	0.50
Red-bellied Woodpecker	0.50
Blue Jay	0.42
Mourning Dove	0.42
American Crow	0.38
Gray Catbird	0.38
Laughing Gull	0.38
Chuck-will’s-widow	0.31

Table 31 (continued). Proportion of sites where each bird species was detected at TIMU during 2010 monitoring by Byrne et al. (2011).

Common Name	Proportion of Sites Where Observed
Pine Warbler	0.31
Red-eyed Vireo	0.31
Great Crested Flycatcher	0.27
Prairie Warbler	0.27
Downy Woodpecker	0.23
Pileated Woodpecker	0.19
Barred Owl	0.15
Carolina Chickadee	0.15
Canada Goose	0.12
Acadian Flycatcher	0.08
Blue Grosbeak	0.08
Clapper Rail	0.08
Common Moorhen	0.08
Fish Crow	0.08
Great Blue Heron	0.08
Great Egret	0.08
Northern Bobwhite	0.08
Northern Mockingbird	0.08
Osprey	0.08
Red-winged Blackbird	0.08
Snowy Egret	0.08
Summer Tanager	0.08
White Ibis	0.08
Brown Thrasher	0.04
Common Grackle	0.04
Eastern Phoebe	0.04
Eastern Screech-owl	0.04
House Finch	0.04
Little Blue Heron	0.04
Ovenbird	0.04
Red-shouldered Hawk	0.04
Ruby-crowned Kinglet	0.04
Yellow-billed Cuckoo	0.04
Yellow-breasted Chat	0.04

Wading Bird Nesting Numbers

Note, for the purpose of this and future assessments, the definition of a wading bird will include herons, egrets, and bitterns (Family *Ardeidae*), ibises and spoonbills (Family *Threskiornithidae*), cranes (Family *Gruidae*), limpkins (Family *Aramidae*), and storks (Family *Ciconiidae*). Few studies have documented wading bird nesting numbers in the park. The studies that have observed wading birds usually did so as part of a broader avian survey, not targeted at nesting species or wading birds specifically. Some studies, such as Kurimo-Beechuk (2015) (TIMU secretive marsh bird survey) and Tardona et al. (2019) (Anhinga Pond Survey/Rookery investigation) have documented wading bird presence and crude nesting estimates, but have not noted nesting success or other vital nesting parameters.

Wading birds undoubtedly nest within TIMU, but the degree to which they are present yearly is under-represented in the data. Wading bird species that have been documented in TIMU include Wood Stork, Roseate Spoonbill, White Ibis, Glossy Ibis, and many heron, egret, and bittern species (Appendix J). It is likely that wading birds utilize the emergent vegetation and standing timber of the area to nest, but a detailed investigation is necessary to document trends and nesting locations. These types of investigations will be critical to better understanding the nesting usage of TIMU for priority wading bird species such as wood storks and white ibises.

Threats and Stressor Factors

Climate change is one of the major forces affecting bird communities across the globe; this threat is becoming better understood as research and data continue to become available. Changes in the temperature and precipitation norms in the park could have both direct and indirect effects on the bird community of TIMU. An example of a direct impact to the bird community in the park includes potential shifts in the timing of spring plant phenology, while indirect impacts resulting from shifts in temperature and precipitation could include effects on the frequency, extent, and severity of insect outbreaks. These changes may influence food availability for birds.

Another climate-related threat facing breeding bird populations is the shifting of species' reproductive phenology. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American Robins in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success and population declines (Jones and Cresswell 2010).

Temperatures are projected to rise across the southeastern United States over the next century as a result of global climate change (Carter et al. 2014). This increase in temperatures will likely increase evapotranspiration rates, meaning that even if annual precipitation remains constant or slightly increases, overall conditions could become drier in the future (Carter et al. 2014). An additional effect of temperature increases is that the frequency and intensity of droughts will also increase. These periods also affect availability of food for birds. Drought may reduce forage items such as insects and plant species (Smith 1982), and could lead to starvation or malnourishment for many birds in the park. Another impact of drought is that it may alter the nesting success of colonial nesting species, as Gaines et al. (2000) noted that colonial nesting species have been observed relocating entire rookeries in response to drought conditions. Drought could also interrupt or alter the migratory patterns of species (Zeng 2003, Dai et al. 2004, Gordo 2007).

Wetlands represent a habitat type that has been declining across much of the continental U.S., with Dahl (1990) estimating that 53% of the wetlands in the continental U.S. were lost between 1780 and 1980. As mentioned previously, climate change can impact ecosystems in a variety of ways. Without precipitation increases accompanying the predicted temperature increases, climate change has the potential to have severe impacts on wetland communities, especially in relation to the loss of water inputs and reduction in wetlands' water storage capacity (NABCI 2010). Marsh specialist species in the American Southeast have suffered declines in the past 40 years, with many grebe, rail, ibis, and kite species existing well below historic population levels (NABCI 2009). The expansive protected marsh areas of TIMU likely represent critical habitat areas for secretive marsh specialist species and should be monitored for potential climate change-related impacts in the future. Observations suggest black mangrove may be migrating north along Florida's Atlantic Coast (Williams et al. 2014). Salt marsh plant species cannot compete with the taller mangrove trees for light and will be shaded out if mangroves invade (Kangas and Lugo 1990, Stevens et al. 2006). This shift in habitat could impact avian communities in the area and may trigger changes in overall species composition (McGinley et al. 2016). If global warming continues as expected, mangrove migration is likely to continue and may even accelerate (Rodriguez et al. 2016).

The City of Jacksonville is currently experiencing population growth; from 2017–2018, the city experienced one of the highest overall population increases in the country (U.S. Census Bureau 2019). Since the 2010 census, Jacksonville's population has increased by nearly 11%, from approximately 822,000 to 911,500 (U.S. Census Bureau 2020). Accordingly, the lands surrounding TIMU have been developed heavily, with human development rates among the most rapid in all of Florida (Byrne et al. 2012b). A 2003 report from the City of Jacksonville called for over 34,000 single-family homes to be developed in the surrounding areas. The developments near TIMU in North Jacksonville will likely be home to over 110,000 people by 2025. This increase in development and urbanization will expose park vegetation communities to additional internal stressors, such as habitat fragmentation, invasive species, hydrological alterations, and herbicide use (Byrd 2007).

While the threat of predation is a natural occurrence for avian species, instances of predation from non-native predators may represent a more quantifiable threat. Domestic and feral cats (*Felis catus*) are one of the largest causes of bird mortality in the United States. According to Loss et al. (2013), annual bird mortality caused by outdoor cats is estimated to be between 1.4 and 3.7 billion individuals. The median number of birds killed by cats was estimated at 2.4 billion individuals, and almost 69% of bird mortality due to cat predation was caused by un-owned cats (i.e., strays, barn cats, and completely feral cats) (Loss et al. 2013).

Waves generated by boat wakes can significantly disturb shorelines, sometimes contributing to the erosion and loss of salt marsh vegetation and oyster reefs (Herbert et al. 2018). Boat wakes may also re-suspend sediment, increasing turbidity and potentially transporting sediment out of the estuarine system, where it is needed for accretion to maintain marsh elevation (Herbert et al. 2018). Recreational boat traffic is increasing in estuaries worldwide and demand for waterfront access, including new marina construction, is high in Florida (Frazel 2009, Dix et al. 2017, Herbert et al. 2018).

Data Needs/Gaps

Continuation of the SECN landbird monitoring efforts are needed to better characterize the species richness of the park, and to analyze any potential trends in species presence or abundance over a longer period. Summarization of visits to the park since 2010 is also needed (currently underway). The SECN will continue to provide distribution data at the 30 previously identified locations, with surveys occurring on a set schedule.

Many of the measures in this assessment represent data gaps due to the lack of distribution data and wading bird-specific research. There is very little information on wading bird nesting numbers and fledging success. Until expanded research efforts are established in the park, an assessment of current condition for these measures is not possible.

Overall Condition

While there can be little doubt that TIMU represents a critical bird habitat for a variety of species, data as they relate to the specific measures of this assessment are lacking or are now out of date and do not provide an accurate snapshot-in-time picture of the park’s current status. The most recent avian survey with summarized data was completed 10 years ago (Byrne et al. 2011). Surveys have been completed in more recent years (SECN-led monitoring), but those data are not yet summarized or published and cannot be used to inform current condition in this assessment. While CBC data are available from relatively recent counts, count data can be unreliable (see previous discussion in this component), and only captures the avian community of the park on 1 day during the winter; a large portion of the park’s avian community (e.g., breeding birds) are underrepresented in these counts. While current condition is not assigned to this component, it is important to recognize that this is not a statement of poor health or condition, but rather represents a need for expanded research and data collection for this very diverse community in the park. TIMU draws visitors from across the world to view its unique avifauna, and an expansion of knowledge as it relates to current conditions and community structure would be very beneficial.

Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3 during project scoping. TIMU is home to a large number of bird species (estimated over 300 species), including rare vagrant species as they pass through the park during migration. Monitoring of the park’s avifauna community has been sporadic, with the most recent data coming from annual CBC efforts. Byrne et al. (2011) established a baseline for the landbird community of the park, but the results from this survey are now over 10 years old. Continuation of network monitoring has taken place, but the data are not yet summarized and published. The publication of these data would allow for a more accurate depiction of the park's species richness. While it is unlikely that the species richness of the park's bird community is in poor condition, until more recent data become available, a *Condition Level* for this measure cannot be accurately assigned.

Species Abundance

A *Significance Level* of 3 was assigned to the species abundance measure. As discussed previously, the only data that exist for this measure are either not suitable for a snapshot-in-time condition assessment (Byrne et al. 2011), or are only representative of a single day's survey that captures the migratory and overwintering community and underrepresents the breeding community (CBC efforts). Other data summarized in this component are useful for a historical perspective and baseline establishment (TNC 1996). A *Condition Level* was not assigned to this measure.

Species Distribution

Species distribution was assigned a *Significance Level* of 3 during project scoping. Few studies have documented the distribution of avian species across the park. Byrne et al. (2011) provided appendices that outline where species occurred in the park; however, these surveys are now over 10 years old. The summarization of SECN bird monitoring efforts in TIMU is needed to accurately summarize the current condition in the park and a *Condition Level* was not assigned at this time.

Wading Bird Nesting Numbers

The NRCA project team assigned this measure a *Significance Level* of 3 during project scoping. At present, the number of nesting wading birds is understudied. Until an investigation takes place that accurately assesses the number of nesting species/individuals, a *Condition Level* cannot be assigned.

Weighted Condition Score

The *Weighted Condition Score* for the birds component in TIMU is currently undefined (Table 32). While it is known that the park has a broad assemblage of birds, additional annual monitoring of the many groups of birds, specifically wading birds, is needed. There are several species of high conservation concern that utilize the park at various stages of the year, and continued annual monitoring would also help to identify potential trends in these species. Summarization and publication of ongoing SECN-led bird monitoring will be highly useful for future assessments of avian condition.

Table 32. Current condition of birds at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Species Richness	3	n/a	–
Species Abundance	3	n/a	–
Species Distribution	3	n/a	–
Wading Bird Nesting Numbers	3	n/a	–
Overall	**–**	**–**	◌

4.4.6 Sources of Expertise

- Michael Parrish, SECN Wildlife Biologist

4.5 Saltwater Fish Community

4.5.1 Description

Fish communities play essential roles in ecosystems and often serve as indicators of degradation within an environment (Fausch et al. 1990, Dennis et al. 2001b, UNF and JU 2019). Fish are critical links in the aquatic food web, with some species serving as prey for a variety of wildlife and others as predators; species that feed on plankton or detritus (i.e., dead organic material) help cycle energy/nutrients through the ecosystem (Durako et al. 1988, UNF and JU 2019).

The fish community of the Lower Saint Johns River (SJR), which forms the southern boundary of TIMU, holds great ecological, recreational, and commercial value to the public (UNF and JU 2019). The estuary and bordering coastal marshes, in particular, serve as important nursery areas for many fish species (Durako et al. 1988, Dennis et al. 2001b). The Nassau River along TIMU's northern border offers a relatively pristine aquatic environment, as it is the only drainage along Florida's Atlantic Coast that has not been channelized or stabilized by engineering structures (Anderson et al. 2005). In the SJR, salt and freshwater mix for up to 48 km (30 mi) inland from the river's mouth due to tidal influence. In the Nassau River, this "mixing zone" extends to the western boundary of TIMU (Anderson et al. 2005).

The most common and commercially or recreationally important saltwater fish species in the Lower SJR Basin include striped mullet (*Mugil cephalus*, Figure 41), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), Atlantic croaker (*Micropogonias undulatus*), sheepshead (*Archosargus probatocephalus*), southern flounder (*Paralichthys lethostigma*), spot (*Leiostomus xanthurus*), menhaden (*Brevoortia* spp.), and anchovies (*Anchoa* spp.) (Durako et al. 1988, UNF and JU 2019).

Figure 41. Striped mullet in a Florida river (USFWS photo by Ryan Hagerty).

4.5.2 Measures

- Species richness
- Indices of abundance for age classes

4.5.3 Reference Condition/Values

A reference condition for TIMU's fish communities is currently not well-defined. Management goals are no further deterioration or loss in the community (Steven Kidd, personal communication, January 2020). The condition information presented in this document could be used as a reference point for future assessments.

4.5.4 Data and Methods

During a study of blue crab (*Callinectes sapidus*) conducted by the Bureau of Commercial Fisheries (now the National Marine Fisheries Service), Tagatz (1967) documented the occurrence of fish in the SJR between April 1961 and November 1963. Collections were made using a 21-m (70-ft) seine and a 2.4-m (8-ft) trawl net. The study area extended from 16 km (10 mi) upstream of the river mouth to 217 km (135 mi) upstream. Only two of the study locations (A and B) fell within or alongside current TIMU boundaries (Figure 42). A species list was generated based on these collections and on previous observations by McLane (1955). For each euryhaline species collected, Tagatz (1967) reported the location and month taken, as well as the number and length range of fish. Species that were identified as "confined to fresh water" (Tagatz 1967, p. 32) will be excluded from this assessment, since the focus is on the saltwater fish community.

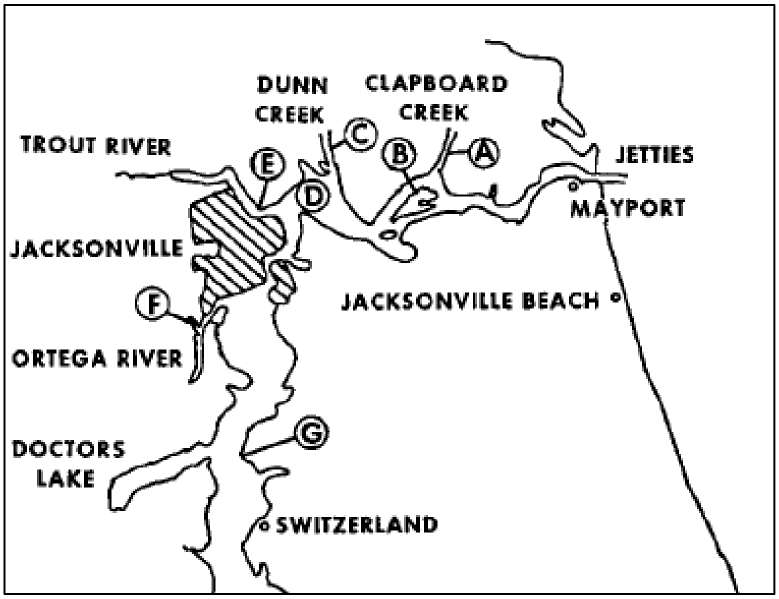

Figure 42. Location of collection stations on the St. Johns River within or near TIMU boundaries utilized by Tagatz (1967).

Dennis et al. (2001b) studied the effects of urbanization on tidal creek fish by sampling four creeks in the Jacksonville area with varying levels of development and freshwater input. Two of these creeks—Clapboard Creek and Cedar Point Creek—are within TIMU. Ten sampling sites were randomly selected in the upper and middle reaches of each creek; samples were collected in July 1996, December 1996, February 1997, and April/May 1997 (Dennis et al. 2001b). Dennis et al. (2001a) also conducted a nekton inventory for TIMU, which served as the primary source for the NPS Certified Species List for the park's fish community (NPS 2020d).

Each year since 2008, the University of North Florida and Jacksonville University have collaborated to produce an annual "State of the Lower St. Johns River Basin" report. Since 2012, these reports have included yearly indices of abundance (IOA) by fish species for relevant age classes (young of the year, adults) (UNF and JU 2008, 2012, 2019). These data come from ongoing research by the Florida Fish and Wildlife Research Institute's (FWRI) Fisheries Independent Monitoring (FIM) program, initiated in 2001. Saltwater species included in these reports are red drum, spotted seatrout, striped mullet, southern flounder, sheepshead, and Atlantic croaker. However, because of the gear used for monitoring, data for adult striped mullet and southern flounder are limited. Figure 43 below shows that TIMU falls in Areas B (Nassau River) and C (SJR) of the overall FIM study area. The majority of IOA data presented in the annual reports are for areas C and D combined or for areas C, D, E and F combined.

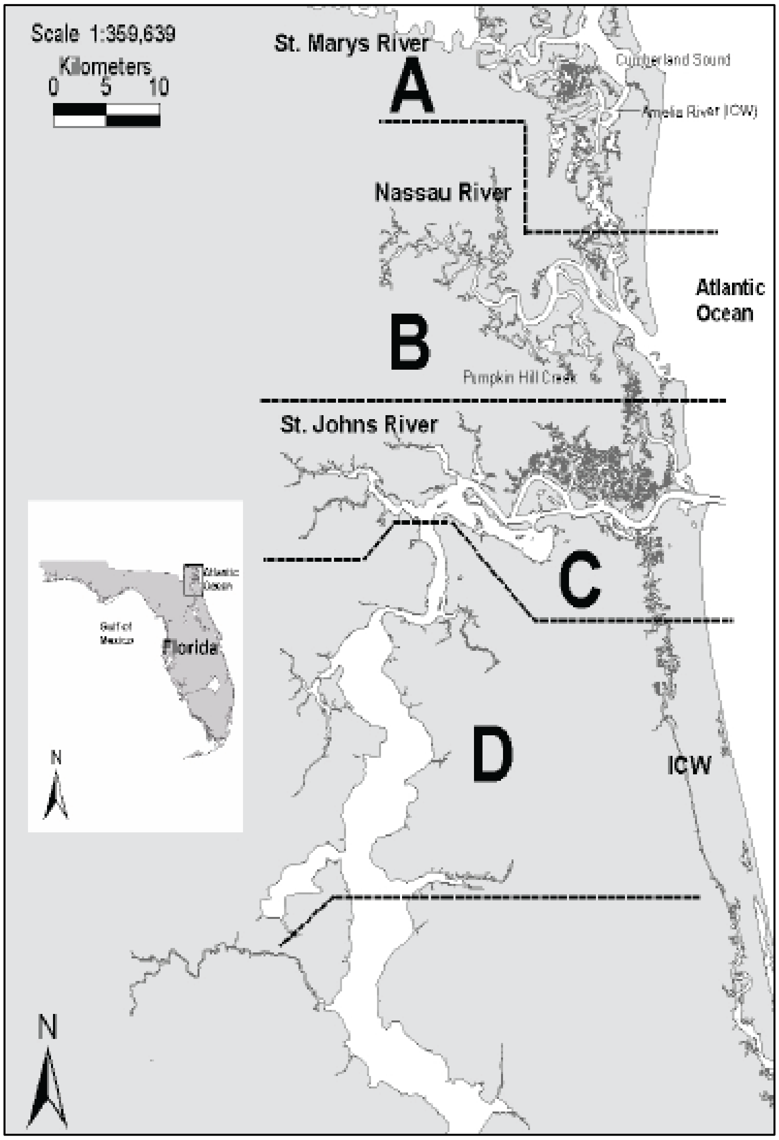

Figure 43. The northern portion of the FWRI's FIM study area (Reproduced from UNF and JU 2019). TIMU falls in Areas B and C. Areas E and F, not shown on this map, are to the south of area D.

4.5.5 Current Condition and Trend

Species Richness

According to the park's Certified Species List (NPS 2020d), which is primarily based on Dennis et al. (2001a), 119 saltwater fish species have been documented in the waters within or adjacent to TIMU. An additional 13 saltwater species not currently on the Certified Species List were captured in or adjacent to TIMU's current boundaries by Tagatz (1967). Combined, 132 saltwater fish species have been confirmed at the park over time, all of which are considered native (Appendix M). It is unclear whether species documented by Tagatz (1967) but not currently on the species list reflect changes in species composition over time or differences in sampling locations, timing, and methodology (e.g., gear used).

Indices of Abundance for Age Classes

Since 2001, the FWRI's FIM program has gathered IOA data for six key saltwater fish species in the Lower SJR. The 2019 Lower SJR "State of the River" report presented IOA results for 2006–2018 (UNF and JU 2019). For three species (red drum, sheepshead, and spotted seatrout), results were grouped for Zones C (which includes portions of TIMU) and D. Since 2006, the adult red drum IOA has been relatively stable, while young of the year IOA has fluctuated with no clear increase or decrease over time (Figure 44). Sheepshead IOAs for young of the year and adults (legally harvestable) have also been relatively stable, but with more fluctuation among adults (Figure 45). Spotted seatrout IOAs have also fluctuated; young of the year data seem more stable over time, while adult IOAs have been slightly lower from 2013–2018 when compared to numbers for 2006–2012 (Figure 46). Overall, however, the State of the River report (UNF and JU 2019), considers the status of red drum and spotted seatrout in the Lower SJR satisfactory with an "unchanged" trend. The status and trend for sheepshead is "uncertain" (UNF and JU 2019). Additional IOA graphs showing data from 2001–2011 are included in Appendix N.

For the remaining three species (striped mullet, southern flounder, and Atlantic croaker), results were grouped for Zones C, D, E and F. Only young of the year IOAs were available for these species in recent years. Striped mullet IOA has fluctuated with no clear trend (Figure 47) while southern flounder has remained relatively stable with an occasional spike (Figure 48). Atlantic croaker young of the year fluctuated from 2006–2012, but have been stable since 2013 (Figure 49). According to the State of the River report (UNF and JU 2019), striped mullet status is considered satisfactory with an improving trend. Atlantic croaker status is satisfactory with an uncertain trend. Southern flounder status and trend are uncertain (UNF and JU 2019). As with the previous species, additional IOA graphs showing data from 2001–2011, including adult and juvenile IOAs, can be found in Appendix N.

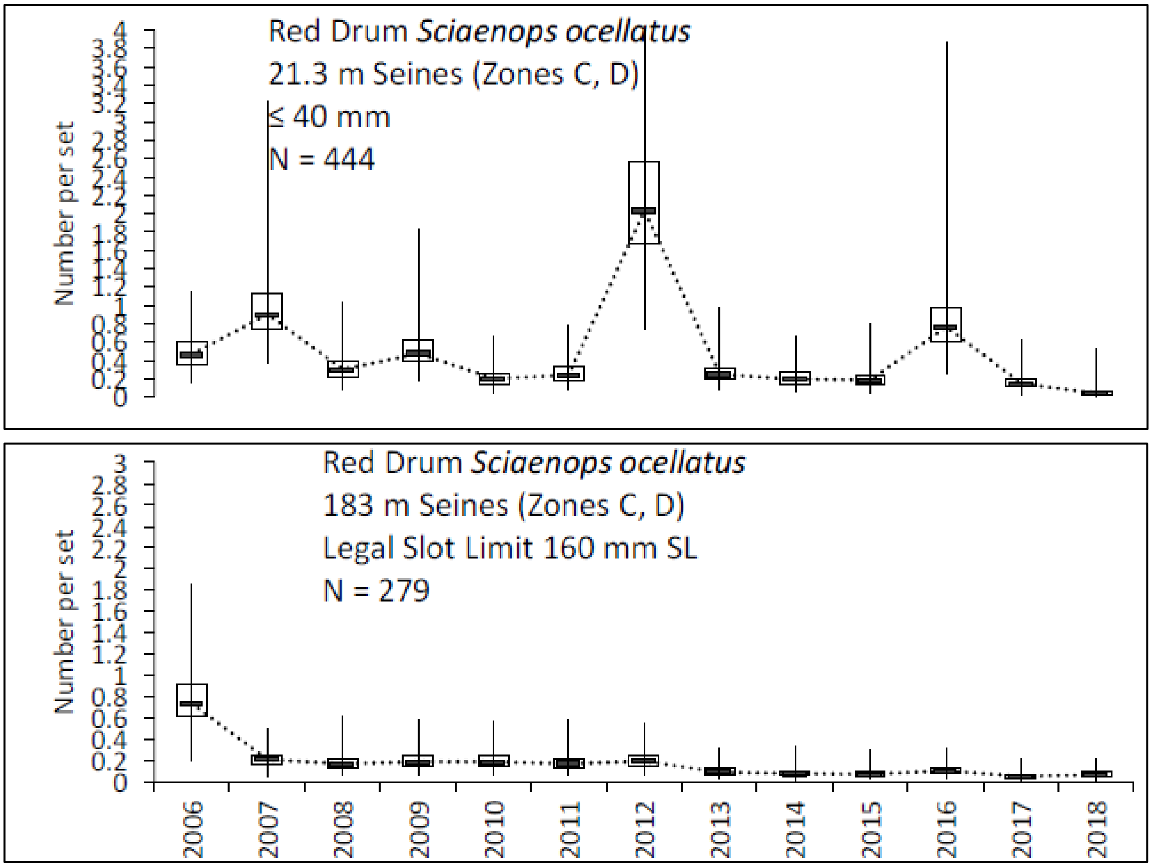

Figure 44. Indices of abundance for red drum young of the year (top) and adults (bottom) in the Lower SJR, 2006–2018 (reproduced from UNF and JU 2019). SL = standard length, or the length from the tip of the snout to the end of the last vertebra.

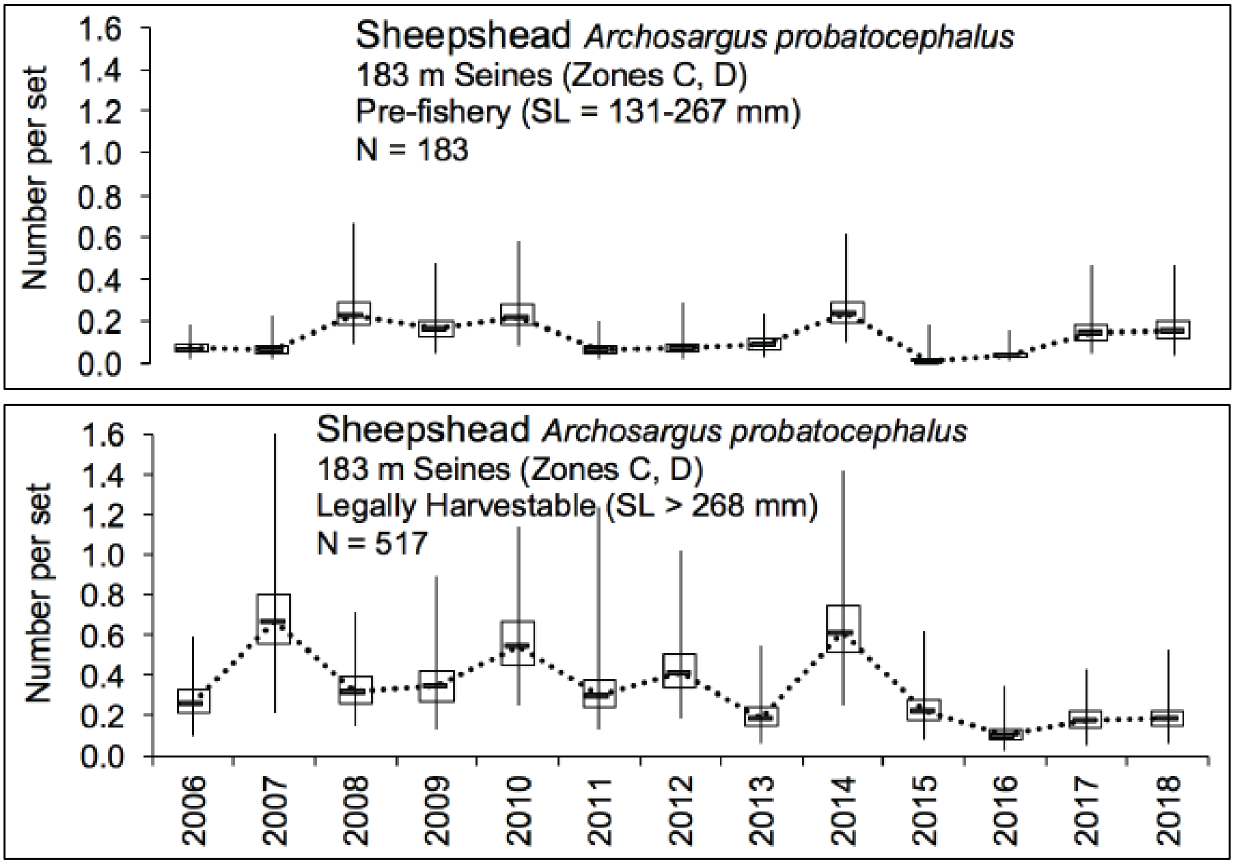

Figure 45. Indices of abundance for sheepshead of pre-fishery size (top) and harvestable size (bottom) in the Lower SJR, 2006–2018 (reproduced from UNF and JU 2019).

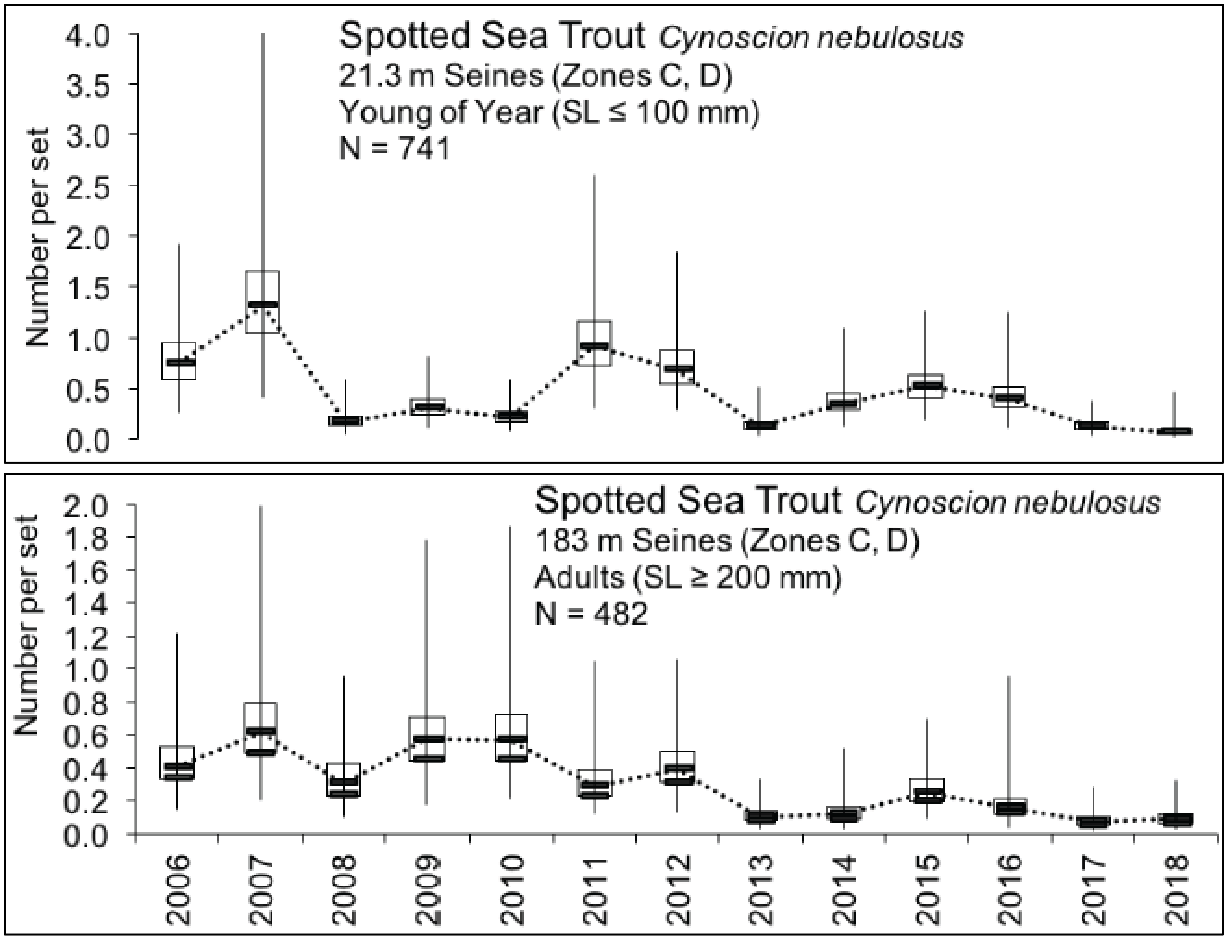

Figure 46. Indices of abundance for spotted sea trout young of the year (top) and adults (bottom) in the Lower SJR, 2006–2018 (reproduced from UNF and JU 2019).

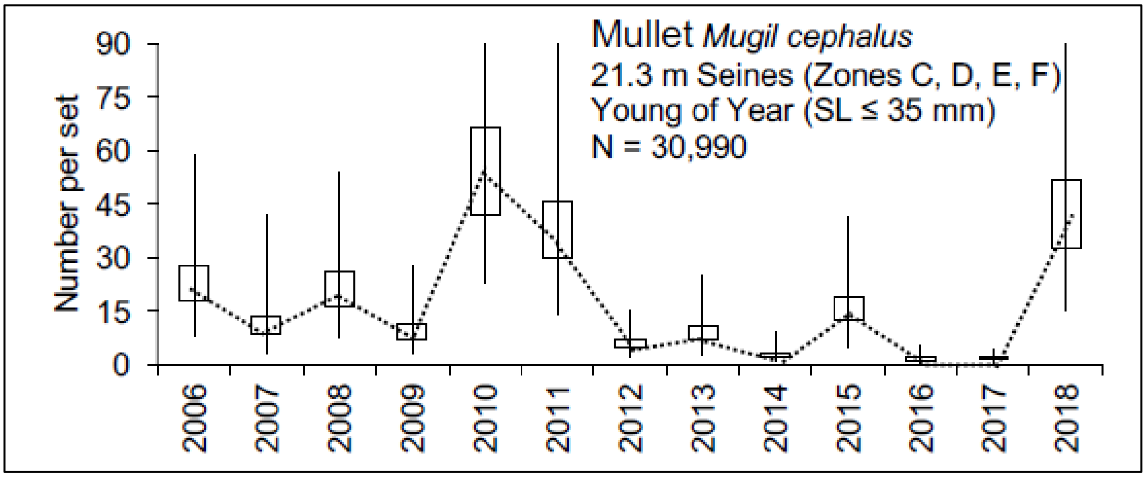

Figure 47. Indices of abundance for striped mullet young of the year in the Lower SJR, 2006–2018 (reproduced from UNF and JU 2019).

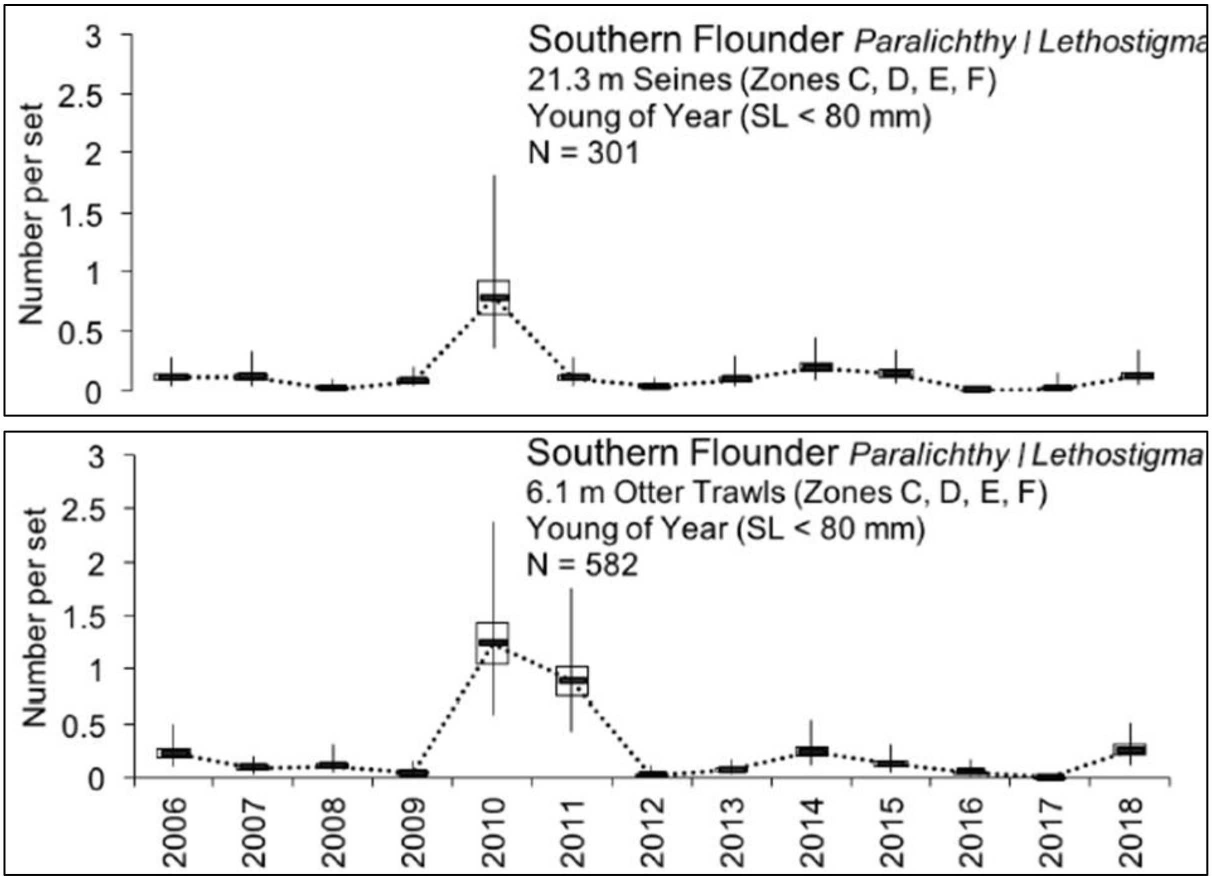

Figure 48. Indices of abundance for southern flounder young of the year in the Lower SJR, 2006–2018, using two different net types: a seine (top) and an otter trawl (bottom) (reproduced from UNF and JU 2019).

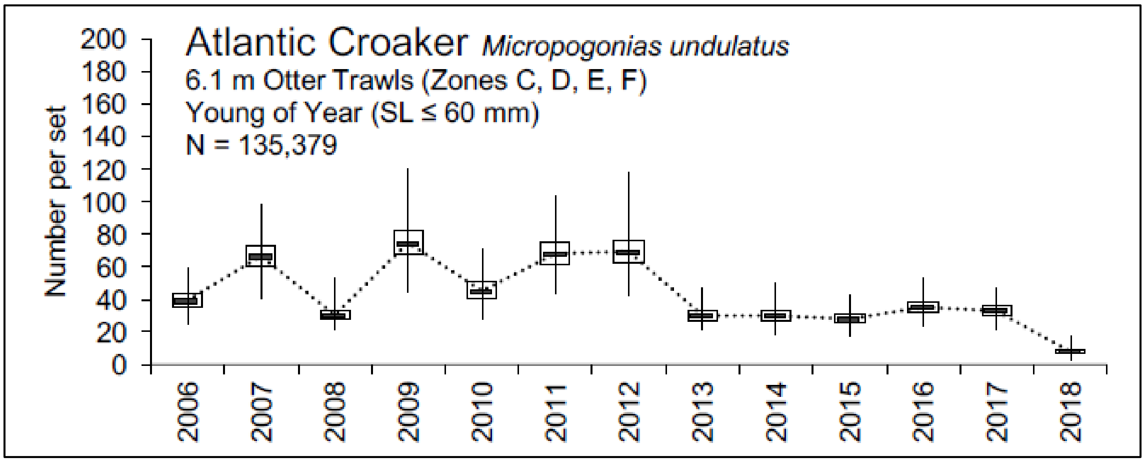

Figure 49. Indices of abundance for Atlantic croaker young of the year in the Lower SJR, 2006–2018 (reproduced from UNF and JU 2019). Note that young of the year Atlantic croaker were sampled over a split-year recruitment window from October to April, and 2018 data include October–December but *not January*–April.

Threats and Stressor Factors

Threats to TIMU's saltwater fish community include loss of nursery habitat due to development and shoreline armoring, water quality degradation, climate change, and possible illegal or over-harvest. Currently, no saltwater fish species in the Lower SJR are considered at risk of over-harvest (UNF and JU 2019). However, if harvest pressure were to increase or fish populations declined due to other stressors while harvest pressure stayed consistent, over-fishing could become a threat.

Urban development or modification has been shown to impact habitat structure, aquatic species diversity, and fish community integrity in estuarine environments (Felley 1987, Bilkovic and Roggero 2008). Development activities that threaten fish habitat include direct physical destruction/degradation, dredging for navigation, shoreline armoring to prevent erosion (e.g., bulkheads), and increased salinity due to freshwater inflow alterations (Durako et al. 1988, Dennis et al. 2001b). Upstream landscape alterations that alter freshwater inflow can impact salinity, nutrients, sedimentation, and toxins in estuaries, altering the overall ecological functioning of these habitats (Sklar and Browder 1998).

Shoreline hardening or armoring has been shown to impact fish communities, generally favoring larger species over smaller species (Toft et al. 2011, Kornis et al. 2017). Hardening degrades nearshore environments by altering water quality, sedimentation, benthic invertebrate communities, and submerged aquatic vegetation (Kornis et al. 2017). In the TIMU area, installation of rip-rap, groins, and jetties to prevent shoreline erosion has altered inlet dynamics (e.g., sediment supply, inlet migration), particularly at the Fort George Inlet (Anderson 2005). Currently, the opening of Fort George Inlet is at risk of closing due to sediment accumulation in Ward's Bay, on Ward's Bank, and upstream of the bridge over the Fort George River (Figure 50). The closure of this inlet would affect the water quality of upstream tidal creeks and marshes and limit fish movements through the estuarine system (Anderson 2005).

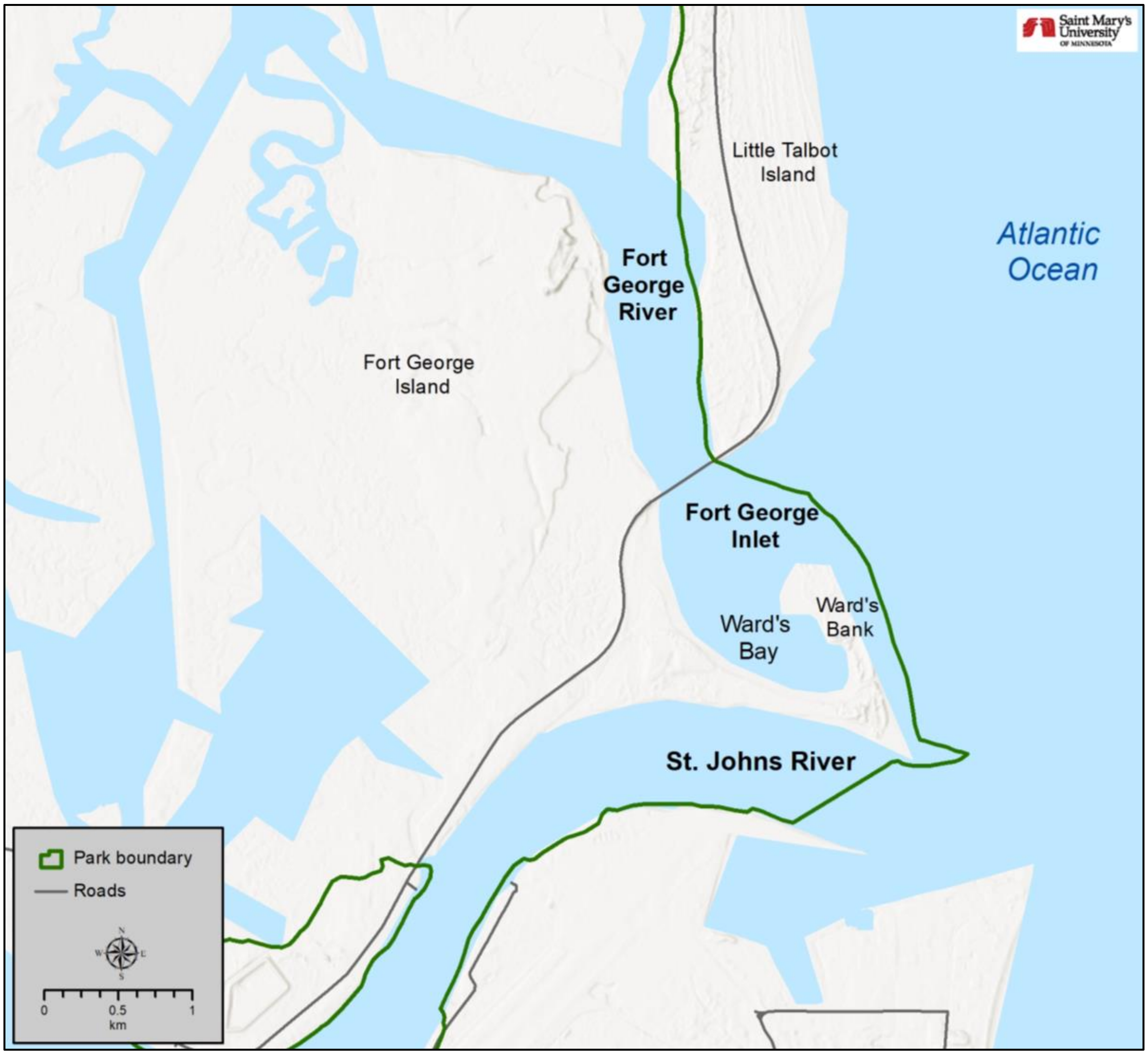

Figure 50. Location of Fort George Inlet and River within TIMU.

Water quality degradation, often linked to human activity, can impact fish abundance, distribution, and health, both directly and through impacts on habitat (Carpenter et al. 1998, Anderson 2005, UNF and JU 2019). Nutrient enrichment, particularly nitrogen and phosphorous, due to fertilizer and sewage treatment runoff causes eutrophication and contributes to excessive algal blooms (Dennis et al. 2001b). Algal blooms often result in reduced dissolved oxygen (DO) levels, which can stress and even kill fish (UNF and JU 2019). Mercury, a heavy metal known to impact the reproductive and immune systems of fish (Morcillo et al. 2017), has also been detected in some species in the Lower SJR (Anderson 2005, UNF and JU 2019).

Climate change is projected to increase temperatures in the southeastern U.S. and may alter weather/precipitation patterns, in addition to driving sea level rise (Carter et al. 2014, 2018). These changes may reduce fish nursery habitat, alter streamflow/hydrology, and increase contaminated stormflow runoff (Wetz and Yoskowitz 2013, Cakir 2014). Sea level rise could eliminate estuarine juvenile fish habitat or alter habitat conditions through increased saltwater inflow (Fulford et al.

2014, Ross et al. 2015). Fish species composition and distribution is strongly influenced by salinity, and any changes in salinity related to sea level rise could alter TIMU's fish community (Dennis et al. 2001b).

Data Needs/Gaps

Despite the importance of fisheries in the Lower SJR Basin, information regarding fish populations within the watershed is limited (Dennis et al. 2001b, UNF and JU 2019). In particular, little is known about fish assemblages in the upper reaches of estuaries (e.g., tidal creeks and marshes) (Dennis et al. 2001b). Data gathered by the FWRI's FIM program since 2001 has contributed to fisheries knowledge for the SJR, but due to the gear used for sampling, information for adults of several species is limited (UNF and JU 2019).

Recent information specific to fish communities within TIMU's waters could not be found. To properly assess the condition of the park's saltwater fish community, a park-wide survey or sampling would be needed, followed by regular monitoring (e.g., every 2–3 years) to identify any changes within the community. Since fish may serve as indicators of environmental degradation (Fausch et al. 1990), such monitoring could help detect threats to the broader ecosystem.

Overall Condition

Species Richness

The project team assigned this measure a *Significance Level* of 3. Over time, surveys have confirmed a total of 132 saltwater fish species occurring in TIMU's waters, 119 of which are currently on the park's Certified Species List (NPS 2020d). However, this species list is largely based on surveys from nearly two decades ago (Dennis et al. 2001a) and no recent surveys have occurred to determine whether species richness has changed since that time. As a result, a *Condition Level* cannot be assigned for this measure.

Indices of Abundance for Age Classes

This measure was also assigned a *Significance Level* of 3. While the FWRI's FIM program has provided some information regarding IOA for selected species within the Lower SJR, the published data are not specific to the park, and the age classes sampled have been somewhat limited for several species by the gear used (UNF and JU 2012, 2019). In addition, there is no IOA information for any of the park's waterways other than the SJR. Therefore, a *Condition Level* could not be assigned for this measure.

Weighted Condition Score

A Weighted Condition Score could not be calculated for TIMU's saltwater fish community due to a lack of current or park-specific data for the selected measures (Table 33). To properly assess the condition and trend of the fish community, a park-wide survey/sampling followed by regular monitoring would be needed.

Table 33. Current condition of the saltwater fish community at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Species Richness	3	n/a	–
Indices of Abundance for Age Classes	3	n/a	–
Overall	**–**	**–**	◌

4.5.6 Sources of Expertise

- Brian Gregory, SECN Program Manager/Aquatic Ecologist
- Steven Kidd, TIMU Science and Resource Manager

4.6 Oysters

4.6.1 Description

Oysters provide a number of important ecosystem services in estuarine and coastal communities around the world (Durako et al. 1988, Radabaugh et al. 2019a). As filter-feeding mollusks, they remove organic matter and fine sediments from the water as they feed, improving water quality and clarity (Radabaugh et al. 2019a). Oyster beds provide habitat and food sources for a multitude of other species (e.g., birds, fish, invertebrates), including many of conservation concern in Florida (FWCC 2012). Oyster beds or reefs can also stabilize or protect shorelines from erosion; due to their reef-building nature and the influence of these structures upon physical processes and the biological community, oysters are considered “ecosystems engineers” (Radabaugh et al. 2019a). Historically, oysters were a key food source for indigenous people and were used as a construction material by European settlers (Radabaugh et al. 2019a, NPS 2020g).

In Florida, the eastern oyster (*Crassostrea virginica*) is the most abundant and the only reef-building oyster species (Radabaugh et al. 2019a). Oysters form both subtidal and intertidal reefs in coastal and estuarine environments throughout the state. Subtidal reefs occur below low tide levels and are nearly always submerged, while intertidal reefs are exposed during low tide and submerged during high tide. In northeast Florida, oyster reefs are generally intertidal, and are often found on the fringes of salt marshes or shallow embankments (Dix et al. 2019). Oyster reefs were once abundant in Florida’s estuaries, but their areal extent has declined dramatically since European settlement (Radabaugh et al. 2019b). Globally, oyster reefs have declined in extent by 85%; in the U.S., oyster extent has decreased by as much as 64%, and biomass has dropped by 88% (Beck et al. 2011, Zu Ermgassen et al. 2012, Radabaugh et al. 2019a). These global declines are due to a combination of unsustainable harvest practices, pollution, sedimentation, disease and competition from non-native species (Radabaugh et al. 2019a). Florida oyster reefs have been more stable than populations in other regions, but as of 2012, the communities were considered in relatively poor and declining condition with a very high level of habitat threat (FWCC 2012).

Oysters reproduce through broadcast spawning and external fertilization (Radabaugh et al. 2019a). Fertilized eggs develop into larvae which float with other plankton for 2–3 weeks before settling and attaching to a solid substrate, and transforming into sessile adults. Once settled, oysters can reach reproductive maturity in as little as 4 weeks in warm waters (FWCC 2018a, Radabaugh et al. 2019a). Spawning typically requires water temperatures above 20°C (68°F) and may occur year-round in Florida, although it peaks between May and October. Successful “recruitment” for oysters includes both settlement and a period of post-settlement survival (Baggett et al. 2014, Radabaugh et al. 2019a).

TIMU contains the largest oyster reef communities in the Jacksonville area, primarily located in salt marsh areas (Figure 51) (Anderson 2005). While oysters are still a commercially valuable food source in some Florida coastal areas, harvesting has not been allowed in the TIMU area since the mid-1990s due to water quality concerns (Anderson 2005, Dix et al. 2019, Radabaugh et al. 2019b). As filter feeders and sessile (i.e., immobile) organisms, oysters and other mollusks absorb and accumulate contaminants from the water, including toxic metals, persistent organic pollutants, and harmful bacteria (Durako et al. 1988, Radabaugh et al. 2019a). The entire Duval County shellfish harvesting area has been closed for decades due to unpredictability in water quality, particularly fecal coliform bacteria levels, and a lack of resources for routine monitoring to ensure shellfish are safe for consumption (Anderson 2005).

Figure 51. Oysters on the intertidal fringe of TIMU's Round Marsh (SMUMN GSS photo).

4.6.2 Measures

- Change in oyster bed extent
- Recruitment
- Contaminant levels

4.6.3 Reference Condition/Values

Reference conditions for this component vary by measure. For the oyster bed extent and recruitment measures, the reference condition is no net loss or decline from the current condition. For contaminant levels, the reference conditions will be the low ranges identified by NOAA's long-term Mussel Watch program (Table 34) (Kimbrough et al. 2008).

Table 34. Contaminant condition ranges for oysters, as determined by NOAA's Mussel Watch program (Kimbrough et al. 2008). ppm = parts per million, ppb = parts per billion.

Category	Contaminant	Contaminant levels		
		Low	Medium	High
Metals (concentrations in ppm)	Arsenic	3–11	12–22	23–57
	Cadmium	0–3	4–6	7–15
	Copper	7–211	212–636	637–1,660
	Lead	0.1–0.5	0.6–0.9	1.0–2.2
	Mercury	0.00–0.07	0.08–0.15	0.16–0.33
	Nickel	0.7–1.6	1.7–2.5	2.6–4.9
	Tin	0.0–0.2	0.3–0.6	0.7–1.9
	Zinc	99–3,260	3,261–9,165	9,166–18,950
Organics (concentrations in ppb)	Butyltins	2–87	88–366	367–876
	Chlordanes	0–7	8–21	22–55
	DDTs	1–34	35–105	106–202
	Dieldrins	0–5	6–30	31–65
	PAHs	47–828	829–2,511	2,512–10,717
	PCBs	4–38	39–87	88–157

4.6.4 Data and Methods

In 2019, Florida's FWRI published a state-wide Oyster Integrated Mapping and Monitoring Program (OIMMP) Report (Radabaugh et al. 2019b), which included chapters describing the conditions, threats, and available research in each region of the state. TIMU falls in the Northeast region, which includes Nassau, Duval, St. Johns, Flagler, and Volusia Counties (Figure 52) (Dix et al. 2019). The primary objective of the OIMMP is "to build and maintain a collaborative network of stakeholders with interest in mapping and monitoring Florida's oyster habitats in order to identify the status of and management priorities for oysters and their habitats" (Radabaugh et al. 2019b, p. v). The OIMMP has compiled available oyster mapping data from across the state and included distribution maps in the 2019 report.

Figure 52. OIMMP's Northeast Florida region (reproduced from Dix et al. 2019). TIMU is in Duval County along the St. Johns River.

Larger-scale oyster reef mapping utilizes georeferenced aerial multispectral or hyperspectral imagery, with ground-truthing to verify mapping accuracy (Radabaugh et al. 2019b). Oyster reefs can be identified in aerial imagery by patterns of color, texture, and shape. However, identification can be difficult if oysters are mixed in with algae, mud, or seagrass, or if they are growing on vertical surfaces, like seawalls or mangrove roots (Radabaugh et al. 2019a). While most mapping efforts group all oysters together into one class, reefs may also be categorized by mean size of oyster, tidal exposure, live or dead, reef height, or other characteristics. In the TIMU region, oyster reef mapping was conducted by the St. Johns River Water Management District (SJRWMD) in 2015 (Dix et al. 2019). Statewide oyster mapping data, including the SJRWMD data for TIMU, can be downloaded from the Florida FWC website at https://geodata.myfwc.com/datasets/oyster-beds-in-florida.

Grubbs et al. (2013) conducted research to quantify and evaluate oyster growth rates, recruitment, mortality, and population viability at three NPS properties on the southern Atlantic Coast: TIMU, CUIS, and Canaveral National Seashore (CANA). To study recruitment, researchers deployed a single recruitment collector at 25 oyster reefs per park in April 2012 (Figure 53). The reefs sampled at TIMU were along Pumpkin Hill and Clapboard Creeks (Figure 54). Recruitment collectors were visited and replaced in August and November of 2012 and February of 2013 (Grubbs et al. 2013). The juvenile oysters, called "spat", were quantified to evaluate temporal and spatial patterns in recruitment. To study survival, researchers also deployed tiles with 12 juvenile oysters attached, which were revisited every 3 months to record how many remained (Grubbs et al. 2013).

Figure 53. University of North Florida students deploying recruitment collectors at TIMU (left) and a close-up of recruitment collectors with oyster spat (right) (NPS photos).

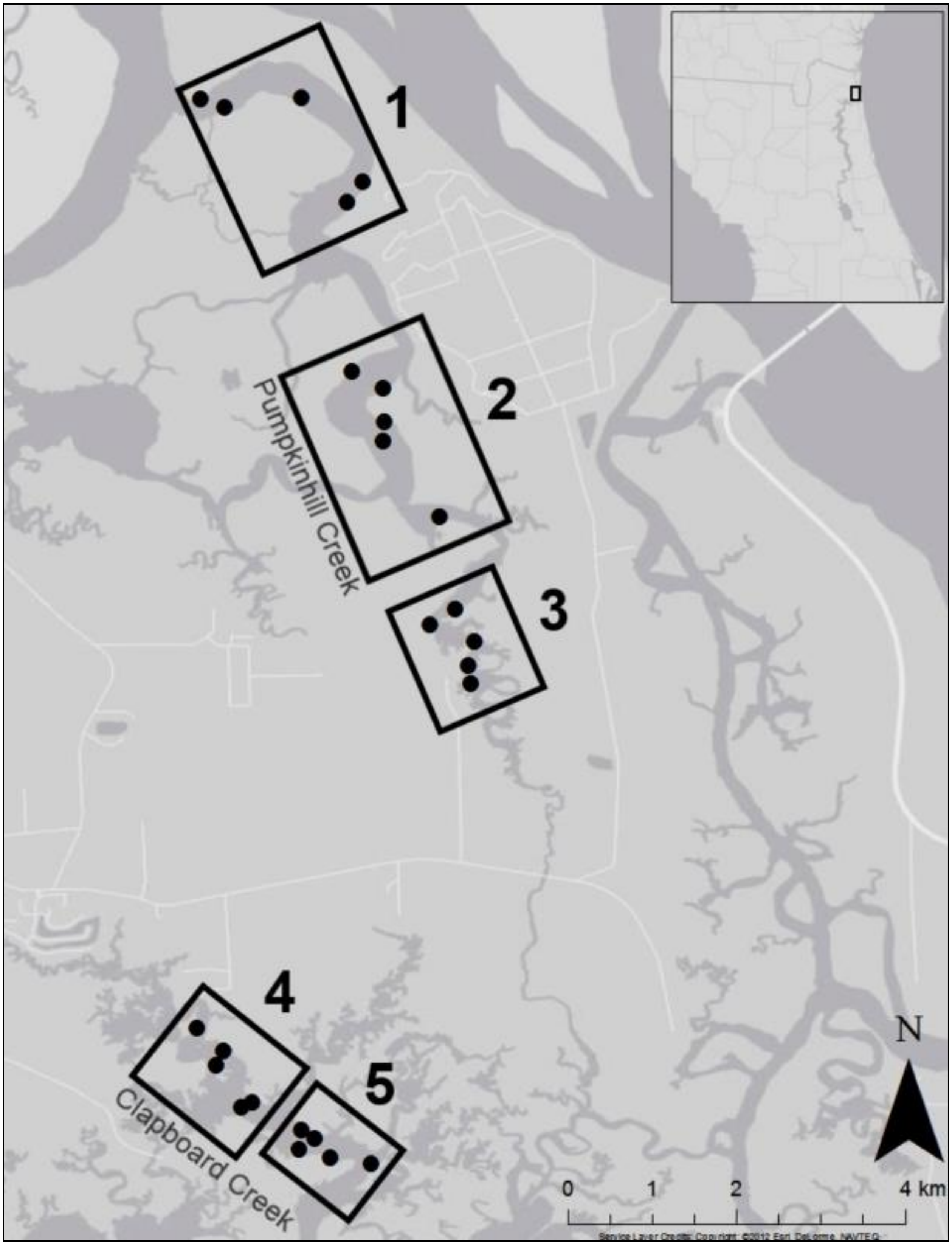

Figure 54. Locations of TIMU oyster reefs visited by Grubbs et al. (2013).

NOAA initiated its Mussel Watch program in 1986 to monitor the status and trends of chemical contamination in U.S. coastal waters, including contaminant levels in mussels (Kimbrough et al. 2008). Over time, various mussel species have been sampled from more than 300 sites throughout the U.S (Figure 55). Mussel Watch monitors for about 140 contaminants, including metals and organic compounds. While metals occur naturally in the environment, human use of metals in industry have contributed to excessive releases of certain toxic metals (Kimbrough et al. 2008). Many organic chemical contaminants (e.g., pesticides, PCBs) have also been manufactured and released into the environment through human activity. As part of the Mussel Watch program, oysters from Chicopit Bay (Figure 55) were sampled for contaminants from 1986–2011. The program's 2004–2005 data and trends are summarized in Kimbrough et al. (2008). Additional data for 2007–2011 were downloaded from NOAA's Status and Trends Data website (NCCOS 2021).

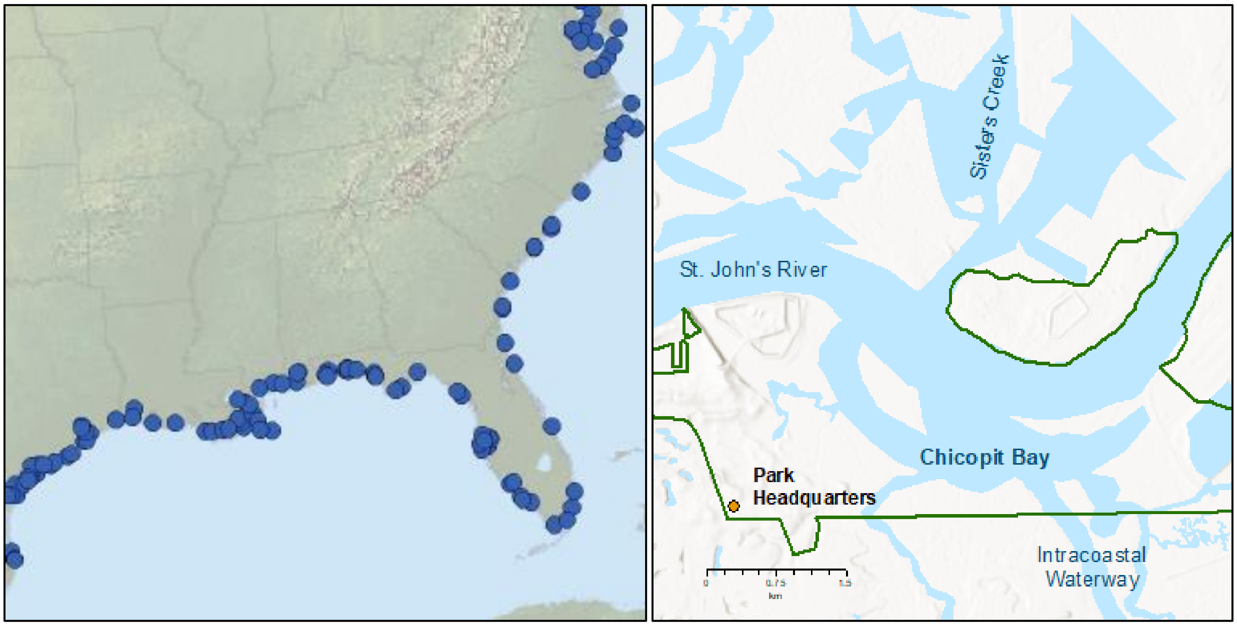

Figure 55. Mussel Watch oyster sampling locations along the Atlantic and Gulf Coasts (left, reproduced from Kimbrough et al. 2008) and the location of Chicopit Bay within TIMU (right).

4.6.5 Current Condition and Trend

Change in Oyster Bed Extent

Oyster beds are distributed throughout most of the waterways of TIMU, with the exception of the upper reaches of the Nassau River (Figure 56). Only one data set exists for oyster bed extent within TIMU boundaries, the 2015 SJRWMD mapping included in the OIMMP's statewide data (FWC 2019). According to these data, there were nearly 128 ha (315.5 ac) of oyster beds within TIMU (FWCC 2019). TIMU's oyster beds account for 20% of all beds within the five-county northeast Florida region (see Figure 52). The vast majority of these (91%) were classified as live, with less than 9% considered dead (Table 35). Across the northeast region as a whole, 6.1% of oyster beds were classified as dead, and all were along important boating channels (Dix et al. 2019).

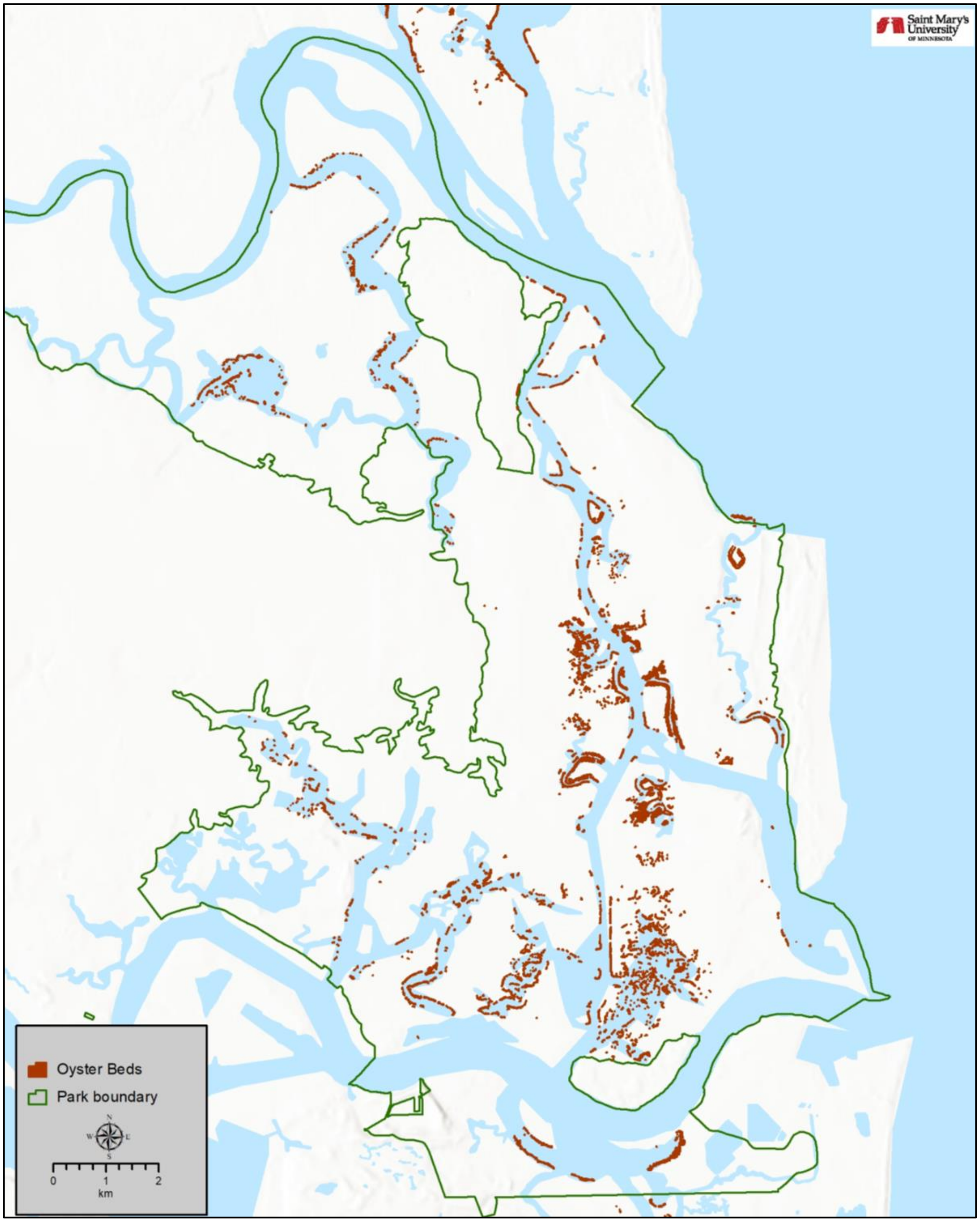

Figure 56. Oyster bed extent at TIMU (FWCC 2019).

Table 35. Oyster bed extent within TIMU boundaries, based on 2015 SJRWMD mapping (FWCC 2019).

Status	**Area in ha (ac)**
Live	116.62 (288.17)
Dead	11.05 (27.31)
Total	127.67 (315.48)

Recruitment

Oyster recruitment is known to be highly variable, both spatially and temporally (by season and between years) (Radabaugh et al. 2019a). At TIMU, Grubbs et al. (2013) found that recruitment was similar across the 25 sampled reefs along Pumpkin Hill and Clapboard Creeks. Recruitment was considered intermediate throughout the spring, summer, and fall, but the greatest number of spat were documented during the April–June period (Figure 57).

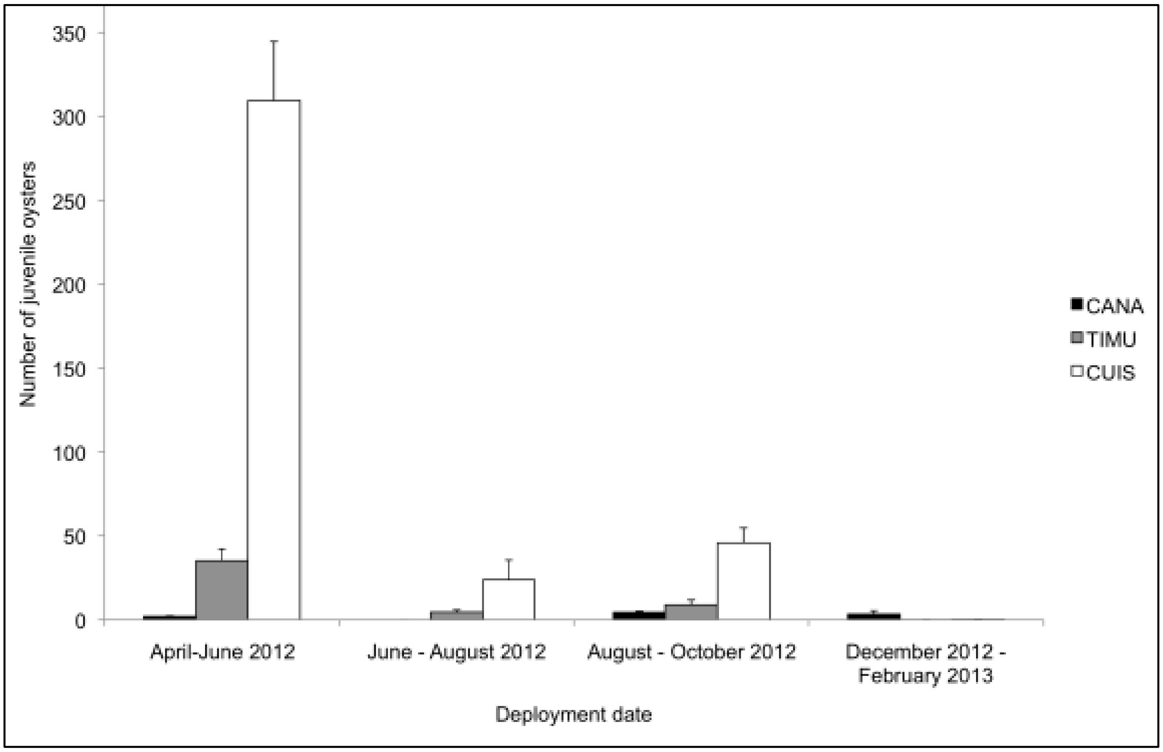

Figure 57. Oyster recruitment at three SECN parks by season, 2012–2013 (reproduced from Grubbs et al. 2013).

Juvenile oyster survival, which also plays a role in recruitment, was higher in Clapboard Creek than in Pumpkin Hill Creek (Grubbs et al. 2013). Survival was lowest at Location 1, the site closest to the Nassau River. Grubbs et al. (2013) also found that survival averaged across all TIMU locations declined over time. From June to August 2012, average survival at protected sites (i.e., spat protected from predators by cages) was approximately 83%, then dropped to ~75% by November, and finished at ~58% in February 2013. With no protection (i.e., no cages), juvenile survival from June to August 2012 was approximately 8% and declined further through February 2013 (Grubbs et al. 2013).

Contaminant Levels

Contaminants of concern for oysters and other aquatic organisms include heavy metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) (Radabaugh et al. 2019a). In 2008, a summary of Mussel Watch program data was published, including a nation-wide assessment, state-wide results, and some site-specific data (Kimbrough et al. 2008). Based on 2004–2005 sampling, oysters in Chicopit Bay contained low to medium levels of metal contaminants (Table 36). Organic contaminants were at low levels in Chicopit Bay's oysters (Kimbrough et al. 2008). For contaminants where a regional condition could be assigned, Chicopit Bay levels were near or below the southeast regional condition (Table 36).

Table 36. Concentration of contaminants in Chicopit Bay oysters, 2004–2005, as well as the regional condition (southeast) and national trend, if available (Kimbrough et al. 2008).

Category	Contaminant	Concentration (Condition)	Regional condition	National trend
Metals (ppm)	Arsenic	20 (Medium)	Medium	–
	Cadmium	1.6 (Low)	–	Increasing
	Copper	71 (Low)	–	–
	Lead	0.49 (Low)	Medium	–
	Mercury	0.1 (Medium)	Medium	–
	Nickel	1.8 (Medium)	Medium	–
	Tin	0.49 (Medium)	–	Decreasing
	Zinc	2,010 (Low)	–	Decreasing
Organics (ppb)	Butyltins	70 (Low)	Medium	Decreasing
	Chlordanes	2.5 (Low)	–	–
	DDTs	6.6 (Low)	–	–
	Dieldrins	1.1 (Low)	–	–
	PCBs	34 (Low)	–	–
	PAHs	638 (Low)	–	–

A closer look at the PAHs found in Chicopit Bay's oysters suggests that the source may be petroleum contamination, possibly due to the proximity of a high-traffic shipping channel (UNF and JU 2019). Historically, the most prevalent PAHs were pyrene and fluoranthene (Figure 58), which are formed during the incomplete combustion of hydrocarbons, including coal and oil (Abas and Mohamad 2011). In 2003, the most prevalent PAHs were naphthalene and the related 2-methylnaphthalene, both of which are produced by the burning crude oil, coal, and wood (Benedict et al. 2003, Gervais et al. 2010). Naphthalene is also used as an insecticide and pest repellent (Gervais et al. 2010).

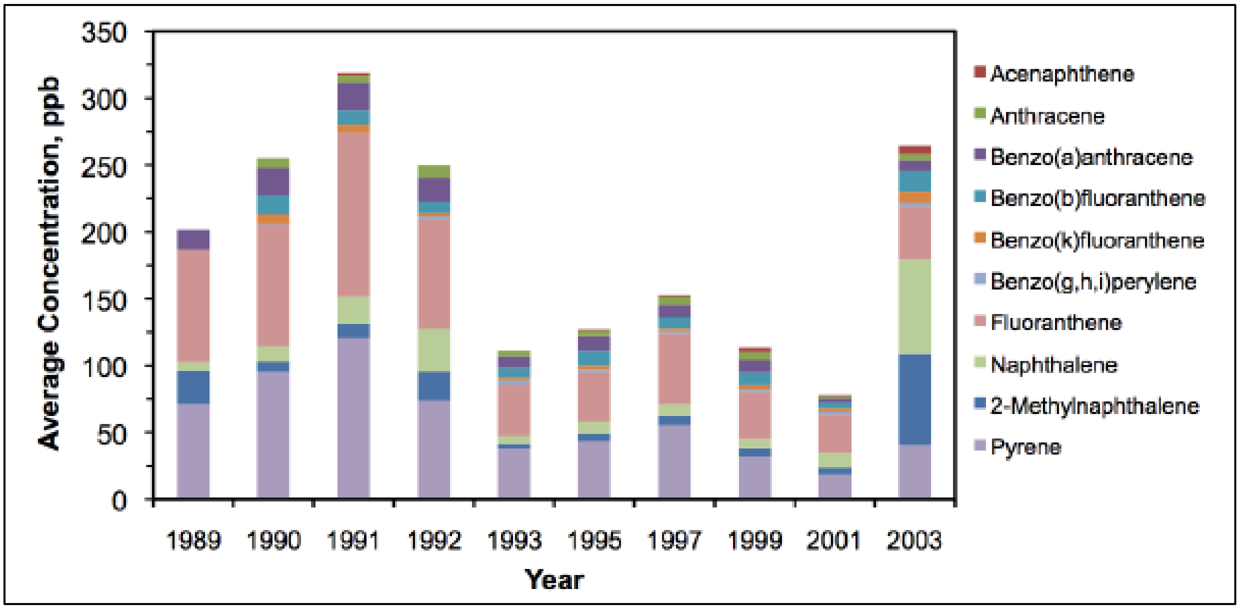

Figure 58. Concentration of select PAHs in Chicopit Bay oysters, 1989–2003 (graph reproduced from UNF and JU 2019, based on NOAA Mussel Watch data).

Subsequent Mussel Watch contaminant data for Chicopit Bay oysters were downloaded from NOAA's Status and Trends Data website (NCCOS 2021). According to 2011 sampling, most metal contaminant levels were lower than previous 2004–2005 results (Table 37). In 2011, only lead was at a medium level and the other seven metal levels were low; for comparison, four metals were at medium levels and four were low from 2004–2005 (NCCOS 2021). Among organics, the majority of contaminants were lower in 2011 than in 2004–2005. However, PAHs and PCBs were higher in 2011, with PCBs increasing from low to medium levels. A greater *number* of PCBs were also detected in 2011; in 2009, only 17 of the 39 PCBs tested for were detected, compared to 31 out of 39 PCBs detected in 2011. Additionally, over a dozen PAHs were detected in 2011 that had not been detected in 2009 (NCCOS 2021).

Among the PAHs detected in 2009 and 2011, pyrene and fluoranthene were most prevalent, similar to pre-2003 results (Table 38). Naphthalene and 2-methylnaphthalene were low, suggesting that 2003 levels may have been an isolated spike (NCCOS 2021). PAHs that spiked or were first detected in 2009 or 2011 included biphenyl, C29- and C30-hopane, decalin, and C1-decalin. Biphenyl occurs naturally in crude oil, coal tar, and natural gas, but is also used as an antimicrobial food preservative (NCBI 2021). Hopanes are primarily produced by fossil fuel combustion, including traffic emissions (Fabianska et al. 2016). Decalin, a chemical analog of naphthalene, is used as an industrial solvent, including in fuel additives (Moldoveanu 2019).

Table 37. Concentration of contaminants in Chicopit Bay oysters, 2007–2011, and a comparison to 2004–2005 levels (NCCOS 2021).

Category	Contaminant	Contaminant levels			
		2007	**2009**	**2011**	**Compared to 2004–2005**
Metals (ppm)	Arsenic	9.0	–	10.7 (Low)	Lower
	Cadmium	1.39	–	0.82 (Low)	Lower
	Copper	150	–	59.9 (Low)	Lower
	Lead	0.76	–	0.64 (Medium)	Higher
	Mercury	0.1	–	0.07 (Low)	Similar
	Nickel	1.36	–	1.63 (Low)	Lower
	Tin	Not detected	–	0.18 (Low)	Lower
	Zinc	3,040	–	1,990 (Low)	Similar
Organics (ppb)	Butyltins	–	29.8	10.8 (Low)	Lower
	Chlordanes	–	1.16	1.44 (Low)	Lower
	DDTs	–	Not detected	1.28 (Low)	Lower
	Dieldrins	–	0.87	0.21 (Low)	Lower
	PCBs	–	29.45	85.36 (Medium)	Higher
	PAHs	–	376.2	703.98 (Low)	Higher

Table 38. Concentration of selected PAHs in Chicopit Bay oysters over time (NCCOS 2021). ND = not detected.

Contaminant	PAH levels (ppb)		
	2003	**2009**	**2011**
Pyrene	40.6	25.6	40.1
Fluoranthene	38.9	34.1	59.9
2-methylnaphthalene	67.9	6.3	9.08
Naphthalene	71.3	7.1	18.8
Biphenyl	9.3	9.3	33.7
C29-Hopane	not tested for	ND	44.9
C30-Hopane	not tested for	ND	27.7
C1-Decalin	not tested for	35.4	ND
Decalin	not tested for	45.2	ND

Threats and Stressor Factors

Threats to TIMU's oysters include water quality changes (e.g., turbidity, contaminants, salinity), boat wakes, channel manipulation, and climate change/sea level rise. Water quality has a significant impact on oysters; as filter feeders and sessile organisms, they are particularly sensitive to contaminants and shifts in water chemistry (e.g., salinity, dissolved oxygen, dissolved solids) (Durako et al. 1988, Radabaugh et al. 2019b). Contaminants taken in by oysters while filter feeding can build up over time, causing cumulative toxicity and damage. Impacts include mortality, inhibited growth, and reduced resistance to disease (Radabaugh et al. 2019a). Changes in salinity levels can have cascading impacts on oyster populations. The optimal salinity range for oysters is 14–28 ppt, but they can tolerate extremes of 5–40 ppt for short periods (Baggett et al. 2014, Radabaugh et al. 2019a). At low salinities, oyster growth and reproduction are reduced, and mortality can occur in freshwater conditions. At high salinity levels, oysters are increasingly vulnerable to disease, parasites, and marine predators, such as carnivorous snails (Durako et al. 1988, Garland and Kimbro 2015, Radabaugh et al. 2019b). Low dissolved oxygen levels reduce oyster settlement, growth, and survival; mortality can occur among subtidal oysters at levels below 2 mg/L (Baker and Mann 1992, Radabaugh et al. 2019a).

River and stream channel manipulation can alter hydrology, posing a serious threat to oyster populations (FWCC 2012, Radabaugh et al. 2019b). Channelization and other manipulations can both reduce or concentrate freshwater inflows and allow for saltwater intrusion further into the estuarine system. These changes can shift salinity levels outside the optimal range for oyster survival and reproduction (Radabaugh et al. 2019b). Altered hydrology can also increase sedimentation, which could bury oysters or disrupt their filter feeding. Dredging to maintain navigation channels may destroy or bury oyster beds, or increase turbidity to a level that can impede filter feeding and respiration (Radabaugh et al. 2019a).

The waves generated by boat wakes have contributed to the erosion and mortality of oyster reefs in northeast Florida, particularly along the Intracoastal Waterway (ICW) (Figure 59) (Herbert et al. 2018, Dix et al. 2019). The wave energy can physically disturb or eliminate the surfaces where oysters attach, and the increased turbidity (i.e., particles dissolved in water) can disrupt larval movements and filter feeding (Herbert et al. 2018). Oysters have been shown to slow or stop filtering water in high turbidity conditions, likely to avoid "clogging" their gills with sediment (Loosanoff 1962, Wilson 1974). In Mosquito Lagoon, approximately 175 km (~110 mi) south of TIMU, an increase in boating activity has caused the development of "dead margins" (i.e., mounds of empty shells) on the seaward side of oyster reefs along major navigation routes (Stiner and Walters 2008). These dead margins have significantly altered oyster reef structure at Mosquito Lagoon by increasing reef weight, compressing reef width, and creating steeper slopes. Such changes reduce the surface area available for new oyster spat settlement and reduce structural complexity, which then reduces the richness and density of other species living on the oyster reef (Stiner and Walters 2008).

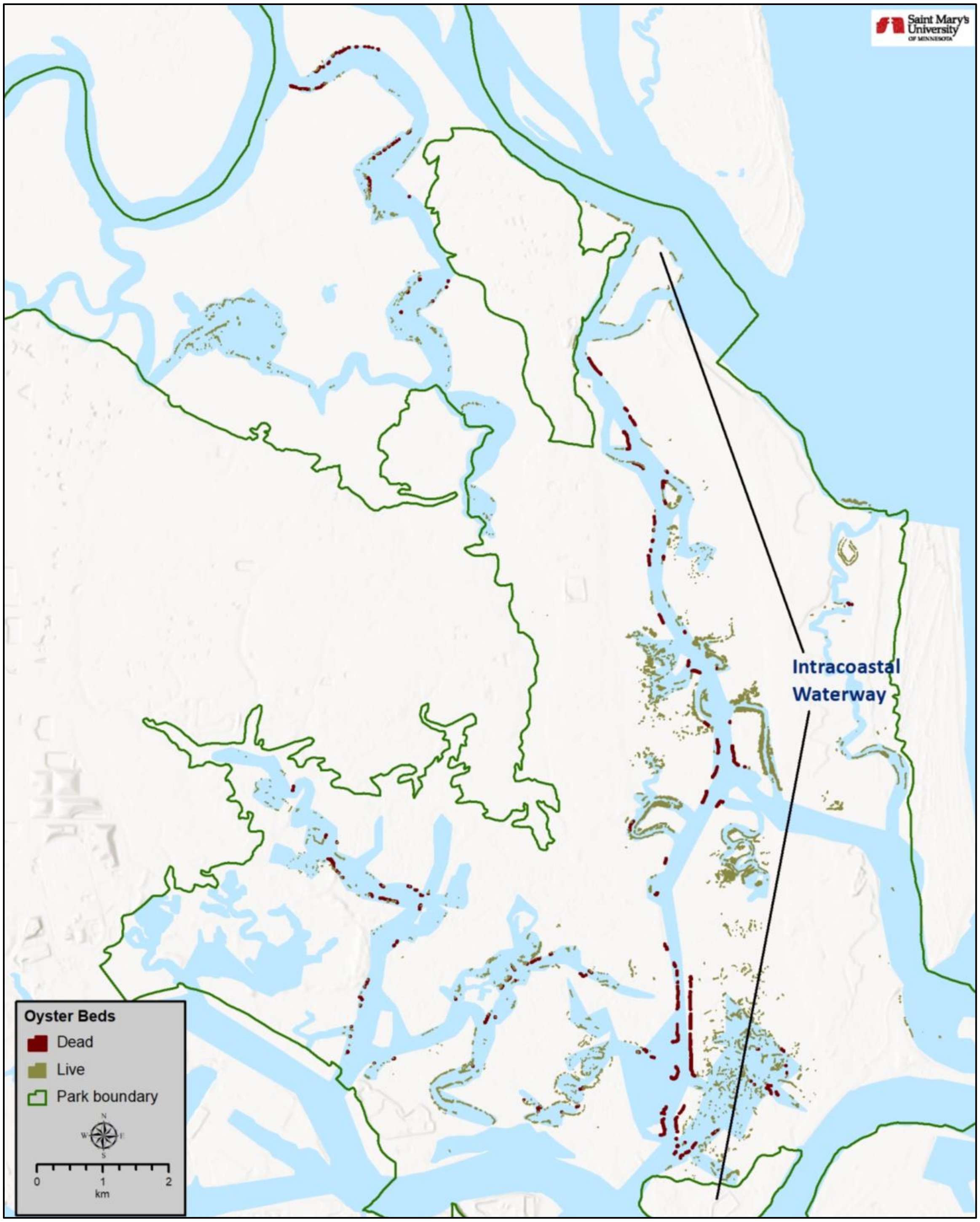

Figure 59. Distribution of oyster beds classified as dead, showing a particular concentration of dead oysters along the ICW (FWCC 2019).

Global warming and sea level rise are likely to increase the frequency and severity of temperature and salinity stress upon estuarine oyster beds (Rodriguez et al. 2014, Radabaugh et al. 2019b). Oysters can survive extreme water temperatures as high as 36–40°C (97–104°F), but their tolerance decreases above 28°C (82°F) if low dissolved oxygen or salinity extremes are also occurring (Rybovich et al. 2016, Southworth et al. 2017). Because the oxygen-holding capacity of water declines as water temperature increases, oysters can “suffocate” as dissolved oxygen drops in warming waters (USGS 2016b, Radabaugh et al. 2019a). In addition, high temperatures or abrupt temperature changes contribute to increased disease susceptibility and declines in oyster spawning and larval development (Dekshenieks et al. 1993, Radabaugh et al. 2019a). Sea level rise threatens oysters not only by increasing salinity in estuarine areas, but also by increasing inundation times for intertidal oyster beds, which increases their exposure to aquatic predators (Shumway 1996, Radabaugh et al. 2019a).

Data Needs/Gaps

While some data are available for each of the measures selected for this component, these data are either limited to a single study or are outdated. For example, the most recent contaminant data for oysters in the TIMU region are from 2011, and they are limited to a single location, Chicopit Bay (NCCOS 2021). With regards to oyster bed extent, if high-quality aerial imagery exists for earlier years (pre-2015), an experienced photo-interpreter may be able to map the historic extent of oyster beds for comparison to current extent.

Radabaugh et al. (2019b) recommended regular mapping of oyster beds every 5–7 years, differentiating between live and dead reefs to track dead margins and mortality over time. The authors also proposed standardized, long-term monitoring across several estuaries to allow comparisons between populations. Parameters monitored should include oyster size structure of the population, shell height, reef height, oyster density, and automated measurements of key water quality parameters (e.g., temperature, salinity, dissolved oxygen) (Dix and Marcum 2018, Radabaugh et al. 2019b). Continuous, automated water quality measurements may help determine how extreme events (e.g., high temperatures, freshwater pulses, hypoxia) impact oyster reefs. A monitoring protocol has been outlined for the Guana Tolomato Matanzas National Estuarine Research Reserve, south of TIMU in St. John’s County, and could be utilized or adapted for the park (Dix and Marcum 2018).

Grubbs et al. (2013) recommended repeating studies of recruitment and survival rates at TIMU and other parks over time to determine whether these rates and patterns vary over time. Survival of adult oysters could also be evaluated. At the time of this writing, a study of the availability and survival of oyster spat along the Kingsley Plantation shoreline is in progress and scheduled for completion in July 2021 (Smith 2019).

Dix et al. (2019) suggests continued studies of species interactions involving oysters (e.g., predation, competition, algal blooms), including how these will be impacted by climate change in Northeast Florida. Also, genetic analysis could clarify the scale of larval export and genetic isolation among TIMU’s reefs; genetic diversity will aid oysters in persisting through the environmental stressors faced by the species (Radabaugh et al. 2019a).

Overall Condition

Change in Oyster Bed Extent

The project team assigned this measure a *Significance Level* of 3. According to 2015 SJRWMD data, there are nearly 128 ha (315.5 ac) of oyster beds within TIMU (FWCC 2019). The vast majority of these (91%) were classified as live, with less than 9% considered dead. However, because these are the only extent data available and there are no other points in time available for comparison, a *Condition Level* cannot be assigned at this time.

Recruitment

This measure was also assigned a *Significance Level* of 3. Grubbs et al. (2013) found that recruitment was at intermediate levels across the reefs sampled at TIMU, with the greatest number of spat documented during the April–June period. As this limited study represents the only data currently available regarding recruitment within TIMU, a *Condition Level* also cannot be assigned for this measure.

Contaminant Levels

A *Significance Level* of 3 was assigned for the contaminant levels measure. According to Mussel Watch data, metal and organic contaminant levels in Chicopit Bay oysters have generally been in the low and medium ranges (Kimbrough et al. 2008, NCCOS 2021). Many of the contaminants declined between 2004–05 and 2011, but PCBs and PAHs increased (Table 34). However, 2011 sampling data are the most recent contaminant information available for the TIMU area. As a result, a *Condition Level* cannot be assigned.

Weighted Condition Score

A Weighted Condition Score was not calculated for oysters at TIMU, as *Condition Levels* could not be assigned for any of the measures due to a lack of current data (Table 39). Any trends are also unknown.

Table 39. Current condition of oysters at TIMU.

Measures	Significance Level	Condition Level	WCS = N/A
Change in Oyster Bed Extent	3	n/a	–
Recruitment	3	n/a	–
Contaminant Levels	3	n/a	–
Overall	**–**	**–**	◌

4.6.6 Sources of Expertise

- Eric Starkey, SECN Aquatic Ecologist

4.7 Water Quality

4.7.1 Description

Water quality and quantity influence nearly all aspects of wetland and aquatic ecosystems, from vegetation and soils to wildlife, particularly sensitive species such as fish, aquatic invertebrates, and amphibians (UNEP 2008). Impaired water quality can alter plant and animal species composition, health, and reproduction (UNEP 2008, USGS 2016b). Water quality is particularly important at TIMU, where nearly 75% of the protected area consists of wetlands and open water (NPS 1996, Starkey et al. 2019). The vast majority of these wetlands and waterways are tidal estuarine, meaning there is a mix of freshwater inflow from upstream and saltwater inputs from the nearby Atlantic Ocean. Tidal "flushing", the routine movement of water in and out of an estuarine system, can play a critical role in water quality (NPS 1996, Phlips et al. 2004). This flushing can help wash excess nutrients and contaminants out of the estuarine system (NPS 1996, Dame et al. 2000). Therefore, maintaining the flow and connectivity of tidal creeks and wetlands in the estuarine system is critical to their continued health and productivity (Herzog et al. 1998, Dennis et al. 2001b).

Estuarine salt marsh in the Nassau River (NPS photo).

4.7.2 Measures

- Dissolved oxygen
- Salinity
- Total nitrogen
- Total phosphorus
- Indicator bacteria
- Water clarity
- Chlorophyll a
- Total organic carbon in sediment
- Sediment contaminant rating

Dissolved Oxygen

Dissolved oxygen (DO) is critical for oxygen-dependent organisms that live in water. In order to survive, organisms such as fish, invertebrates, and zooplankton use DO from the water (USGS 2016b). Oxygen enters water from the air via diffusion, when atmospheric oxygen mixes with water by wind and wave action, or when released by algae and other plants as a byproduct of photosynthesis. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2016b). According to the Environmental Protection Agency (EPA) (2016d), waters with DO levels below 1 mg/l are typically hypoxic and devoid of life. The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than warm water (USGS 2016b). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2016b). Salinity also influences dissolved oxygen levels, with more saline waters holding less oxygen than fresh water (NOS 2021).

Salinity

Salinity is the measure of dissolved salts in water, usually reported in parts per thousand (ppt) (EPA 2006)(Figure 60). The level of salinity also controls the types of organisms (plants and animals) that can survive in the body of water. Some species, such as smooth cordgrass, can withstand higher levels of salinity, while other species only tolerate lower salinity levels (EPA 2006). Chemical methods for measuring salinity can be time-consuming and inconvenient, so salinity is often calculated from measurements of conductivity or total dissolved solids (TDS), as higher salinity levels lead to higher TDS and conductivity (EPA 2006).

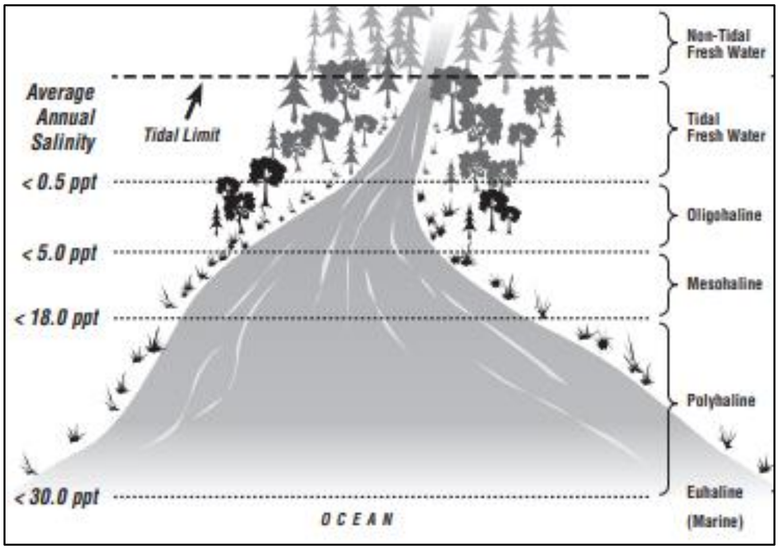

Figure 60. Diagram showing salinity ranges (ppt) in estuarine environments (EPA 2006).

Nutrients (Nitrogen, Phosphorus)

Nutrients, such as nitrogen and phosphorus, are crucial in supporting healthy aquatic environments. However, elevated concentrations of these nutrients can negatively impact water quality and threaten the ability of plants and aquatic organisms to thrive (Munn et al. 2018). Nitrogen occurs naturally in the atmosphere and in soils and is deposited into surface waters through precipitation and runoff; nitrogen deposition is increased by human inputs such as sewage, fertilizers, and livestock waste (USGS 2017b). Nitrate (NO_3) can cause a host of water quality related problems when present in high concentrations including, but not limited to, excessive plant and algae growth, eutrophication, and depleted dissolved oxygen available to aquatic organisms. Nitrate in drinking water can be harmful to humans, particularly young children, and livestock (USGS 2017b). Phosphorus is commonly found in agricultural fertilizers, manure, organic wastes in sewage, and sometimes industrial effluent (USGS 2016a). In excess, phosphorus in water systems can increase the rate of eutrophication, encourage overgrowth of aquatic plants, deplete dissolved oxygen, and threaten fish and macroinvertebrate populations (USGS 2016a).

Indicator Bacteria

Bacteria are a common natural component of surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals, can cause illness in humans (USGS 2011). Fecal coliform bacteria are a subgroup of coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. It is often tested by counting bacterial colonies that grow on filters placed in an incubator for 22–24 hours. High concentrations of certain fecal coliform, such as E. coli, can cause serious illness in humans (USGS 2011). Enterococci are another type of bacteria that indicate fecal contamination from warm-blooded animals and can cause illness or infections (FDH 2020).

Water Clarity

Water clarity is critical in order for sunlight to reach submerged aquatic vegetation, which supports a wealth of aquatic organisms, and is valued for recreational purposes (Parman et al. 2012). Turbidity assesses the amount of fine particle matter (e.g., clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) that is suspended in water by measuring the scattering effect they have on light that passes through water (USGS 2016b). The more light that is scattered, the higher the turbidity measurement, which results in lower water clarity. Turbidity often increases following rainstorms, when sediments are washed into the water from adjacent lands and stream velocity increases (USGS 2016b). High turbidity decreases light penetration, which can reduce the productivity of aquatic plants and other organisms (Parman et al. 2012, USGS 2016b). In lieu of turbidity measurements, water clarity can be estimated from Secchi disk depth observations (Figure 61).

Figure 61. A Secchi disk being lowered into the water (USGS photo).

Chlorophyll a

Chlorophyll a is a standard measure of phytoplankton biomass (e.g., algae); its concentrations can be indicative of elevated nutrients and/or eutrophication, contributing to water quality degradation (Parman et al. 2012). While phytoplankton are a natural component of aquatic ecosystems, excessive levels can lead to bad odors and unsightly scums, as well as contributing to reduced DO levels (EPA 2016c). Some phytoplankton can also produce toxins that pose a threat to wildlife and people in high concentrations (EPA 2016c).

Total Organic Carbon (TOC)

Organic carbon in sediments can act as a "sink" for contaminants through adsorption (i.e., adhesion to a surface) (NPS 1996, Hall and Anderson 2014). While this process may reduce the levels of contaminants available in water, protecting aquatic organisms from contamination, the presence of contaminants in the sediment can adversely impact benthic organisms (NPS 1996, Anderson 2005), as will be explained in the next paragraph. Measurements of TOC may provide insight into whether sediments already contain or are likely to adsorb contaminants.

Sediment Contaminant Rating

Organic and metal contaminants in the bottom sediments of waterways can persist in estuarine systems for years or even decades and may contribute to chronic stress on organisms and ecosystem functions (Gregory et al. 2013, USGS 2020). These contaminants enter aquatic systems through runoff, particularly following storms in urban and agricultural areas. They are of particular concern for benthic organisms that live in the sediment, such as mussels, crustaceans, and insect larvae (Carman et al. 1997, USGS 2020).

4.7.3 Reference Condition/Values

For the DO, nitrogen, phosphorus, water clarity, and chlorophyll a measures, this assessment will utilize the same reference conditions used by the SECN coastal water quality monitoring program (Table 40). The SECN also offers reference conditions for TOC and sediment contamination that will be used for the NRCA (Table 41). These criteria are based on the EPA's National Coastal Condition Assessment (NCCA) sediment quality guidelines (SQGs) for estuarine waters (EPA 2016e). The SQGs incorporate the mean Effects-Range Median Quotient (mERM-Q) and Logistic Regression Model (LRM), which together "provide a holistic interpretation of sediment chemistry and its potential effects on benthic organisms" (Starkey et al. 2019, p. 7). A reference condition has not been established for salinity. Acceptable salinity levels are likely to vary by location, depending on proximity to the ocean and a freshwater inflow source. Therefore, no reference condition has been defined at this time.

Table 40. Coastal water quality condition criteria used for SECN monitoring at TIMU (Hynds and Starkey 2019, Starkey et al. 2019). DIN = dissolved inorganic nitrogen, DIP = dissolved inorganic phosphorous. DIN consists of nitrate + nitrite and ammonium.

Rating	Dissolved Oxygen (mg/l)	DIN (mg/l)	DIP (mg/l)	Water clarity (k)	Chlorophyll a (µg/l)
Good	>5	<0.1	<0.01	<1.61	<5
Fair	2–5	0.1–0.5	0.01–0.05	1.61–2.30	5–20
Poor	<2	>0.5	>0.05	>2.30	>20

Table 41. Sediment condition criteria used for SECN monitoring. Effects range median (ERM) thresholds are determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects (Gregory et al. 2013, Starkey et al. 2019).

Rating	Total organic carbon (%)	Sediment contamination
Good	<2%	mERM-Q < 0.1 and LRM Pmax ≤ 0.5
Fair	2–5%	mERM-Q ≥ 0.1 – ≤ 0.5 or LRM Pmax > 0.5 – < 0.75
Poor	>5%	mERM-Q >0.5 or LRM Pmax ≥ 0.75

The SECN also has guidelines for assessing overall park water quality conditions based on the percentage of sampling sites in each condition category (Starkey et al. 2019). Overall condition is good when more than 50% of sites are good and less than 10% of sites are poor. Overall condition is poor when more than 20% of sites are in poor condition. Anything between these two is considered in fair condition overall.

The reference condition for indicator bacteria will be based on Florida Class II (shellfish propagation or harvesting) water quality standards (State of Florida 2016). For fecal coliform, this standard is that mean probable number (MPN) counts shall not exceed a median value of 14 with not more than 10% of the samples exceeding the Ten Percent Threshold Value (TPTV) of 43, nor exceed 800 on any one day. For *Enterococci* bacteria, the standard is that MPN counts shall not exceed a monthly geometric mean of 35 nor exceed the TPTV of 130 in 10% or more of the samples during any 30-day period. In this case, monthly geometric means must be based on a minimum of 10 samples over a 30-day period (State of Florida 2016).

4.7.4 Data and Methods

The NPS (2002) presented the results of surface-water quality data retrievals for TIMU using six EPA national databases. Although many of the sampling sites identified were either single-event or limited-time sampling efforts, five stations within TIMU had longer-term water quality records: Sisters Creek south of the confluence with the Fort George River (TIMU 0114), Intracoastal Waterway at Buoy No. 9 (TIMU 0120), St. Johns River near Marker 34 (TIMU 188 [1986–1996], TIMU 0191 [1972–1988]), and Nassau River at the U.S. Route 17 Bridge (TIMU 0405). These are all estuarine sites (Figure 62). An additional two tidal creek sites (TIMU178 and TIMU213), although sampled for only 16–17 months (1997–1998), generated over 20,000 observations.

Figure 62. Locations of past water quality sampling stations at TIMU with longer-term records or large numbers of observations (NPS 2002).

Anderson (2005) conducted a coastal watershed assessment of TIMU, focused on water quality and land use. This thesis contained sediment quality information for the park from the 1980s and 1990s, as well as insight into threats to TIMU's water quality.

Shehane et al. (2005) sampled locations along the St. John's River and tributaries for fecal indicator bacteria in the spring, summer, and winter between December 2000 and July 2002. Only one sampling location (F1) fell within TIMU boundaries, on Clapboard Creek. Researchers also determined the sources of fecal bacteria present (e.g., human, livestock, wild animal).

The SECN initiated an estuarine water quality monitoring program in 2005, which first sampled sites at TIMU in 2008 (Gregory et al. 2011, Wright et al. 2013). The objectives of the program were to:

1. Determine diel and seasonal water quality patterns for five core parameters (DO, salinity, temperature, pH, and turbidity) using fixed-station continuous data loggers;
2. Determine monthly and seasonal patterns in nutrients (nitrogen, phosphorus, and chlorophyll a) by collecting discrete water samples;
3. Determine status and spatial variability of water and nutrient chemistry conditions in estuarine waters every five years near SECN parks; and
4. Determine status and spatial variability of benthic sediment quality in estuarine waters every ten years (Gregory et al. 2013).

The monitoring program consists of two parts: continuous monitoring at one fixed station per park, and additional sampling at numerous random locations every 5 years. At TIMU, continuous, fixed-station monitoring has occurred from the dock at Kingsley Plantation in the Fort George River (Figure 63) (Wright and Mockus 2015, Hynds and Starkey 2019). This station collects temperature, pH, DO, salinity, conductivity, and turbidity data at 30-minute intervals. In addition, since 2016, a chlorophyll a sensor has been added to the suite of sensors deployed at this station (Eric Starkey, SECN Aquatic Ecologist, written communication, 22 February 2021). A second continuous, fixed-station monitor was added by the Florida Department of Environmental Protection (FLDEP) at the mouth of Clapboard Creek (on the Highway 105 bridge) in 2016, and is maintained and operated by FLDEP (Eric Starkey, written communication, 22 February 2021). An additional 30–31 random estuarine sites were sampled at TIMU in July 2008, August 2013, and July 2018 (Figure 64) (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Sediment samples, which are monitored on a 10-year cycle, were also collected at estuarine sites in 2008 and 2018. Sampling methods are described in Gregory et al. (2013). Monitoring data through 2018 have been published in SECN reports, and more recent continuous data for the Kingsley Plantation station is available through the NPS Aquarius WebPortal (https://irma.nps.gov/aqwebportal/).

Figure 63. Map (left) and photo (right) of the SECN continuous water quality monitoring stations at the Kingsley Plantation dock (NPS photo by Peter Mockus) and Clapboard Creek. The Kingsley Plantation station is approximately 6.4 river km (4 river mi) from the Atlantic Ocean while the Clapboard Creek is approximately 12.6 river km (7.8 river miles) from the ocean.

Figure 64. The locations of 31 random estuarine sites sampled for water and sediment quality at TIMU in July 2018 (reproduced from Starkey et al. 2019).

In addition to SECN monitoring, the City of Jacksonville collects water quality data from 12 locations within or near TIMU (Figure 65). Sampling is conducted approximately every 2 months. Results for 2012–2016 were included in the SECN's TIMU water quality monitoring reports (Wright et al. 2012, Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019)

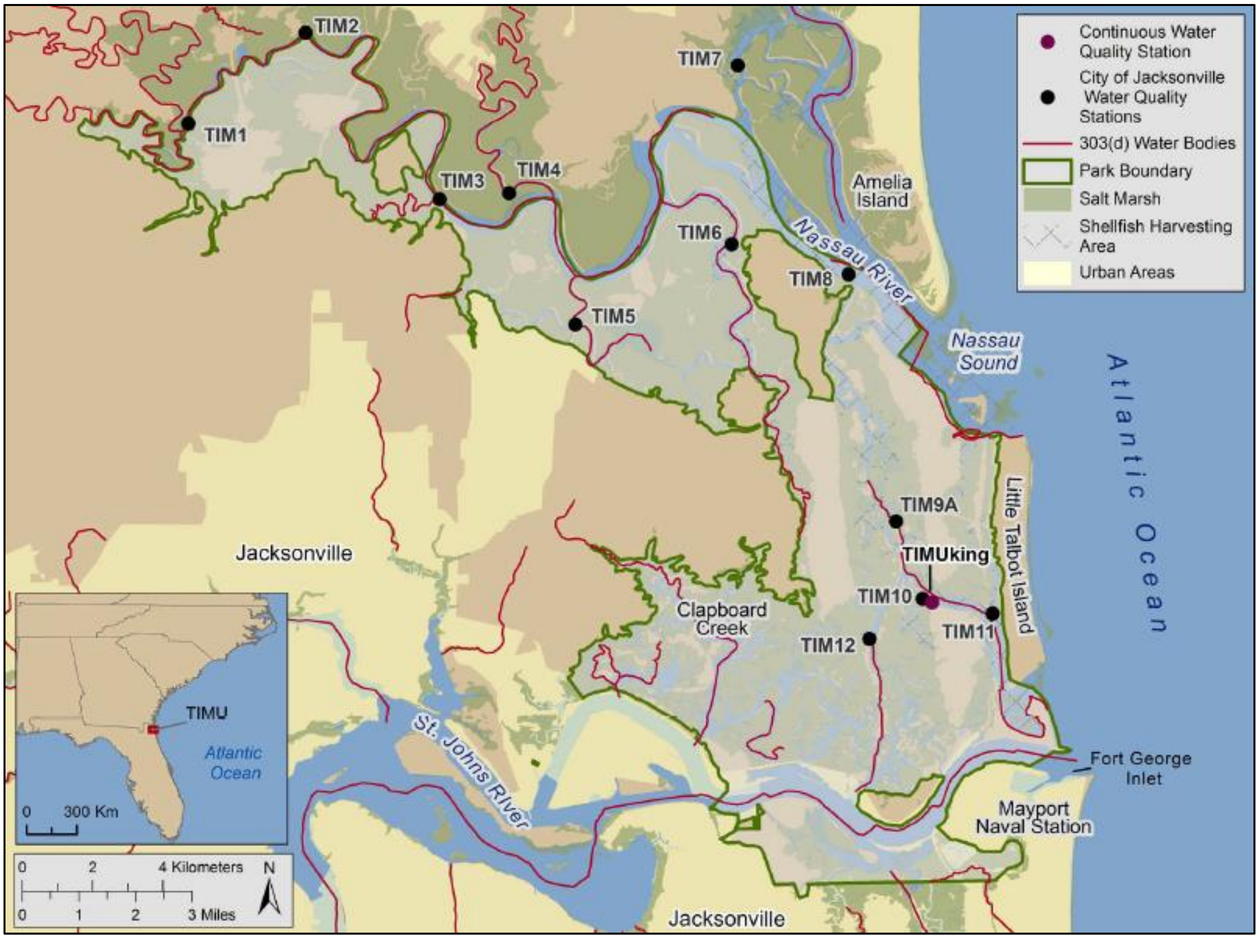

Figure 65. Locations of water quality stations monitored by the SECN (TIMUking - continuous) and the City of Jacksonville (TIM1-TIM12) (reproduced from Hynds and Starkey 2019).

In 2000, the Florida Department of Health (FDH) expanded its Florida Healthy Beaches program to include 10 locations within Duval County (Anderson 2005). This includes one site within TIMU boundaries, at Huguenot Park. Water samples are taken biweekly and tested for *Enterococci* bacteria. Results are categorized as good (<35.4/100 ml), moderate (35.5–70.4/100 ml), or poor (>70.5/100 ml). The most recent data are available on the Florida Healthy Beaches website (FDH 2020).

4.7.5 Current Condition and Trend

Dissolved Oxygen

Previous studies have noted that some tidal creeks within TIMU naturally experience seasonal low DO levels during the summer, when water temperatures are high (Kalmbacher and DiDonato 2005, Parman et al. 2012). During historic water quality sampling of estuarine park waters (1971–1998), DO across seven locations ranged from 0.3–12.5 mg/l with means from 5.7–7.0 mg/l (Table 42).

Table 42. Historic DO measurements (mg/l) at water quality monitoring sites (NPS 2002). See Figure 62 for site locations. SJR = St. Johns River, ICWW = intracoastal waterway.

Station	Water body	Period of record (# of observations)	Range	Mean
TIMU114	Sisters Creek	5/1977–7/1998 (99)	4.5–9.8	6.8
TIMU120	ICWW south of SJR	9/1971–10/1994 (52)	3.9–9.4	6.9
TIMU178	Cedar Point Creek	2/1997–6/1998 (23,638)	0.3–10.0	5.7
TIMU188	St. Johns River	5/1986–12/1996 (121)	4.5–11.0	7.0
TIMU191	St. Johns River	7/1972–2/1987 (53)	4.0–12.5	6.8
TIMU213	Clapboard Creek	2/1997–5/1998 (20,110)	1.3–9.4	6.2
TIMU405	Nassau River	6/1995–12/1998 (38)	3.3–8.7	6.2

DO measurements from SECN estuarine water quality monitoring at TIMU in 2008, 2013, and 2018 were split between good (>5 mg/l) and fair condition (2–5 mg/l) (Table 43). No locations were considered in poor condition. Most recently, in 2018, 55% of sites were in good condition and 45% were fair (Starkey et al. 2019). Sampling was conducted in July or August, meaning DO levels at some locations could be influenced by warmer summer water temperatures. Most sampling locations in fair condition were further upstream into the salt marsh and, therefore, less influenced by tidal flushing.

Table 43. Dissolved oxygen (mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008	2013	2018
TIMU-01	5.5	3.3	4.3
TIMU-02	5.9	6.8	4.0
TIMU-03	5.5	6.4	6.1
TIMU-04	4.5	6.1	5.3
TIMU-05	5.7	4.8	6.1
TIMU-06	7.0	4.9	4.9
TIMU-07	5.4	6.3	5.4
TIMU-08	4.8	4.9	4.3
TIMU-09	4.2	7.0	4.5
TIMU-10	4.9	4.7	5.2
TIMU-11	4.3	6.8	5.8
TIMU-12	4.9	6.8	3.6
TIMU-13	4.4	4.9	4.4
TIMU-14	4.9	7.1	5.5
TIMU-15	4.7	7.2	4.8

Table 43 (continued). Dissolved oxygen (mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008	2013	2018
TIMU-16	4.8	5.7	5.7
TIMU-17	3.9	5.5	4.3
TIMU-18	6.9	6.1	3.8
TIMU-19	5.4	7.0	6.2
TIMU-20	5.2	7.1	6.0
TIMU-21	5.2	7.0	6.6
TIMU-22	–	5.6	5.1
TIMU-23	4.7	7.1	5.1
TIMU-24	5.5	5.9	5.2
TIMU-25	6.9	5.6	4.7
TIMU-26	–	6.5	5.4
TIMU-27	4.7	8.5	4.2
TIMU-28	4.4	5.9	5.6
TIMU-29	5.7	5.9	4.0
TIMU-30	–	5.8	4.3
TIMU-31	–	–	5.2
TIMU-ALT-01	5.1	–	–
TIMU-ALT-02	5.4	–	–
TIMU-ALT03	5.6	–	–

Data from additional sampling by the City of Jacksonville at 12 locations within TIMU (see Figure 65) were included in SECN water quality monitoring reports (Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019). From 2012–2016, DO observations at these sites ranged from 2.2 mg/l at an upstream Nassau River location in September 2015 to 9.7 mg/l at a location near the mouth of the Nassau River in March 2013 (Appendix O). The majority of measurements (74%) indicated good condition, and no observations fell in the poor condition range (<2 mg/l).

Monthly mean DO concentrations were calculated using measurements from SECN monitoring of estuarine waters at the Kingsley Plantation dock. In 2011 and from 2013–2019, all measurements were in good condition, with the exception of one observation in June 2011 (Table 44). Mean daily values from continuous monitoring at Kingsley Plantation in 2019 show that DO levels briefly dropped below good condition level in August (Figure 66) (NPS 2020c).

Table 44. Monthly mean DO measurements (mg/l), Kingsley Plantation monthly monitoring (Wright et al. 2012, Wright and Mockus 2015, Hynds and Starkey 2019).

Month	2011	2013	2014	2015	2016	2017	2018	2019
Jan	8.2	8.2	8.1	8.2	7.9	7.7	9.1	–
Feb	7.3	7.7	8.0	8.5	8.6	7.5	8.0	–
March	6.7	7.8	7.7	7.9	7.4	7.5	7.8	7.7
April	5.8	7.0	6.9	6.6	6.9	6.7	–	7.0
May	5.2	6.4	6.3	6.5	6.1	6.3	–	6.0
June	4.6	5.7	5.7	5.7	5.7	5.9	5.8	5.7
July	–	5.8	5.3	5.7	5.6	5.6	5.9	–
Aug	–	5.5	5.3	5.5	5.7	5.5	–	5.5
Sept	–	5.6	5.3	5.3	6.0	5.7	–	6.1
Oct	–	5.2	6.1	6.6	6.1	6.5	–	6.2
Nov	–	7.5	5.8	6.7	–	7.1	–	7.2
Dec	–	7.8	7.3	7.2	7.6	7.6	–	7.8

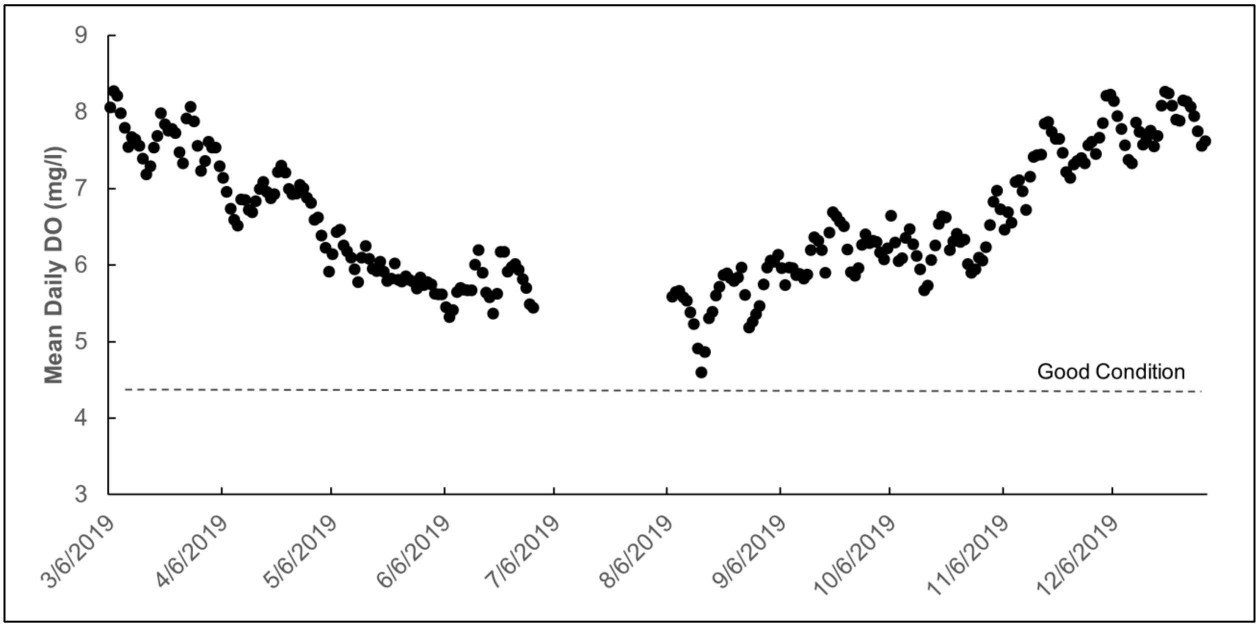

Figure 66. Mean daily values for dissolved oxygen at Kingsley Plantation station, March–December 2019 (NPS 2020c).

Monthly mean DO measurements from FLDEP monitoring of Clapboard Creek from 2017 through June 2020 were also all at good condition levels, with one exception in August 2019 (Table 45). The lowest DO levels at this location typically occurred between July and September.

Table 45. Monthly mean DO measurements (mg/l), Clapboard Creek monthly monitoring (NPS 2020c). Means are not reported for months where fewer than 12 daily observations were available.

Month	2017	2018	2019	2020
Jan	8.0	–	8.2	7.9
Feb	7.9	8.4	8.2	8.0
March	7.3	7.8	7.7	7.0
April	6.6	7.1	7.1	–
May	6.1	6.2	5.9	–
June	5.7	5.5	5.5	5.0
July	5.7	5.4	5.3	–
Aug	5.1	5.1	4.9	–
Sept	5.2	5.1	5.1	–
Oct	6.4	5.7	5.5	–
Nov	7.0	6.9	–	–
Dec	7.7	8.2	7.5	–

Salinity

Historic water quality sampling of five estuarine locations within TIMU documented salinity levels from 0.3–35.0 ppt, with means of 19.5–28.5 ppt (Table 46). Based on these means, the waters at these locations would be considered polyhaline (18–30 ppt).

Table 46. Historic salinity measurements (ppt) at water quality monitoring sites (NPS 2002).

Station	Water body	Period of record (# of observations)	Range	Mean
TIMU114	Sisters Creek	12/1982–7/1998 (44)	10.0–35.0	28.5
TIMU120	ICWW south of SJR	9/1971–10/1994 (23)	7.2–32.0	22.5
TIMU178	Cedar Point Creek	2/1997–6/1998 (26,330)	2.4–31.8	20.3
TIMU188	St. Johns River	7/1986–12/1996 (117)	4.8–35.0	22.1
TIMU213	Clapboard Creek	2/1997–6/1998 (23,519)	0.3–32.3	19.5

Several additional historic observations were available for Sisters Creek at the confluence with the Fort George River through the USGS and EPA Water Quality Portal (USGS and EPA 2020). In 2003, salinity ranged from 18.1–32.3 ppt, and in 2008, observations ranged from 30.3–34.5 ppt (Table 47).

Table 47. Salinity measurements (ppt) from Sisters Creek at the confluence with the Fort George River (USGS and EPA 2020).

Year	# of observations	Range	Mean
2003	4	18.1–32.3	24.2
2008	4	30.3–34.5	32.8

Salinity measurements from SECN estuarine water quality monitoring at TIMU in 2018 ranged from 7.0–34.8 ppt (Table 48). Similar to historic sampling, the highest number of observations fell in the polyhaline range (18–30 ppt), with a high number also in the mesohaline range (5–18 ppt) and some in the euhaline or marine range (>30 ppt) (ranges defined by EPA 2006). As would be expected, higher salinity levels (>30 ppt) were observed at locations closer to the Atlantic Ocean and lower levels (<12 ppt) were further upstream in the Nassau River (Starkey et al. 2019).

Table 48. Salinity (ppt) measurements from SECN estuarine water quality monitoring, 2018 (Starkey et al. 2019).

Site #	Salinity
TIMU-01	19.4
TIMU-02	9.5
TIMU-03	22.8
TIMU-04	16.7
TIMU-05	24.6
TIMU-06	16.9
TIMU-07	21.6
TIMU-08	18.4
TIMU-09	13.7
TIMU-10	31.5
TIMU-11	23.1
TIMU-12	15.6
TIMU-13	13.0
TIMU-14	33.5
TIMU-15	19.3
TIMU-16	34.2
TIMU-17	11.8
TIMU-18	7.0
TIMU-19	33.1
TIMU-20	28.4
TIMU-21	29.9
TIMU-22	28.5
TIMU-23	19.4

Table 48 (continued). Salinity (ppt) measurements from SECN estuarine water quality monitoring, 2018 (Starkey et al. 2019).

Site #	Salinity
TIMU-24	17.4
TIMU-25	20.6
TIMU-26	34.8
TIMU-27	20.0
TIMU-28	32.0
TIMU-29	11.8
TIMU-30	8.0
TIMU-31	30.4

The SECN continuous water quality monitoring site at the Kingsley Plantation dock collected salinity data from 2011–2019, with some gaps. Measurements ranged from 21.8–36.3 ppt, with lower levels (<30 ppt) most often observed in the fall and early winter (Table 49). Mean daily values from continuous monitoring in 2019 (March–December) show salinity fluctuations at Kingsley Plantation throughout the year (Figure 67).

Table 49. Mean monthly salinity measurements (ppt), Kingsley Plantation monthly monitoring (Wright et al. 2012, Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019).

Month	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jan	35.6	34.3	34.2	32.1	30.0	31.3	32.7	32.2	–
Feb	33.5	34.6	34.2	32.6	30.9	29.1	33.9	31.3	–
March	34.1	35.2	34.1	33.7	30.9	30.9	32.8	30.6	29.3
April	34.3	35.5	32.3	31.8	32.8	31.8	34.6	–	30.8
May	35.9	36.3	32.0	33.7	33.8	33.8	36.1	–	34.8
June	–	32.7	33.5	34.8	34.7	34.1	34.7	28.8	34.9
July	–	30.9	33.8	33.7	35.9	34.3	33.9	–	–
Aug	–	33.0	32.2	34.5	33.7	37.0	32.7	–	32.3
Sept	–	31.9	31.2	32.3	31.1	36.2	27.3	–	34.4
Oct	–	33.3	24.7	21.8	33.1	34.0	29.0	–	33.7
Nov	–	35.0	32.4	27.0	31.2	–	29.5	–	33.6
Dec	–	34.3	32.5	28.0	30.8	32.6	29.1	–	32.1

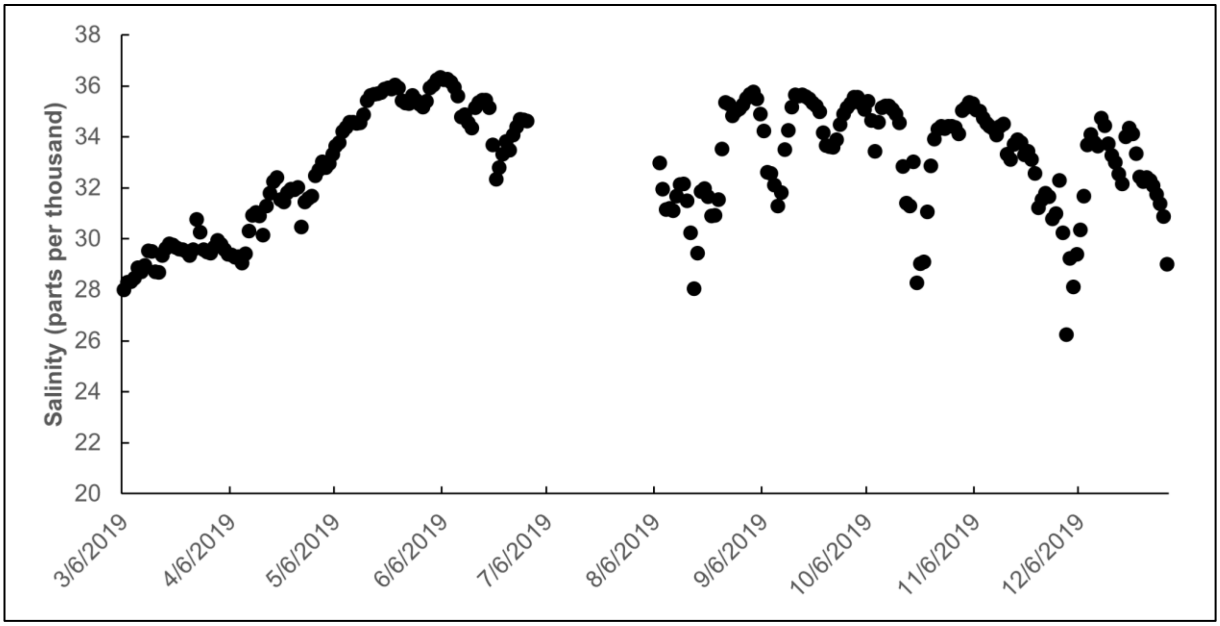

Figure 67. Mean daily values for salinity (ppt) at the Kingsley Plantation station, March–December 2019 (NPS 2020c).

The FLDEP continuous water quality monitoring site on Clapboard Creek recorded salinity levels ranging from 10.2–32.5 ppt in 2017 and from 15.1–28.7 ppt in 2018–2019 (Table 50) (NPS 2020c). Salinity observations at this station were generally lower and more variable than at Kingsley Plantation.

Table 50. Monthly mean salinity measurements (ppt), Clapboard Creek monitoring station (NPS 2020c). Means are not reported for months where fewer than 12 daily observations were available.

Month	2017	2018	2019	2020
Jan	22.0	21.4	19.1	21.4
Feb	27.8	19.9	18.4	24.2
March	28.4	28.1	22.5	24.5
April	30.9	24.6	22.9	–
May	32.5	23.3	28.6	–
June	28.5	16.8	28.7	23.9
July	22.4	16.6	26.3	–
Aug	22.3	15.1	21.9	–
Sept	14.1	20.3	24.7	–
Oct	10.2	23.9	22.5	–
Nov	17.1	26.8	–	–
Dec	16.9	18.2	22.8	–

Dissolved Inorganic Nitrogen

Historic water quality sampling of estuarine sites at TIMU yielded mean total inorganic nitrogen observations ranging from 0.082–0.228 mg/l (Table 51). The highest mean was observed at a station on the Nassau River (TIMU405) while the lowest mean was on Sisters Creek (TIMU114) (NPS 2002).

Table 51. Historic total inorganic nitrogen measurements (mg/l) at water quality monitoring sites (NPS 2002). See Figure 62 for site locations.

Station	Period of record (# of observations)	Nitrite + Nitrate		Ammonia		Total of means
		Maximum	Mean	Maximum	Mean	
TIMU114	7/1978–7/1998 (57)	0.27	0.043	0.28	0.039	0.082
TIMU120	9/1971–10/1994 (24)	0.25	0.106	0.5	0.062	0.168
TIMU188	5/1986–12/1996 (118)	0.44	0.118	0.18	0.046	0.164
TIMU191	10/1973–5/1988 (42)	–	–	1.1	0.101	–
TIMU405	6/1995–12/1998 (23)	1.76	0.127	1.03	0.101	0.228

SECN estuarine water quality monitoring measured total dissolved nitrogen in 2008 and then dissolved inorganic nitrogen in 2013 and 2018 (Table 52). In 2013, 57% of sampled locations were in good condition and 43% were in fair condition (Wright et al. 2013). During 2018 monitoring, 84% of sampled locations were in good condition and 16% were in fair condition (Starkey et al. 2019).

Table 52. Total dissolved nitrogen (TDN) (2008) and dissolved inorganic nitrogen (DIN) (2013, 2018)(mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TDN	2013 DIN	2018 DIN
TIMU-01	0.482	0.144	0.039
TIMU-02	0.147	0.013	0.095
TIMU-03	0.178	0.021	0.087
TIMU-04	0.422	0.040	0.115
TIMU-05	0.245	0.151	0.120
TIMU-06	0.203	0.140	0.150
TIMU-07	0.076	0.027	0.110
TIMU-08	0.376	0.144	0.075
TIMU-09	0.565	0.010	0.067
TIMU-10	0.456	0.152	0.007
TIMU-11	0.134	0.038	0.012
TIMU-12	0.282	0.023	0.014
TIMU-13	0.405	0.048	0.025

Table 52 (continued). Total dissolved nitrogen (TDN) (2008) and dissolved inorganic nitrogen (DIN) (2013, 2018)(mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TDN	2013 DIN	2018 DIN
TIMU-14	0.249	0.012	0.007
TIMU-15	0.425	0.009	0.048
TIMU-16	0.526	0.057	0.007
TIMU-17	0.139	0.064	0.034
TIMU-18	0.161	0.128	0.079
TIMU-19	0.358	0.008	0.034
TIMU-20	0.207	0.119	0.068
TIMU-21	0.245	0.011	0.024
TIMU-22	–	0.193	0.007
TIMU-23	0.282	0.008	0.090
TIMU-24	0.287	0.176	0.101
TIMU-25	0.161	0.188	0.074
TIMU-26	–	0.141	0.008
TIMU-27	0.398	0.017	0.042
TIMU-28	0.472	0.154	0.023
TIMU-29	0.072	0.191	0.055
TIMU-30	–	0.010	0.090
TIMU-31	–	–	0.023
TIMU-ALT-01	0.263		–
TIMU-ALT-02	0.385	–	–
TIMU-ALT03	0.26	–	–

Additional results from City of Jacksonville (COJ) sampling were available for TIMU from 2012–2016 (Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019). Dissolved inorganic nitrogen observations at these sites ranged from 0.005 mg/l at two tributary locations in June 2016 to 0.259 mg/l at an upstream Nassau River location in January 2012 (Appendix O). However, only seven measurements (<5%) from three locations on the Nassau River exceeded 0.2 mg/l, and all but one were prior to 2014. Based on NPS condition criteria, 28% of all observations were in fair condition and 72% were in good condition.

Dissolved Inorganic Phosphorus

During historic water quality sampling of estuarine park waters, total phosphorous levels ranged from 0.005–0.536 mg/l, with means from 0.086–0.149 mg/l (Table 53). As with total nitrogen, the highest mean level was on the Nassau River (TIMU405), but the lowest mean was on the St. John River, near TIMU's western boundary (TIMU188) (NPS 2002).

Table 53. Historic total phosphorus measurements (mg/l) at water quality monitoring sites (NPS 2002).

Station	Period of record (# of observations)	Range	Mean
TIMU114	5/1977–7/1998 (64)	0.005–0.536	0.105
TIMU120	12/1972–10/1994 (28)	0.022–0.517	0.138
TIMU188	5/1986–12/1996 (123)	0.005–0.34	0.086
TIMU405	6/1995–12/1998 (23)	0.043–0.288	0.149

As with nitrogen, SECN estuarine water quality monitoring measured total dissolved phosphorus in 2008 and then dissolved inorganic phosphorus in 2013 and 2018 (Table 54). During 2013 monitoring, 30% of locations were in good condition, 37% in fair condition, and 33% in poor condition. Most recently, in 2018, only one location was in poor condition, one was in good condition, and the remainder (93.5%) were in fair condition (Starkey et al. 2019).

Table 54. Total dissolved phosphorus (TDP) (2008) and dissolved inorganic phosphorus (DIP) (2013, 2018)(mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TDP	2013 DIP	2018 DIP
TIMU-01	0.045	0.158 [a]	0.019
TIMU-02	0.028	0.010	0.046
TIMU-03	0.034	0.011	0.038
TIMU-04	0.055	0.014	0.048
TIMU-05	0.049	0.042	0.021
TIMU-06	0.026	0.037	0.024
TIMU-07	0.042	0.013	0.039
TIMU-08	0.049	0.044	0.041
TIMU-09	0.035	0.008	0.046
TIMU-10	0.050	0.042	0.012
TIMU-11	0.049	0.007	0.020
TIMU-12	0.034	0.007	0.018
TIMU-13	0.069	0.028	0.032
TIMU-14	0.037	0.007	0.010
TIMU-15	0.048	0.007	0.036
TIMU-16	0.077	0.033	0.008

[a] Poor condition for DIP (condition criteria are not available for TDP), also shown with red cell shading.

Table 54 (continued). Total dissolved phosphorus (TDP) (2008) and dissolved inorganic phosphorus (DIP) (2013, 2018)(mg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TDP	2013 DIP	2018 DIP
TIMU-17	0.045	0.034	0.036
TIMU-18	0.023	0.055 [a]	0.055 [a]
TIMU-19	0.060	0.008	0.016
TIMU-20	0.037	0.051 [a]	0.029
TIMU-21	0.032	0.007	0.015
TIMU-22	–	0.063 [a]	0.014
TIMU-23	0.056	0.007	0.042
TIMU-24	0.032	0.061 [a]	0.046
TIMU-25	0.023	0.064 [a]	0.043
TIMU-26	–	0.058 [a]	0.011
TIMU-27	0.048	0.042	0.036
TIMU-28	0.054	0.054 [a]	0.012
TIMU-29	0.026	0.065 [a]	0.035
TIMU-30	–	0.060 [a]	0.048
TIMU-31	–	–	0.013
TIMU-ALT-01	0.044		–
TIMU-ALT-02	0.033	–	–
TIMU-ALT03	0.034	–	–

[a] Poor condition for DIP (condition criteria are not available for TDP), also shown with red cell shading.

Additional dissolved inorganic phosphorus observations from 2012–2016 COJ sampling ranged from below the detection level to 0.978 mg/l in October of 2013, at the furthest upstream Nassau River station within TIMU boundaries (Appendix O). Based on NPS condition criteria, 37% of all measurements were in poor condition, 52% in fair condition, and just 11% in good condition.

Indicator Bacteria

Historic water quality sampling of estuarine sites at TIMU found median fecal coliform levels ranging from 20.0–155.0 MPN, with a maximum in the St. Johns River of 4,900 MPN (Table 55). All five sites experienced exceedances of EPA standards, ranging from 5–50% of samples.

Table 55. Historic fecal coliform observations (MPN) at water quality monitoring sites (NPS 2002). The "exceedances" column represents the number of observations over the period of record that exceeded EPA standards. See Figure 62 for site locations.

Station	Water body	Period of record (# of observations)	Maximum	Median	Exceedances
TIMU114	Sisters Creek	5/1977–7/1995 (41)	330	20.0	2 (5%)
TIMU120	ICWW south of SJR	12/1972–1/1992 (18)	1,700	79.0	3 (17%)
TIMU188	St. Johns River	5/1986–6/1995 (85)	350	20.0	4 (5%)
TIMU191	St. Johns River	10/1973–7/1988 (41)	4,900	80.0	12 (29%)
TIMU405	Nassau River	11/1996–5/1997 (4)	500	155.0	2 (50%)

In Clapboard Creek, between December 2000 and July 2002, fecal bacteria averaged 11.3 CFU/100 ml, while *Enterococci* bacteria averaged 5.6 CFU/100 ml (Table 56) (Shehane et al. 2005). The majority of bacteria isolated at the sampling location were of human source (75.6%).

Table 56. Geometric means (CFU/100 ml) of indicator bacteria at a Clapboard Creek sampling location, December 2000–July 2002 (Shehane et al. 2005). CFU = colony forming units.

-P	Fecal coliform	*Enterococci*
Geometric mean (range)	11.3 (3–40)	5.6 (1–10)

Water samples taken by Florida's Healthy Beaches Program at Huguenot Park were sampled for *Enterococci* bacteria bimonthly from March through October. From March 2019 through September 2020 (most recent data available), samples fell in the "good" range (<35.4/100 ml) 47 out of 48 times. Only one sample fell in the poor range (>70.5/100 ml), in early March of 2019 (FDH 2020).

Water Clarity

The units for turbidity measurements vary depending on the equipment used for sampling, although this distinction was not recognized until 2004 (USGS 2017c). Since 2004, measurements taken with a device using white or broadband light are presented in Nephelometric Turbidity Units (NTUs), while those taken with devices using infrared, monochromatic light are measured in Formazin Turbidity Units (FTU) (USGS 2017c). These two units are not directly comparable. Historically, turbidity was more commonly measured in FTU, but more recent measurements have been in NTU.

Historically, turbidity measurements across seven locations ranged from 0.05–31.0 FTU or 0–927.0 NTU (Table 57). At two creek locations (TIMU178, TIMU213), turbidity maximums in 1997–98 exceeded 800 NTU (NPS 2002).

Table 57. Historic turbidity measurements (NTU or FTU) at water quality monitoring sites (NPS 2002).

Station	Water body	Period of record (# of observations)	Range	Mean
TIMU114	Sisters Creek	5/1977–7/1998 (69)	0.05–31.0 FTU	6.5 FTU
TIMU120	ICWW south of SJR	11/1977–10/1994 (24)	1.7–14.0 FTU	5.7 FTU
TIMU178	Cedar Point Creek	2/1997–6/1998 (26,302)	0–853.0 NTU	17.3 NTU
TIMU188	St. Johns River	6/1986–12/1996 (99)	0–22.0 NTU	6.1 NTU
TIMU191	St. Johns River	8/1978–7/1988 (26)	1.9–14.0 FTU	7.7 FTU
TIMU213	Clapboard Creek	2/1997–6/1998 (23,463)	0–927.0 NTU	13.6 NTU
TIMU405	Nassau River	6/1995–12/1998 (23)	2.2–24.0 NTU	10.6 NTU

The SECN estuarine water quality monitoring program estimates water clarity using a Secchi disk to determine light extinction depths, which are converted to light attenuation coefficients (k). Water clarity measurements at TIMU were primarily in good condition in 2008 and 2013, but more recent estimates have been split between fair and poor condition. In 2013, 80% of locations were in good condition, 3% were in poor condition, and 17% of locations could not be sampled (Table 58). During 2018 sampling, 51.6% of locations were in fair condition and 45.2% were in poor condition; no locations were in good condition. Sites in poor condition were primarily further upstream in the park’s waterways (Starkey et al. 2019).

Table 58. Water clarity (k) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 Clarity	2013 Clarity	2018 Clarity
TIMU-01	0.71	3.33 [a]	2.8 [a]
TIMU-02	0.81	NA	4.7 [a]
TIMU-03	0.50	1.11	1.9
TIMU-04	1.54	1.33	1.9
TIMU-05	0.52	1.67	1.9
TIMU-06	NA	1.33	4.7 [a]
TIMU-07	0.81	1.25	2.3 [a]
TIMU-08	1.30	2.00	2.0
TIMU-09	1.75	NA	2.8 [a]
TIMU-10	2.13	2.00	2.3
TIMU-11	1.31	1.00	3.5 [a]
TIMU-12	1.35	1.00	2.8 [a]
TIMU-13	1.42	1.25	5.6 [a]

[a] Poor condition, also shown with red cell shading.

Table 58 (continued). Water clarity (k) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	**2008 Clarity**	**2013 Clarity**	**2018 Clarity**
TIMU-14	1.14	0.57	2.3
TIMU-15	1.27	0.67	2.8 [a]
TIMU-16	2.33	1.33	1.8
TIMU-17	1.41	1.43	5.6 [a]
TIMU-18	NA	1.11	3.5 [a]
TIMU-19	0.97	0.63	1.8
TIMU-20	1.16	1.00	1.8
TIMU-21	1.03	NA	1.9
TIMU-22	–	1.00	2.8 [a]
TIMU-23	1.30	NA	NA
TIMU-24	1.04	0.83	1.9
TIMU-25	NA	1.00	2.3
TIMU-26	–	0.80	1.8
TIMU-27	1.11	1.25	2.3
TIMU-28	1.79	0.80	1.9
TIMU-29	NA	NA	5.6 [a]
TIMU-30	–	0.80	5.6 [a]
TIMU-31	–	–	2.8 [a]
TIMU-ALT-01	1.27	–	–
TIMU-ALT-02	NA	–	–
TIMU-ALT03	0.76	–	–

[a] Poor condition, also shown with red cell shading.

Additional water clarity observations from 2012–2016 COJ sampling at 12 TIMU locations ranged from 0.52–5.4 (Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019). Several measurements from Nassau River sites have fallen in the SECN's poor condition range (>2.3). The majority of observations from other streams in the park were in the good condition range (<1.6) (Appendix O).

Monthly mean turbidity was calculated using measurements from SECN monitoring of estuarine waters at the Kingsley Plantation dock. From 2011 through mid-January 2014, measurements were taken in NTU and monthly means ranged from 4.1–23.2 NTU with a maximum of 225.1 NTU in April 2011 (Table 59). From mid-January 2014 through 2019, measurements were in FNU and means ranged from 5.4–16.6 FNU, with a maximum of 205.4 FNU in September 2014 (NPS 2020c).

Mean daily values from continuous monitoring at Kingsley Plantation in 2019 show that turbidity generally remained between 5 and 15 FNU, with one spike above 20 FNU in September (Figure 68).

Table 59. Monthly turbidity means and maximums (in parentheses) in NTU (2011–2014) or FNU (2014–2019), Kingsley Plantation monthly monitoring (Wright et al. 2012, Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019, NPS 2020c).

Month	2011 [a]	2012 [a]	2013 [a]	2014	2015	2016	2017	2018	2019
Jan	10.9 (83.3)	–	5.0 (12.0)	8.1 (8.2)	7.9 (29.4)	9.0 (36.6)	6.9 (10.1)	10.3 (27.1)	–
Feb	12.3 (75.2)	–	4.4 (65.4)	8.0 (8.2)	6.3 (20.4)	9.4 (30.0)	7.7 (16.6)	7.2 (12.4)	–
March	15.4 (92.4)	–	4.6 (18.6)	8.0 (8.2)	9.3 (35.9)	7.6 (16.3)	9.7 (12.8)	7.2 (10.6)	8.0 (11.8)
April	21.4 (225.1)	–	4.8 (61.1)	8.0 (8.2)	6.5 (16.8)	8.8 (25.2)	8.5 (10.3)	–	8.4 (12.9)
May	23.2 (187.5)	7.8 (49.7)	11.1 (148.3)	8.0 (8.2)	8.0 (14.1)	8.7 (19.8)	11.3 (14.7)	–	6.5 (8.6)
June	18.9 (46.3)	9.3 (33.0)	12.3 (85.0)	8.0 (8.2)	9.4 (17.2)	7.8 (29.9)	9.6 (12.8)	7.9 (11.3)	7.0 (7.9)
July	–	7.5 (69.3)	7.9 (8.1)	7.0 (30.1)	11.0 (18.5)	7.1 (15.4)	9.3 (12.5)	9.9 (11.8)	–
Aug	–	6.8 (73.5)	8.0 (8.2)	7.2 (241.6)	6.2 (19.4)	12.2 (16.3)	9.1 (12.6)	–	7.2 (9.7)
Sept	–	6.5 (45.1)	7.9 (8.3)	11.1 (205.4)	5.4 (16.8)	9.0 (28.4)	16.6 (78.3)	–	10.9 (27.6)
Oct	–	–	7.8 (8.1)	6.3 (50.0)	10.0 (20.0)	14.7 (75.0)	12.5 (23.9)	–	8.3 (12.7)
Nov	–	9.2 (104.9)	8.0 (8.1)	8.6 (22.4)	7.0 (19.3)	–	11.0 (17.9)	–	7.2 (12.6)
Dec	–	4.1 (15.2)	8.0 (8.2)	8.2 (148.9)	8.3 (39.5)	8.4 (20.0)	7.9 (14.4)	–	8.5 (17.5)

[a] Data from 2011–Jan 2014 were in Nephelometric Turbidity Units (NTU), while Feb 2014–2019 data are in Formazin Nephelometric Units (FNU).

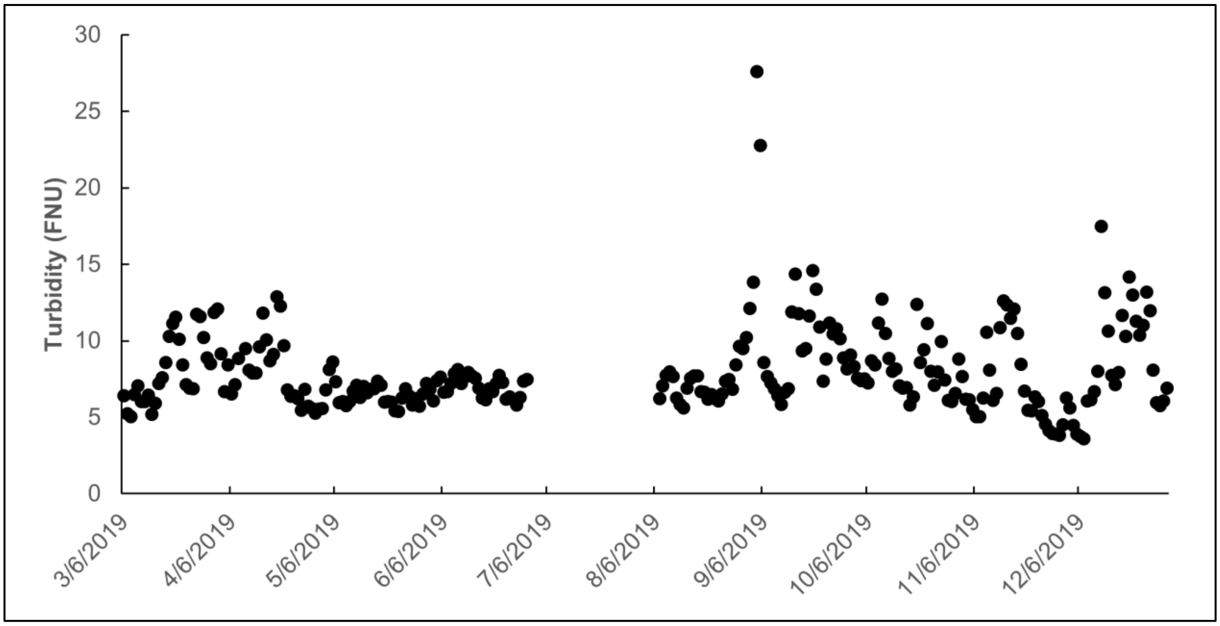

Figure 68. Mean daily values for turbidity (FNU) at the Kingsley Plantation station, March–December 2019 (NPS 2020c).

Monthly monitoring by the FLDEP at Clapboard Creek from 2017–2019 documented mean turbidity measurements ranging from 4.4–13.3 NTU (Table 60). The majority of monthly maximum observations were below 14 NTU, with two maximums exceeding 20 NTU. The highest maximum measurement was 24.6 NTU (January 2018) (NPS 2020c).

Table 60. Monthly turbidity means and maximums (in parentheses) in NTU, Clapboard Creek monitoring station (NPS 2020c). Means are not reported for months where fewer than 12 daily observations were available.

Month	2017	2018	2019
Jan	–	11.5 (24.6)	6.2 (11.3)
Feb	5.4 (8.8)	9.0 (13.4)	8.9 (11.8)
March	–	5.8 (9.1)	6.2 (10.1)
April	4.4 (8.3)	7.1 (11.8)	9.6 (16.4)
May	9.3 (13.6)	6.1 (9.1)	–
June	10.7 (13.0)	5.8 (8.0)	–
July	10.2 (13.4)	–	–
Aug	7.4 (9.9)	7.0 (10.1)	–
Sept	12.0 (21.1)	6.3 (12.4)	–
Oct	–	6.8 (10.2)	–
Nov	13.3 (18.7)	4.6 (6.5)	–
Dec	8.2 (13.7)	6.7 (19.3)	–

Chlorophyll a

A limited number of historic chlorophyll a measurements were available from three park locations. These ranged from 0–21.6 µg/l, with means from 0.23–5.36 µg/l (Table 61). Four additional historic observations were available from the USGS and EPA Water Quality Portal (USGS and EPA 2020) for Sisters Creek at the confluence with the Fort George River. In 2008, chlorophyll a measurements at that location ranged from 3.9–8.1 µg/l, with a mean of 6.2 µg/l (USGS and EPA 2020).

Table 61. Historic chlorophyll a measurements (µg/l) at water quality monitoring sites (NPS 2002).

Station	Period of record (# of observations)	Range	Mean
TIMU120	10/1985–1/1987 (4)	2.33–5.79	4.39
TIMU188	8/1991–8/1996 (46)	0–4.82	0.23
TIMU405	6/1995–12/1998 (15)	0.01–21.60	5.36

Chlorophyll a measurements from three rounds of SECN estuarine water quality monitoring have largely been in fair condition (5–20 µg/l) but with an increasing number of sites in poor condition over time. In 2008, 76.7% of sites were in fair condition and 20% in good condition, with only one site in poor condition (Table 62). During 2013 monitoring, 60% of sites were in fair condition, 30% in good condition, and 10% (three sites) in poor condition. Most recently, in 2018, 45.1% of sites were in fair condition, 32.3% in good condition, and 22.6% (seven sites) in poor condition (Starkey et al. 2019). Sites in poor condition tended to be further upstream on the Nassau River.

Table 62. Chlorophyll a (µg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 Chlorophyll a	2013 Chlorophyll a	2018 Chlorophyll a
TIMU-01	4.88	2.14	16.74
TIMU-02	9.34	13.88	18.07
TIMU-03	4.12	15.19	3.23
TIMU-04	15.57	15.25	3.20
TIMU-05	4.91	15.70	12.04
TIMU-06	8.72	18.79	23.64 [a]
TIMU-07	3.77	21.23 [a]	3.10
TIMU-08	14.32	20.55 [a]	3.49
TIMU-09	19.28	10.82	4.92
TIMU-10	12.89	16.78	9.97
TIMU-11	6.50	6.74	13.38
TIMU-12	9.84	4.54	15.57

[a] Poor condition, also shown with red cell shading.

Table 62 (continued). Chlorophyll a (µg/l) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 Chlorophyll a	2013 Chlorophyll a	2018 Chlorophyll a
TIMU-13	7.71	9.39	23.57 [a]
TIMU-14	5.81	3.44	14.03
TIMU-15	11.10	4.35	21.09 [a]
TIMU-16	27.58 [a]	11.89	5.54
TIMU-17	8.41	10.95	25.14 [a]
TIMU-18	1.96	8.90	21.05 [a]
TIMU-19	8.54	6.60	3.94
TIMU-20	9.87	8.66	2.66
TIMU-21	6.47	5.88	6.41
TIMU-22	–	3.08	17.05
TIMU-23	7.67	6.91	2.86
TIMU-24	9.60	5.86	2.33
TIMU-25	2.48	3.51	2.81
TIMU-26	–	6.93	11.56
TIMU-27	10.96	28.61 [a]	15.69
TIMU-28	19.68	3.88	7.17
TIMU-29	6.45	3.54	42.92 [a]
TIMU-30	–	3.70	26.70 [a]
TIMU-31	–		14.73
TIMU-ALT-01	5.46	–	–
TIMU-ALT-02	8.59	–	–
TIMU-ALT03	10.78	–	–

[a] Poor condition, also shown with red cell shading.

Chlorophyll a observations from additional COJ sampling at 12 TIMU locations between 2012 and 2016 ranged from 1.5–30.3 µg/l (Rinehart et al. 2013, Wright and Mockus 2015, Hynds and Starkey 2019). Most observations were split between the SECN's fair and good ranges, with only four measurements (2.4%) in the poor condition range (>20) µg/l (Appendix O).

Monthly chlorophyll a mean concentrations were calculated using measurements from SECN monitoring of estuarine waters at the Kingsley Plantation dock, and ranged from 4.58–7.60 µg/l (Table 63). These means primarily fall in the fair condition range, with some measurements in the good condition range during 2016 and 2017 (NPS 2020c). Mean daily values from continuous monitoring at Kingsley Plantation in 2019 show variation between 4 and 10 µg/l with no clear seasonal patterns (Figure 69).

Table 63. Mean chlorophyll a measurements (µg/l), Kingsley Plantation monthly monitoring (NPS 2020c). Means are not reported for months where fewer than 12 daily observations were available.

Month	2016	2017	2018	2019
Jan	–	6.12	5.87	–
Feb	6.77	4.97	6.10	–
March	6.28	–	5.86	5.68
April	4.92	5.43	–	7.13
May	4.86	6.17	–	6.56
June	4.58	6.94	7.60	7.22
July	5.13	4.99	7.10	–
Aug	–	6.03	–	6.45
Sept	6.76	7.13	–	6.74
Oct	4.63	6.83	–	7.07
Nov	–	5.88	–	6.67
Dec	–	5.23	–	5.82

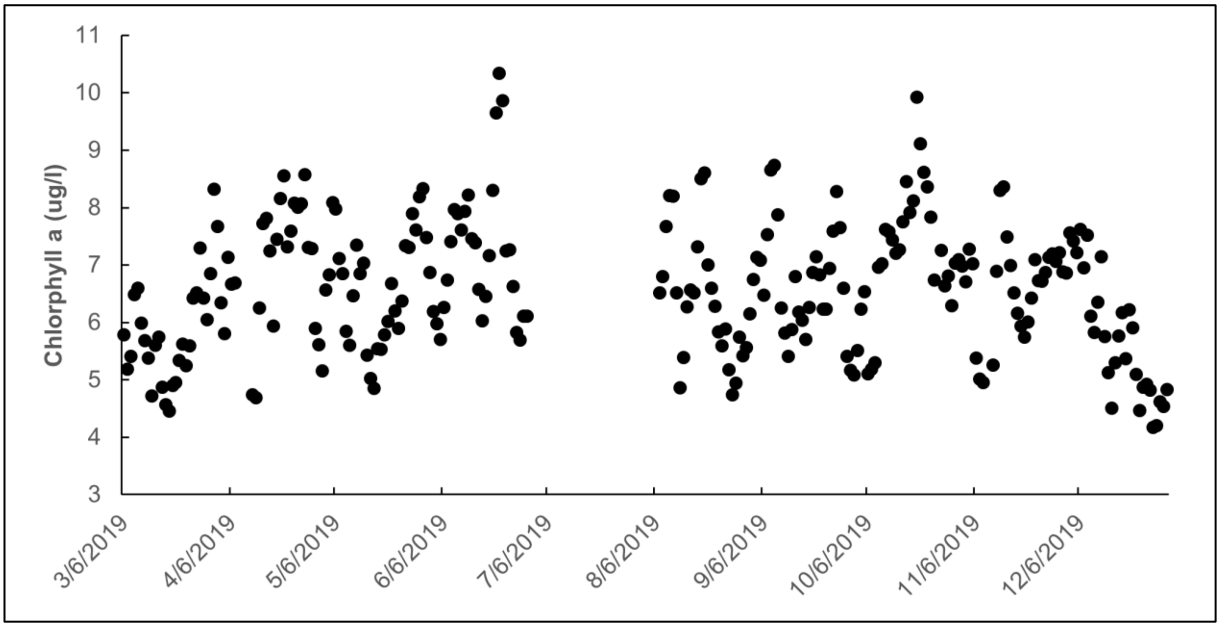

Figure 69. Mean daily values for chlorophyll a (µg/l) at the Kingsley Plantation station, March–December 2019 (NPS 2020c).

Total Organic Carbon in Sediment

SECN sediment sampling is conducted on a 10-year cycle, and has occurred twice at TIMU, in 2008 and 2018. In 2008, TOC measurements ranged from 0.28–5.7%, with only two locations considered in poor condition (>5%) (Table 64) (Gregory et al. 2011). The two locations in poor condition were the sites furthest upstream on the Nassau River. During 2018 monitoring, measurements ranged from 0.01–0.89%, with all values in the good condition (<2%) (Starkey et al. 2019).

Table 64. Total organic carbon (%) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TOC	2018 TOC
TIMU-01	1.4	0.24
TIMU-02	0.32	0.18
TIMU-03	–	0.01
TIMU-04	5.0	0.39
TIMU-05	0.49	0.37
TIMU-06	0.41	0.01
TIMU-07	1.2	0.15
TIMU-08	0.36	0.36
TIMU-09	1.6	0.52
TIMU-10	3.9	0.02
TIMU-11	0.82	0.11
TIMU-12	0.42	0.71
TIMU-13	0.64	0.01
TIMU-14	2.8	0.16
TIMU-15	0.59	0.27
TIMU-16	5.6	0.14
TIMU-17	1.4	0.05
TIMU-18	0.28	0.15
TIMU-19	0.91	0.01
TIMU-20	0.98	0.24
TIMU-21	0.6	0.04
TIMU-22	–	0.01
TIMU-23	0.63	–
TIMU-24	0.29	0.54
TIMU-25	0.28	0.89
TIMU-26	–	0.08
TIMU-27	0.74	0.34
TIMU-28	5.7	0.07
TIMU-29	0.7	0.66
TIMU-30	–	0.44
TIMU-31	–	0.07

Table 64 (continued). Total organic carbon (%) measurements from SECN estuarine water quality monitoring (Gregory et al. 2011, Starkey et al. 2019). Note that sites are randomly positioned each year; as a result, the locations of sites sampled in 2008 do not correspond to the 2013 or 2018 locations.

Site #	2008 TOC	2018 TOC
TIMU-ALT-01	0.41	–
TIMU-ALT-02	1.2	–
TIMU-ALT03	0.3	–

Sediment Contaminant Rating

Contaminants sampled for the rating utilized by the SECN monitoring program include metals (e.g., lead, cadmium, mercury) and toxic organic compounds (e.g., PCBs, DDT, naphthalene). Historically, these contaminants have not been of much concern within TIMU, although some elevated levels have been documented in sediment from Chicopit Bay, an inlet at the confluence of the St. Johns River and the Intracoastal Waterway (Anderson 2005). Samples taken during the 1980s as part of the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program showed concentrations above the "no observed effects level" for arsenic, chromium, lead, and zinc (NOAA 1988). These Chicopit Bay sediments also yielded the 17th highest level of PCM contamination (384 µg/kg) out of 212 coastal sites. A study of mussels in Chicopit Bay also found increasing levels of arsenic in their tissues between 1986 to 1993 (O'Connor and Beliaeff 1996). However, it is worth noting that some high metal levels in sediments and mollusks may be due to natural sources (e.g., erosion of upstream mineral deposits) (Vallette-Silver et al. 1999, Anderson 2005).

During 2008 and 2018 SECN monitoring, the sediment contaminant ratings for all sampling locations were in good condition (Gregory et al. 2011, Starkey et al. 2019). Slightly elevated arsenic levels were found at three sites on the Nassau River in 2008 and at one site near Browns Creek in 2018. During 2008 sampling, a small number of sediment samples from the Nassau River also yielded elevated levels of cadmium, silver, and the pesticide DDT (Gregory et al. 2011).

Threats and Stressor Factors

Threats to TIMU's water quality include wastewater and septic discharges, agricultural runoff, adjacent land development (including fertilizer runoff from residential areas), gas/oil spills from recreational boats/marinas, and dredging projects. Dredging primarily impacts water quality by re-suspending sediment, which increases turbidity and reduces water clarity (Erftmeijer and Lewis 2014, Sangita et al. 2014). The re-suspension of sediment may also increase nutrient levels in waters (Sangita et al. 2014). Any dredging that deepens or widens channels may allow saltwater to flow further into the estuary, increasing salinity (UNF and JU 2019). Dredging has been necessary in the St. Johns River to maintain depth and channel stability for commercial and naval shipping, and will continue in the future (UNF and JU 2019). Dredging will also likely be necessary to maintain the Fort George River Inlet, as sediment accumulation is currently threatening to close off the river's connection to the ocean (Anderson 2005, Hong 2019). If this connection were lost and tidal flushing ceased, water chemistry in the Fort George River would be substantially altered.

Fecal bacteria can enter waterways from the runoff or seepage of septic systems, agricultural/ livestock waste, or wastewater treatment plants (Anderson 2005, UNF and JU 2019). Discharge from insufficient or malfunctioning septic systems is suspected to be a major contributor to nutrient enrichment and bacterial contamination in the TIMU area (Anderson 2005, Shehane et al. 2005, UNF and JU 2019). Several studies have found that the majority of fecal coliform bacteria in St. Johns River tributaries originated from a human source, suggesting septic system leaks (Wicklein 2004, Shehane et al. 2005). Although there is currently no agricultural land in the immediate vicinity of TIMU, agricultural uses still occur further upstream in the watershed and can contribute nutrients and bacteria to waterways (UNF and JU 2019). Efforts have been made to upgrade wastewater treatment plants and sewer systems in the region in recent decades, but overflows or leaks still occur occasionally, particularly during storm events. Heavy rain can overwhelm wastewater treatment facilities and reduce the efficacy of septic drainfields (Shehane et al. 2005). On average, there are 35–40 reportable sanitary sewer overflow events (>1,000 gallons, impacting State waters) annually in the Jacksonville area (JEA 2021).

The addition of nutrients such as nitrogen and phosphorous to surface water bodies from agricultural or residential sources (e.g., fertilizers, livestock waste, septic discharge) often causes eutrophication (USGS 2016a, 2017b). Eutrophication triggers excess algal growth (i.e., “blooms”) in water bodies. As the algae die and decompose, oxygen becomes depleted in the water and may drop to levels where aquatic organisms can no longer survive (Rabalais et al. 2009, USGS 2017a). Some algal blooms may also produce toxins or promote bacterial growth that can harm aquatic life (Lapointe et al. 2015, Wolny et al. 2015).

Stormwater runoff from developed areas is also a potential source of water pollution for park waters. The increase in impervious surfaces associated with development (e.g., roads, driveways, parking lots) has intensified storm runoff, which often carries contaminants from developed areas (Anderson 2005, Shehane et al. 2005). These contaminants can cause altered growth, reduced reproduction, and mortality in aquatic organisms (Lerberg et al. 2000). Runoff can also contain sediment and fine particles that increase turbidity, which can then reduce water clarity (UNF and JU 2019). As a result of climate change, extreme rainfall events are projected to increase in frequency and intensity across the southeast (Carter et al. 2018). This change could not only increase the total volume of stormwater runoff, but also make it “flashier” (i.e., runoff increases in amount and intensity very quickly).

Fuel and/or oil spills from boats are known to pollute coastal and estuarine waters and sediments (EPA 1993, Whitfield and Becker 2014). Boats are typically fueled by diesel or a petroleum and oil-based mixture, which can leak or spill from fuel tanks (Whitfield and Becker 2014). These spills may occur directly into coastal waters or may be washed into the water later by rainfall. Pollutants such as oil and other chemicals may also be spilled during boat maintenance activities (EPA 1993). Harmful chemicals can also be released into waterways when large ships discharge bilge and ballast water (Caric 2016). With approximately 1,500–1,800 vessel calls (i.e., visits) at Jacksonville’s port annually over the past 5 years (JAXPORT 2020a), including around 70–80 cruise ship visits per year, there is a substantial risk of contamination from leaks, spills, or intentional discharges.

Data Needs/Gaps

Given the recent increases in water clarity and chlorophyll a detected by SECN estuarine water quality monitoring, more frequent and focused sampling for these parameters would help to identify the locations and magnitude of increases, how they are impacting overall water quality or other park resources, and what the cause(s) may be. Additional monitoring for indicator bacteria, focused on areas within TIMU where septic contamination is suspected, would also contribute to a better understanding of park-wide water quality. The development of baselines or reference levels for salinity that are location or area-specific within the park would help managers detect changes in salinity over time.

Overall Condition

The NRCA project team assigned a *Significance Level* of 3 for all the selected measures.

Dissolved Oxygen

The majority of DO observations from SECN water quality monitoring and COJ sampling were in the good condition range (>5 mg/l), with no measurements indicating poor condition (<2 mg/l) (Table 43, Table 44, Table 45). As a result, this measure is assigned a *Condition Level* of 1, indicating low concern.

Salinity

Depending on location and distance from the ocean, estuarine waters in TIMU are primarily polyhaline or euhaline, with some observations in the mesohaline range (Hynds and Starkey 2019, Starkey et al. 2019, NPS 2020c). Salinity levels can fluctuate with tidal cycles at many locations. However, because salinity levels vary naturally by location and a clear reference condition was not defined for this measure, a *Condition Level* has not been assigned at this time.

Dissolved Inorganic Nitrogen

The majority of observations from SECN monitoring and COJ sampling were in good condition, particularly since 2016 (Hynds and Starkey 2019, Starkey et al. 2019). Therefore, a *Condition Level* of 1 has been assigned.

Dissolved Inorganic Phosphorus

During early SECN monitoring (2008, 2013), few sampled sites were considered in good condition for phosphorus levels (Gregory et al. 2011, Wright et al. 2013). In 2018, the vast majority of locations (93.5%) were in fair condition, with only one site in good condition and one in poor condition (Starkey et al. 2019). COJ sampling showed 37% of all measurements in poor condition, 52% in fair condition, and just 11% in good condition. Based on these data, a *Condition Level* of 2 has been assigned for this measure, indicating moderate concern.

Indicator Bacteria

Data on indicator bacteria levels in TIMU's waters are limited. Recent monitoring has only been conducted at one location, Huguenot Park, by Florida's Healthy Beaches Program. All biweekly samples from this location in 2019–2020, except for one, were in good condition. However, because data are so limited, a *Condition Level* has not been assigned at this time.

Water Clarity

SECN monitoring suggests that water clarity conditions at TIMU have declined over time. In 2008 and 2013, over 75% of sampled locations were in good condition (Gregory et al. 2011, Wright et al. 2013). During 2018 monitoring, no locations were in good condition and 45.2% were in poor condition. According to SECN guidelines, overall park condition is considered poor when more than 20% of sampling locations are in poor condition (Starkey et al. 2019). Therefore, a *Condition Level* of 3 for significant concern is assigned.

Chlorophyll a

Chlorophyll a measurements from SECN water quality monitoring have largely been in fair condition (5–20 µg/l), but with an increasing number of sites in poor condition (Gregory et al. 2011, Wright et al. 2013, Starkey et al. 2019). In 2008, only one site was in poor condition, but by 2018, seven sites (22.6%) were in poor condition. However, nearly 98% of 2012–2016 COJ sampling observations and all of the monthly means at the Kingsley Plantation continuous monitoring site (2016–2019) fell in the good or fair condition range (Hynds and Starkey 2019, NPS 2020c). A *Condition Level* of 2, indicating moderate concern, was assigned for this measure.

Total Organic Carbon

Sediment samples from 2008 SECN monitoring were primarily in good condition (<2%), with only two observations in poor condition (>5%) and three in fair condition (Gregory et al. 2011). TOC measurements during 2018 SECN monitoring were all in good condition (<2%), with a maximum value of 0.89% (Starkey et al. 2019). Given these 2018 results, this measure is assigned a *Condition Level* of 0 for no current concern.

Sediment Contaminant Rating

Sediment samples taken during 2008 and 2018 were all in good condition. Some slightly elevated levels of metal contaminants were detected in 2008, but overall, this measure is of no concern at TIMU (*Condition Level* = 0).

Weighted Condition Score

The Weighted Condition Score for water quality at TIMU is 0.33, at the upper threshold of the good condition range, very close to the moderate concern condition range (Table 65). An overall park-wide trend could not be assigned. Conditions in some areas of the park appear stable; in other areas, some measures are improving (e.g., nutrients) while others are declining (water clarity, chlorophyll a).

Table 65. Current condition of water quality at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Dissolved Oxygen	3	1	–
Salinity	3	NA	–
Dis. Inorganic Nitrogen	3	1	–
Dis. Inorganic Phosphorus	3	2	–
Indicator Bacteria	3	NA	–
Water Clarity	3	3	–
Chlorophyll a	3	2	–
Total Organic Carbon	3	0	–
Sediment Contaminant Rating	3	0	–
Overall	**–**	**–**	🟢

4.7.6 Sources of Expertise

- Brian Gregory, SECN Program Manager/Aquatic Ecologist
- Eric Starkey, SECN Aquatic Ecologist

4.8 Air Quality

4.8.1 Description

Air pollution can significantly affect natural resources, their associated ecological processes, cultural resources, and the health of park visitors. In the Clean Air Act (CAA), Congress set a national goal "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic or historic value" (42 U.S.C. §7470(2)). This goal applies to all units of the NPS. The act includes special provisions for 48 park units, called "Class I" areas under the CAA; all other NPS areas are designated as Class II, including TIMU. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas which can allow for more development (NPS 2019b). Additional authority to consider and protect air quality in Class II parks is provided by Title 54 (54 USC 100101(a) et seq.), commonly known as the NPS Organic Act.

To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility. In addition, the SECN has identified ozone, wet and dry deposition, and visibility and particulate matter as Vital Signs for all network parks, including TIMU (DeVivo et al. 2008). The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks based on the EPA's current National Ambient Air Quality Standards (NAAQS), ecosystem thresholds, and visibility improvement goals (Taylor 2017), which will be described in section 4.8.3 of this assessment.

The State of Florida boasts one of the nation's most robust air quality monitoring networks, with 211 monitoring stations at 99 locations (FLDEP 2020). In March of 2020, the Florida Department of Environmental Protection (FLDEP) announced that the entire state had met all of the NAAQS, making it the most populous state in the country to do so (FLDEP 2020). The City of Jacksonville's Environmental Quality Division provides current and historic air quality conditions on their website, based on an air quality index (AQI) that incorporates five key pollutants: sulfur dioxide, carbon monoxide, ozone, nitrogen dioxide, and particulate matter (City of Jacksonville 2020a). In the Jacksonville area, index scores historically have fallen into four categories: good, moderate, unhealthy for sensitive groups, and unhealthy; higher categories (very unhealthy and hazardous) exist but have not been experienced in Jacksonville since monitoring began in 1980. In the past 5 years (2016–2020), Jacksonville has recorded only 4 days in the "unhealthy for sensitive groups" range and no days in the "unhealthy" range. For the past 15 years, approximately 80% of days each year have fallen in the good range (City of Jacksonville 2020a).

4.8.2 Measures

- Nitrogen deposition
- Sulfur deposition
- Mercury deposition
- Ozone
- Visibility

Atmospheric Deposition of Sulfur and Nitrogen

Sulfur and nitrogen are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012). While in the atmosphere, these emissions form compounds that may be transported long distances, eventually settling out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2012). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012). Deposition of sulfur and nitrogen can have significant effects on ecosystems, including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water and vegetation (Pardo et al. 2011, Sullivan et al. 2011a, 2011c). The acidic nature of nitrogen and sulfur deposition can also contribute to the deterioration of stone in historic structures (Charola 1998).

Atmospheric Deposition of Mercury

Sources of atmospheric mercury (Hg) include anthropogenic sources such as fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, along with natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008). Atmospheric deposition of mercury from coal-burning power plants has been identified as a major source of mercury to remote ecosystems (Landers et al. 2008). Mercury is a potential problem for ecosystems in regions with heavy current or historic coal use.

Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species, resulting in exposure to wildlife and humans that consume them (EPA 2008). Mercury exposure can cause liver, kidney, and brain (neurological and developmental) damage (EPA 2008). High mercury concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success (Mast et al. 2010, Eagles-Smith et al. 2014).

Ozone

Ozone (O_3) occurs naturally in the earth's upper atmosphere where it protects the earth's surface against ultraviolet radiation (EPA 2012). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight (EPA 2012). These ozone precursors are emitted from both anthropogenic and natural source types, including power plants, industry, motor vehicles, oil and gas development, forest fires, and other sources (Beitler 2006, EPA 2008). Ozone levels often peak during the summer in the afternoon, when temperature and light conditions are most favorable to the chemical reactions that create ozone (EPA 2017).

Ozone is one of the most widespread pollutants affecting vegetation in the U.S. Considered phytotoxic, ozone can cause significant foliar injury and growth defects for sensitive plants in natural ecosystems. Specific defects include reduced photosynthesis, premature leaf loss, and reduced biomass; prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (Sullivan 2016). Plant species occurring in TIMU that are known to be sensitive to ozone include loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), Virginia creeper (*Parthenocissus quinquefolia*), and smooth cordgrass (*Spartina alterniflora*) (Kohut 2004).

At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans through reduced lung function, increased acute respiratory problems, and elevated susceptibility to respiratory infections (EPA 2016b). Visitors and staff engaging in aerobic activities in the park (e.g., hiking, biking, maintenance/physical labor), as well as children, the elderly, and people with heart and lung diseases are especially sensitive to elevated ozone levels.

Visibility (Particulate Matter)

Air pollution, especially particulate matter (PM), influences a visitor's ability to view scenic vistas and landscapes at parks (NPS 2015b). PM is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2016g). There are two particle size classes of concern: $PM_{2.5}$ – fine particles found in smoke and haze, which are 2.5 micrometers or less in diameter; and PM_{10} – coarse particles found in wind-blown dust, which have diameters between 2.5 and 10 micrometers (EPA 2012). Fine particles are a major cause of reduced visibility (haze) in many national parks and wilderness areas (EPA 2012). $PM_{2.5}$ can either be directly emitted from sources (e.g., forest fires) or they can form when gas emissions from power plants, industry, and/or vehicles react in the air (EPA 2016g). Particulate matter can either absorb or scatter light, causing the clarity, color, and distance seen by humans (i.e., visibility) to decrease, especially during humid conditions when additional moisture is present in the air. $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2016g). Exposure to these particles can cause airway irritation, coughing, and difficulty breathing (EPA 2016g).

4.8.3 Reference Condition/Values

The NPS ARD's approach for rating air quality conditions in national parks is discussed by indicator in the following paragraphs and the ratings are summarized in Table 66 and Table 67.

Table 66. National Park Service Air Resources Division air quality index values for wet deposition of nitrogen or sulfur, ozone, particulate matter, and visibility (Taylor 2017).

Condition Level	Human Health Risk from O_3 (ppb)	Vegetation Health Risk from O_3 (ppm-hrs)	Wet Deposition of N or S (kg/ha-yr)	Visibility (dv) [a]
Significant Concern	≥71	>13	>3	>8
Moderate Concern	55–70	7–13	1–3	2–8
Good Condition	≤54	<7	<1	<2

[a] A unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview (dv) represents the minimal perceptible change in visibility to the human eye.

Table 67. National Park Service Air Resources Division air quality assessment matrix for mercury status (Taylor 2017). Assessments are also color coded: green = Good Condition, yellow = Moderate Concern, and red = Significant Concern.

Predicted Methylmercury Concentration Rating	**Mercury Wet Deposition Rating**				
	Very Low (<3 µg/m^2/yr)	**Low (≥3–<6 µg/m^2/yr)**	**Moderate (≥6–<9 µg/m^2/yr)**	**High (≥9–<12 µg/m^2/yr)**	**Very High (≥ 12 µg/m^2/yr)**
Very Low (< 0.038 ng/L)	Good Condition	Good Condition	Good Condition	Moderate Concern	Moderate Concern
Low (≥0.038–< 0.053 ng/L)	Good Condition	Good Condition	Moderate Concern	Moderate Concern	Moderate Concern
Moderate (≥0.053–<0.075 ng/L)	Good Condition	Moderate Concern	Moderate Concern	Moderate Concern	Significant Concern
High (≥0.075–<0.12 ng/L)	Moderate Concern	Moderate Concern	Moderate Concern	Significant Concern	Significant Concern
Very High (≥0.12 ng/L)	Moderate Concern	Moderate Concern	Significant Concern	Significant Concern	Significant Concern

Ozone

The primary NAAQS for ground-level ozone is set by the EPA and is based on human health effects. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb) (Taylor 2017). On 1 October 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb (EPA 2015). The NPS ARD recommends a benchmark for *Good Condition* ozone status in line with the updated Air Quality Index (AQI) breakpoints (Taylor 2017).

Current condition for human health risk from ozone is based on the estimated 5-year 4th-highest daily maximum 8-hour ozone average concentration in ppb (Taylor 2017). Ozone concentrations ≥71 ppb are assigned a *Significant Concern*, from 55–70 ppb are assigned *Moderate Concern*, and ≤54 ppb are assigned a *Good Condition*.

In addition to being a concern to human health, long-term exposures to ozone can cause injury to ozone-sensitive plants (EPA 2014). The W126 metric relates plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the primary (human-health based) standard (EPA 2014). The W126 metric measures cumulative ozone exposure over the growing season in "parts per million-hours" (ppm-hrs) and is used for assessing the vegetation health risk from ozone levels (EPA 2014).

The W126 condition thresholds are based on information in the EPA's Policy Assessment for the Review of the Ozone NAAQS (EPA 2014). Research has found that for a W126 value of:

- ≤7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10% per year in sensitive species.

The NPS ARD recommends a W126 of <7 ppm-hrs to protect most sensitive trees and vegetation. Levels below this guideline are considered *Good Condition*, 7–13 ppm-hrs is *Moderate Condition*, and >13 ppm-hrs is considered to be of *Significant Concern* (Taylor 2017).

Atmospheric Deposition of Sulfur and Nitrogen

Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Wet deposition is used as a surrogate for total deposition (wet plus dry) because wet deposition is the most widely available monitored source of nitrogen and sulfur deposition data (Taylor 2017). Values for nitrogen (from ammonium and nitrate) and sulfur (from sulfate) wet deposition are expressed as amount of nitrogen or sulfur in kilograms deposited over a 1 ha (2.5 ac) area in 1 year (kg/ha/yr). The NPS ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This is based on research linking early stages of aquatic health decline with 1.0 kg/ha/yr wet deposition of nitrogen in both the Rocky Mountains (Baron et al. 2011) and the Pacific Northwest (Sheibley et al. 2014). Parks with <1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned *Good Condition*, those with 1–3 kg/ha/yr are assigned *Moderate Concern*, and parks with depositions >3 kg/ha/yr are assigned *Significant Concern* (Taylor 2017).

Mercury Deposition

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (micrograms per m^2 per year [$\mu g/m^2/yr$]) and the predicted surface water methylmercury concentrations (nanograms per liter [ng/L]) at NPS I&M parks (Taylor 2017). It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition because atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and can accumulate in food webs (Taylor 2017). Therefore, mercury condition should not be assessed using mercury wet deposition alone. Other factors, such as environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH), must also be considered (Taylor 2017). Mercury wet deposition and predicted methylmercury concentration are considered concurrently in the mercury status assessment matrix shown in Table 67 to determine park-specific mercury/toxics status.

Visibility

Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews [dv]) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2013). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier (NPS 2013). The NPS ARD assesses visibility condition status based on the deviation of the estimated current visibility on mid-range days from estimated natural visibility on mid-range days (i.e., those estimated for a given area in the absence of human-caused visibility impairment) (Taylor 2017). The NPS ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network. Visibility on mid-range days is defined as the mean of the visibility observations falling within the 40th and 60th percentiles (Taylor 2017). A visibility condition estimate of <2 dv above estimated natural conditions indicates a *Good Condition*, estimates ranging from 2–8 dv above natural conditions indicate *Moderate Concern*, and estimates >8 dv above natural conditions indicate *Significant Concern* (Taylor 2017).

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days (Taylor 2017). Although this legislation provides special protection for NPS areas designated as Class I, the NPS ARD applies these standard visibility metrics to all NPS units. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend (Taylor 2017).

4.8.4 Data and Methods

NPS Data Resources

Although data on air quality parameters have not been actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in TIMU. NPS ARD provides estimates of ozone, wet deposition (nitrogen, sulfur, and mercury), and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2013–2017). Estimates and conditions data for TIMU were obtained from the NPS Air Quality by park data products page (https://www.nps.gov/subjects/air/park-conditions-trends.htm).

On-site or nearby data are needed for a statistically valid trends analysis (within 10 km [6.2 mi] for ozone and within 16 km [10 mi] for deposition) (Taylor 2017). The only parameter for which a near-enough monitor is present for TIMU is ozone (Site ID 12-031-0077). This monitor is located west of the park on Lanier Road and has collected data continuously since 1990 (Figure 70) (EPA 2020b). For visibility trend analysis, monitoring data from an Interagency Monitoring of Protected Visual Environments Program (IMPROVE) station is required. An IMPROVE monitoring site considered representative of a Class II park must be within +/-30.48 m (100 ft) or 10% of maximum and minimum elevation of the park and at a distance of no more than 150 km (93 mi) (Taylor 2017). There are no IMPROVE stations that meet these criteria for TIMU. However, there is a monitor for $PM_{2.5}$ (Site ID 12-031-0099), a major cause of visibility impairment, in the Sunny Acres area just 5 km (3 mi) southwest of the park (Figure 70). Data from this station may provide some insight into visibility conditions near TIMU.

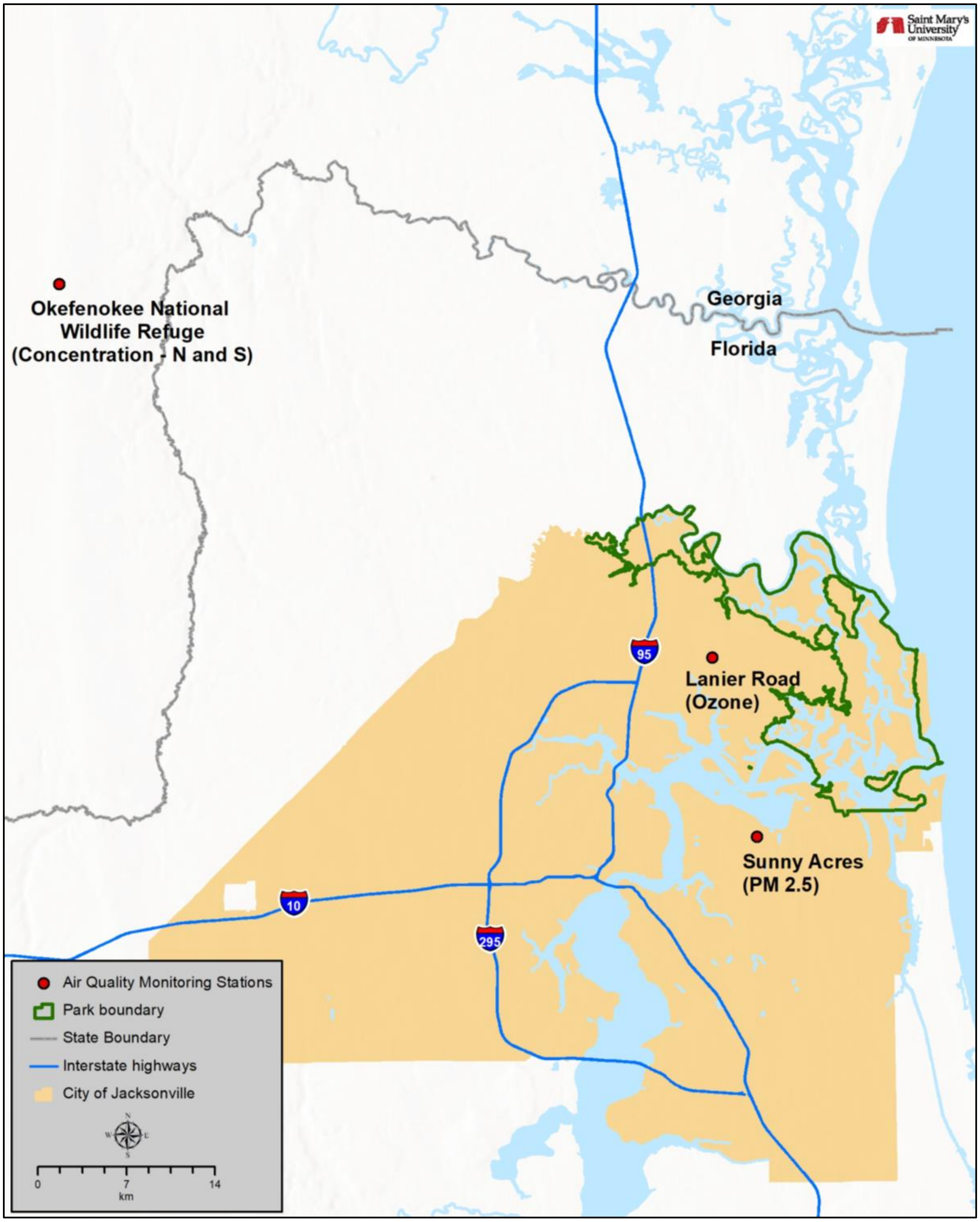

Figure 70. Air quality monitoring locations in relation to TIMU.

Other Air Quality Data Resources

The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database provides annual average summary data for nitrogen and sulfur concentration and deposition across the U.S. (NADP 2019b). The NADP-NTN monitoring site closest to TIMU is at Okefenokee

National Wildlife Refuge in southeastern Georgia (Site ID GA-09), approximately 48 km (30 mi) northwest of the northernmost portion of TIMU (Figure 70). This site has collected deposition data for the region since 1997, which are available on the NADP-NTN website (NADP 2019b). This station also is not close enough to TIMU for a statistically valid trend analysis, but provides insight regarding regional conditions. In addition, the NADP has a Mercury Deposition Network (MDN) that provides weekly summary data for mercury deposition and concentration. These data are used to interpolate annual wet deposition and mercury deposition levels for much of the U.S.

Special Air Quality Studies

Sullivan et al. (2011a, 2011c) identified ecosystems and resources in national parks that were at risk to acidification and excess nitrogen enrichment. These reports provided a relative risk assessment of acidification and nutrient enrichment impacts from atmospheric nitrogen and sulfur deposition for parks in 32 I&M networks. Ecosystem sensitivity ratings to acidification from atmospheric deposition were based on percent sensitive vegetation types, number of high-elevation lakes, length of low-order streams, length of high-elevation streams, average slope, and acid-sensitive areas within the park (Sullivan et al. 2011a). Ecosystem sensitivity ratings to nutrient enrichment effects were based on percent sensitive vegetation types and number of high-elevation lakes within the park (Sullivan et al. 2011c).

Kohut (2004) employed a biologically-based method to evaluate the risk of foliar injury from ozone at parks within the SECN. The assessment allowed resource managers at each park to better understand the risk of ozone injury to vegetation within their park and permits them to make a better-informed decision regarding the need to monitor the impacts of ozone on plants.

Pardo et al. (2011) synthesized current research relating atmospheric nitrogen deposition to effects on terrestrial and aquatic ecosystems in the U.S. and identified empirical critical loads for atmospheric nitrogen deposition.

4.8.5 Current Condition and Trend

Nitrogen Deposition

Five-year interpolated averages of nitrogen (from nitrate and ammonium) wet deposition are used to estimate condition for deposition. The most recent 5-year (2013–2017) estimate for nitrogen deposition at TIMU is 2.3–2.5 kg/ha/yr (NPS 2019a). Based on the NPS ratings for air quality conditions (see Table 66), this falls in the *Moderate Concern* range. A comparison to previous 5-year estimates shows that nitrogen deposition rates have declined slightly in recent years (Figure 71).

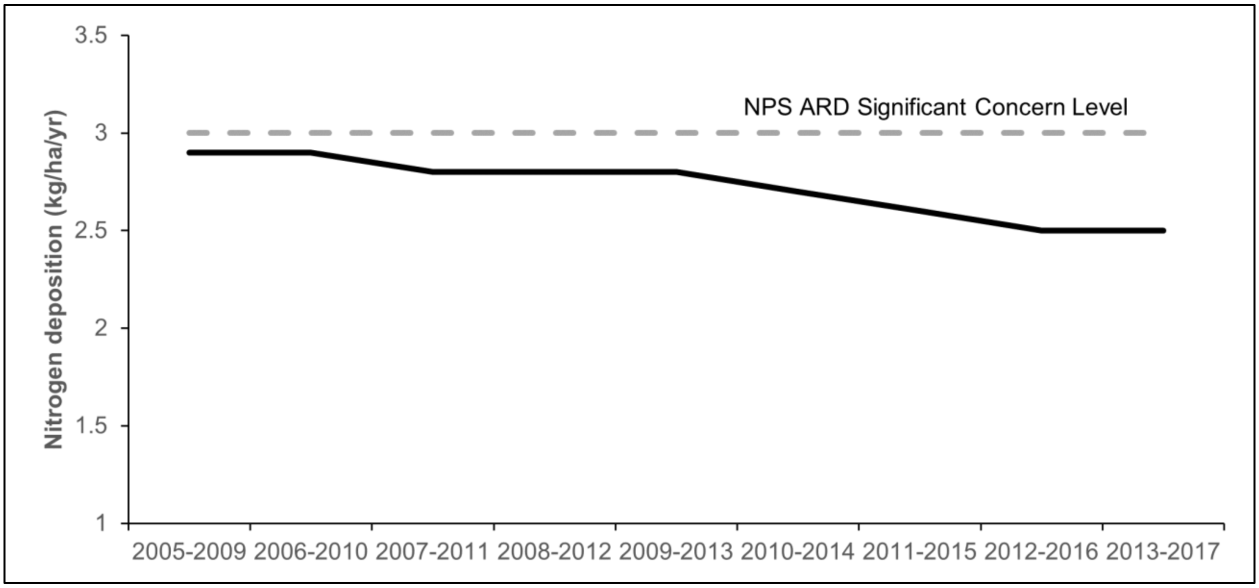

Figure 71. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at TIMU (NPS 2019a).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to park resources (Pardo et al. 2011). A critical load is defined as the level of deposition below which harmful effects to the ecosystem are not expected (Pardo et al. 2011). For the Eastern Temperate Forest, the ecoregion where TIMU is located, Pardo et al. (2011) suggested critical loads for total nitrogen deposition (wet plus dry) of 4–8 kg/ha/yr to protect lichens, 8 kg/ha/yr to protect hardwood forests, and <17.5 kg/ha/yr to protect herbaceous species. The lowest critical load level (4.0 kg/ha/yr) is identified as an appropriate management goal because it will protect the full range of vegetation in the park (Pardo et al. 2011). The 2013–2017 estimated deposition at TIMU of 2.3–2.5 kg/ha/yr was below the minimum ecosystem critical load for the ecoregion, suggesting that sensitive vegetation elements may not be at risk for harmful effects. However, Sullivan et al. (2011d) identified TIMU as being at high risk of nutrient enrichment from nitrogen deposition, due to high pollutant exposure and high levels of ecosystem sensitivity.

Concentrations (mg/L) of nitrogen compounds in wet deposition can also be used to evaluate overall trends in deposition. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Figure 72 suggests that nitrate concentrations in the north Florida/south Georgia region have fluctuated since 1998 but are generally decreasing over time (NADP 2019b). Ammonium concentrations in the region have also fluctuated no clear increasing or decreasing trend, although levels in 3 of the past 5 years have been below average (Figure 73).

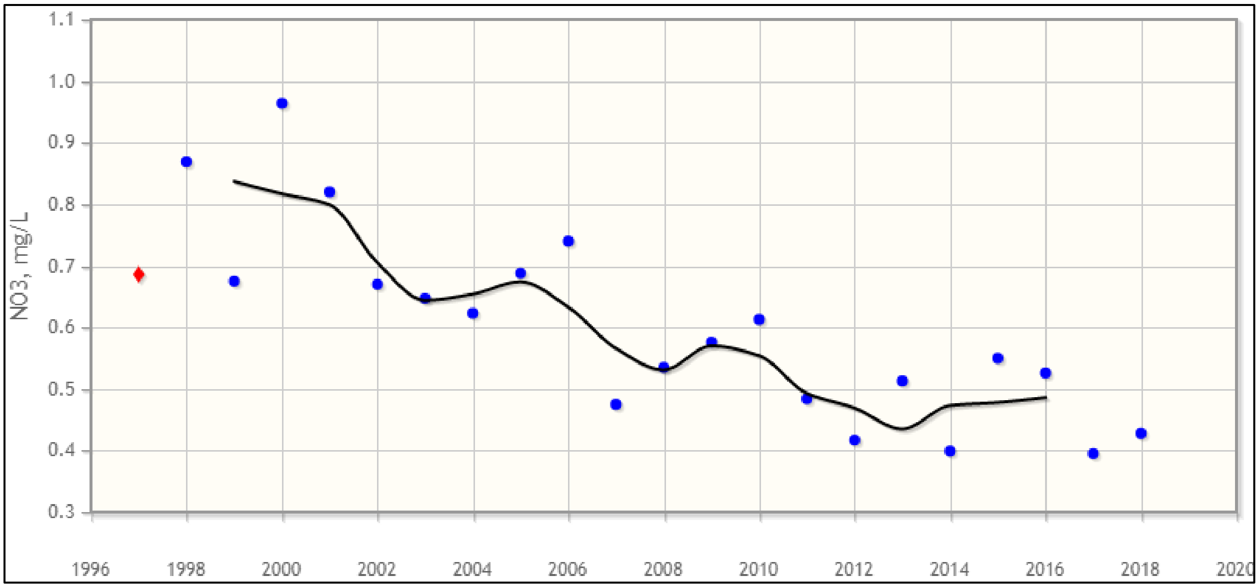

Figure 72. Annual weighted mean concentration of nitrate in wet deposition from Okefenokee NWR (NTN Site GA09), approximately 48 km (30 mi) northwest of the northernmost portion of TIMU (NADP 2019b). The black line represents a smoothed 3-yr moving average.

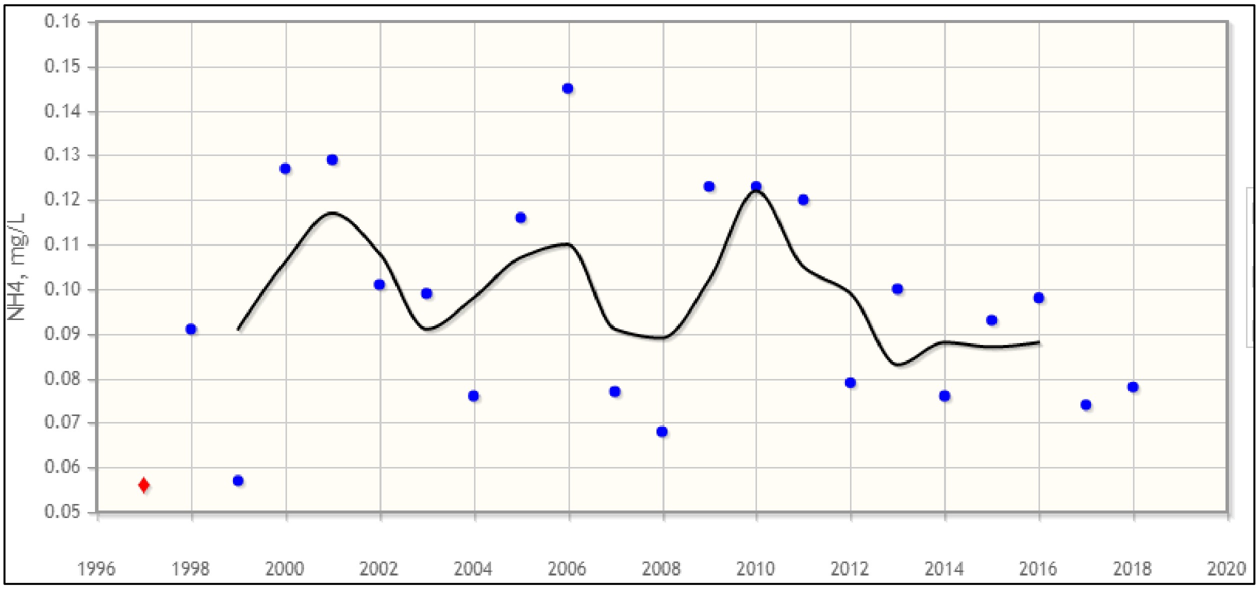

Figure 73. Annual weighted mean concentration of ammonium in wet deposition from Okefenokee NWR (NTN Site GA09) (NADP 2019b). The black line represents a smoothed 3-yr moving average.

In contrast to the nutrient enrichment assessment discussed previously, Sullivan et al. (2011b) ranked TIMU as being at moderate risk of acidification from acidic (nitrogen and sulfur) deposition, due to high pollutant exposure but low levels of ecosystem sensitivity.

<u>Sulfur Deposition</u>

Five-year interpolated averages of sulfur (from sulfate) wet deposition are used to estimate condition for deposition. The most recent 5-year (2013–2017) estimate for sulfur deposition at TIMU is 2.0–2.2 kg/ha/yr (NPS 2019a). This falls in the *Moderate Concern* range. A comparison to previous estimates suggests that sulfur deposition has declined over time, improving from the *Significant Concern* range to the *Moderate Concern* range around 2013 (Figure 74).

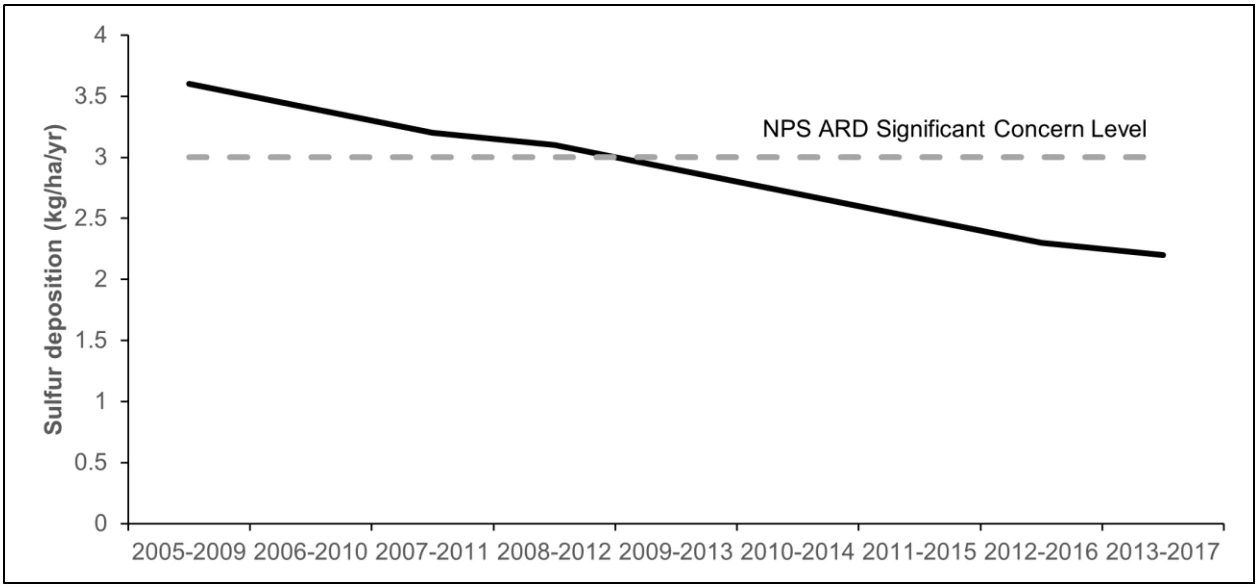

Figure 74. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at TIMU (NPS 2019a).

As with nitrogen, concentrations (mg/L) of sulfur compounds in wet deposition can also be used to evaluate overall trends in deposition. Figure 75 suggests that the sulfate concentration in the north Florida/south Georgia region has declined over time, with levels dropping below 0.4 mg/L in 2017 and 2018 (NADP 2019b).

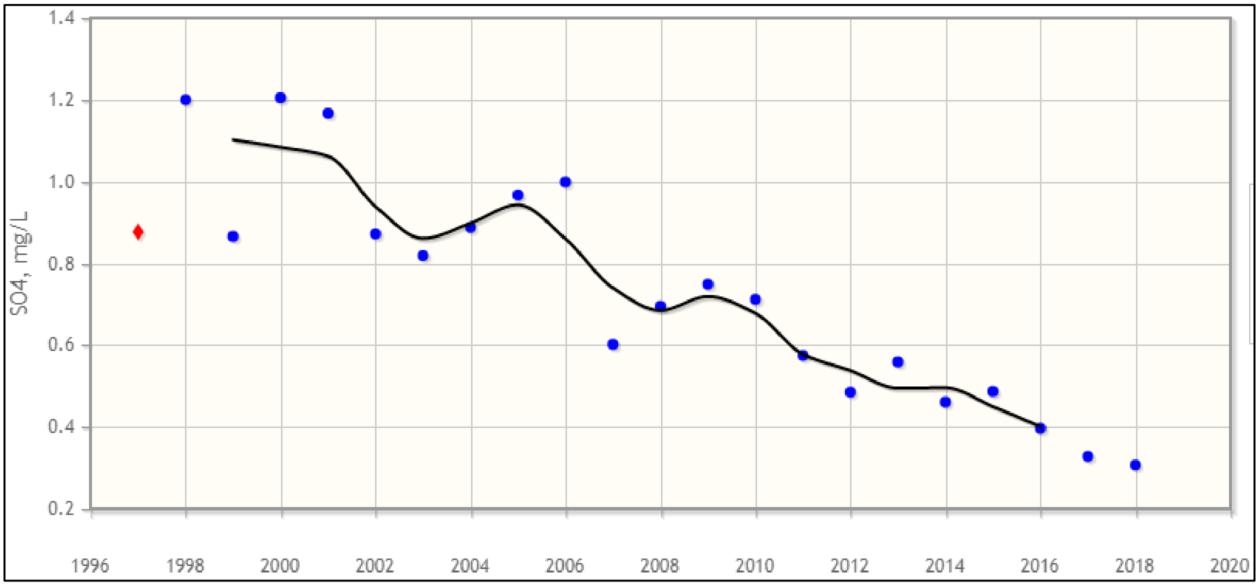

Figure 75. Annual weighted mean concentration of sulfate in wet deposition from Okefenokee NWR (NTN Site GA09) (NADP 2019b). The black line represents a smoothed 3-yr moving average.

Mercury Deposition

The 2016–2018 wet mercury deposition estimate was high for TIMU at 10.9–12.0 µg/m^2/yr (Ksienya Taylor, NPS ARD Planning and Data Analysis, written communication, 5 August 2020). At the time of this writing, predicted methylmercury concentration estimates for 2016–2018 were not yet available. However, predicted concentrations in the north Florida/south Georgia region for 2013–2015 were very high (NPS 2016a, Allen et al. 2018); it is likely that 2016–2018 estimates will also be high or very high. Therefore, the overall mercury status for TIMU is likely of significant concern (see Table 67). Confidence in this assignment is low, given a lack of park-specific contaminant data.

Based on interpolations by the MDN, mercury deposition levels in the TIMU area in 2017 were in the 14–16 µg/m^2 range (Figure 76) (NADP 2019a). Based on interpolations displayed in Figure 77, total mercury concentrations in the area were likely 8.6–8.8 ng/L (NADP 2019a).

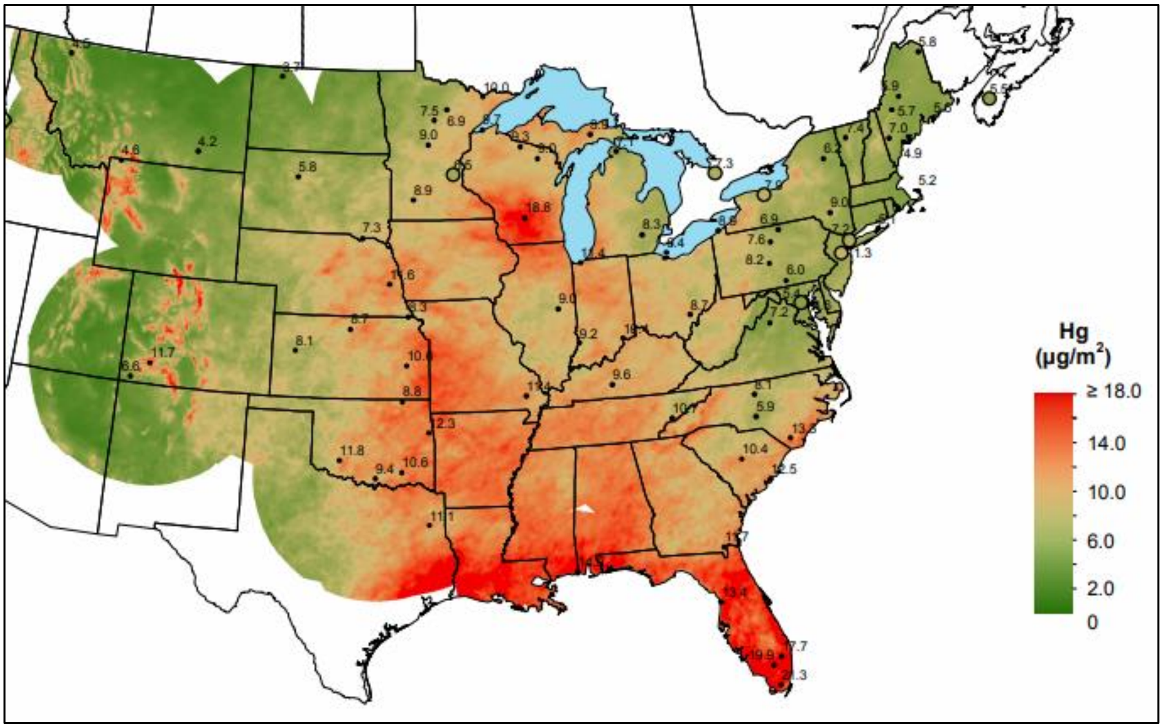

Figure 76. Total annual mercury wet deposition in 2017, based on interpolations by the MDN (NADP 2019a).

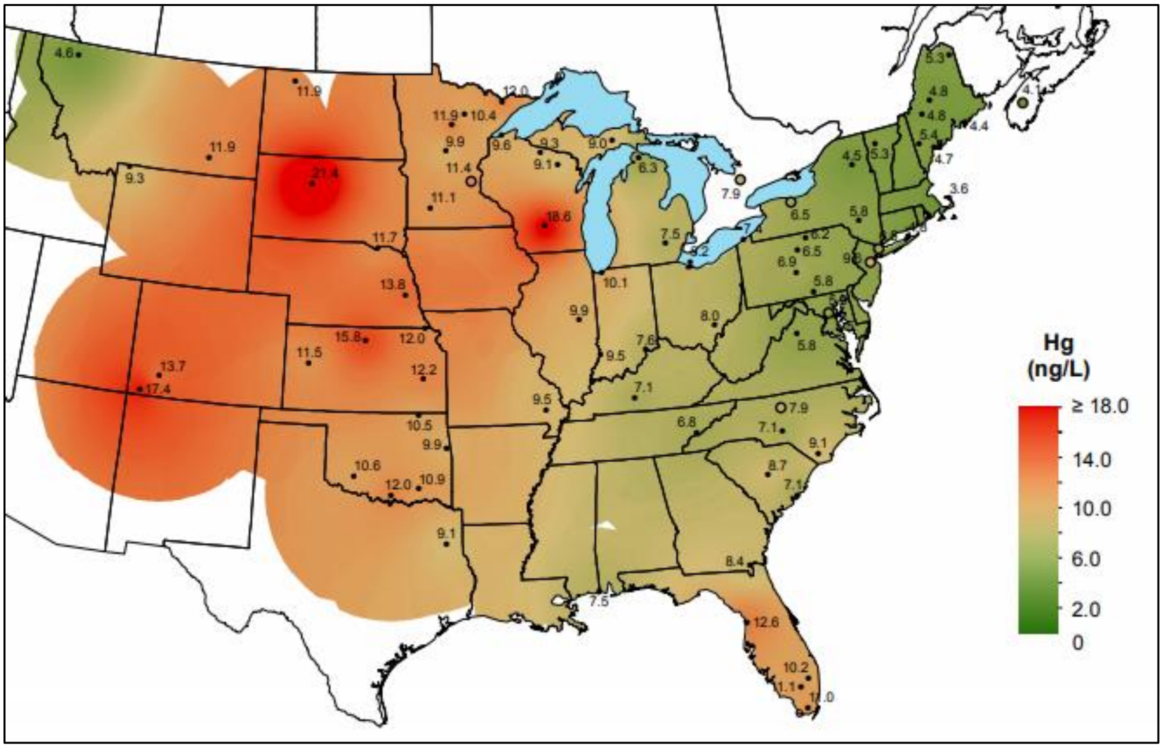

Figure 77. Total mercury concentrations in 2017, based on interpolations by the MDN (NADP 2019a).

Ozone

Historically, ozone has not been a particular concern in the TIMU region. Kohut (2004) determined that the risk of ozone exposure at the park was low, with concentrations estimated (through kriging) to exceed 80 ppb only occasionally between 1995 and 1999. However, during these same years, the estimated W126 value remained above 13 ppm-hrs and exceeded 25 ppm-hrs in 1998 (Kohut 2004).

The condition of human risk from ozone in NPS units is determined by calculating the 5-year average of the 4th-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2013). The most recent 5-year (2013–2017) estimated average for 4th-highest 8-hour ozone concentration at TIMU was 61.4 ppb (NPS 2019a). This falls within the *Moderate Concern* range. A comparison to previous estimates suggests that ozone conditions are improving over time (Figure 78).

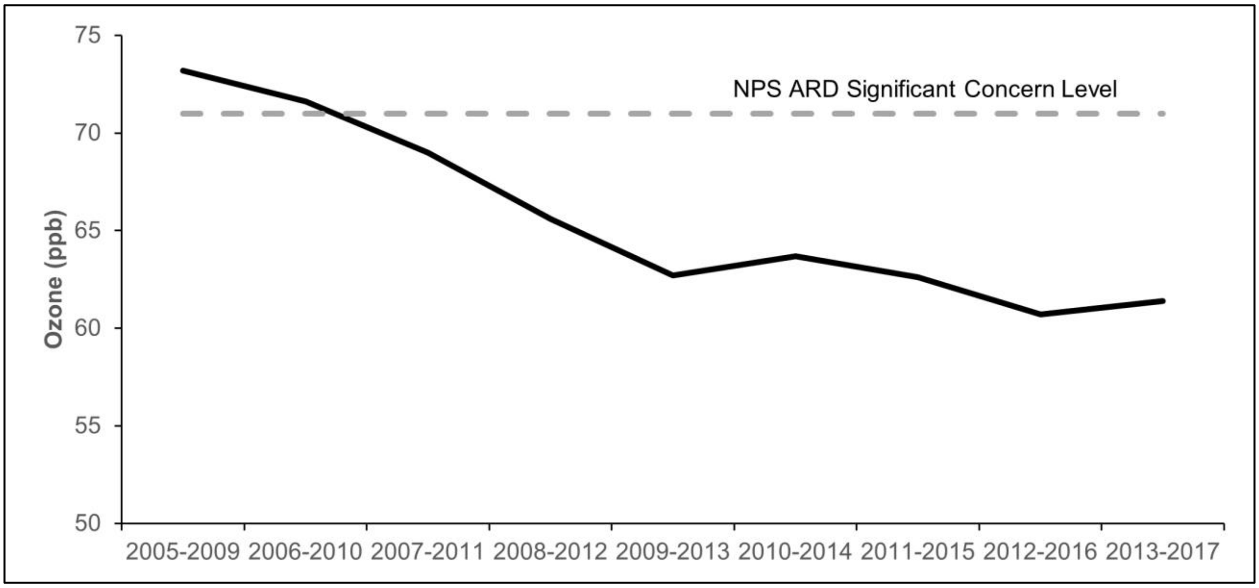

Figure 78. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for TIMU (NPS 2019a).

The apparent improvement in ozone condition is supported by data from the nearest year-round ozone monitor just west of TIMU, which show ozone concentrations fluctuating over time but with a general decreasing trend (Figure 79) (EPA 2020a).

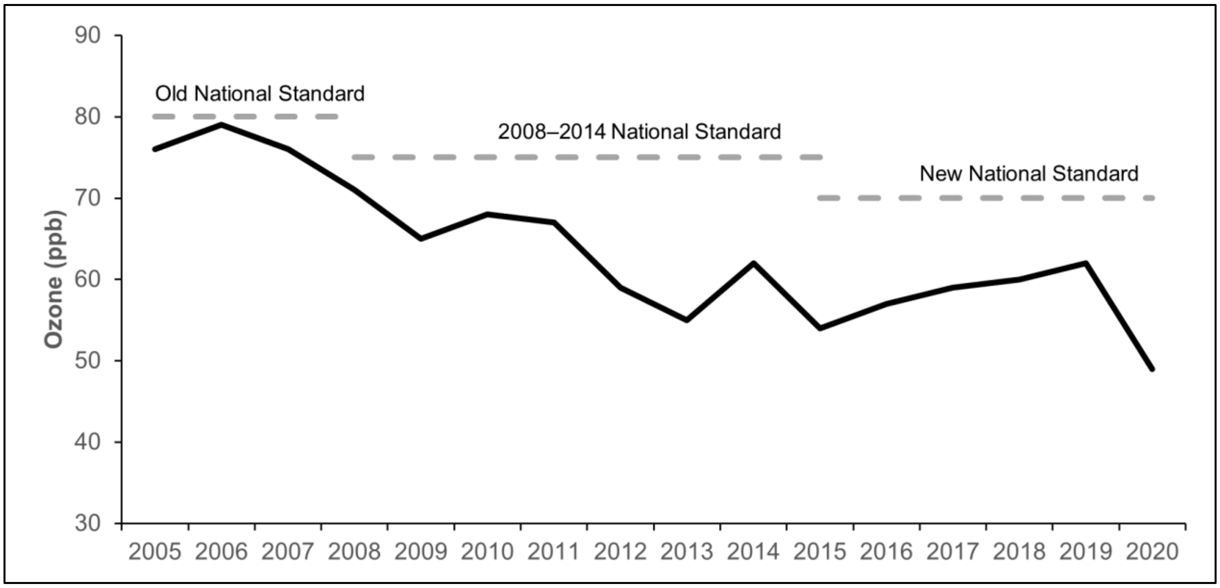

Figure 79. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Lanier Road monitoring site (Site ID: 12-031-0077) just west of TIMU (EPA 2020b).

Vegetation health risk from ground-level ozone condition is determined by estimating a 5-year average of annual maximum 3-month, 12-hour W126 values. The 2013–2017 estimated W126 metric for TIMU of 4.6 ppm-hrs falls in the *Good Condition* category (NPS 2019a). Again, a comparison to previous estimates suggests that ozone conditions improved through 2013 and have since stabilized (Figure 80).

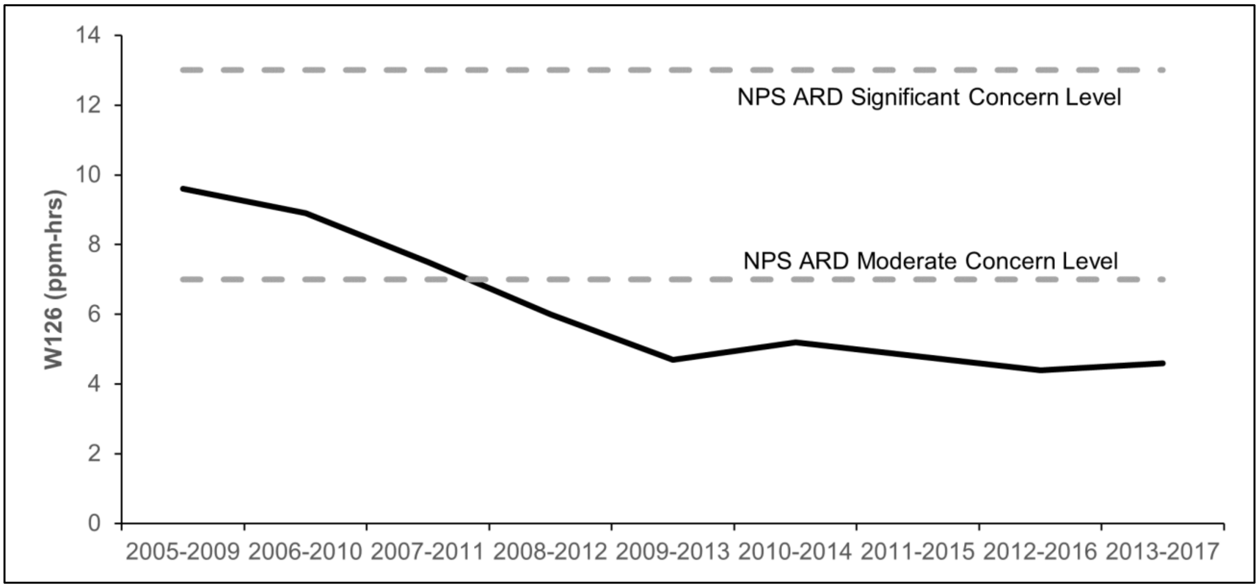

Figure 80. Estimated 5-year averages of the W126 ozone metric for TIMU (NPS 2019a).

Visibility

Five-year estimated averages of visibility on mid-range days minus natural condition visibility on mid-range days are used to estimate condition for visibility. The 2013–2017 estimated visibility on mid-range days for TIMU was 15.7 dv, or 8.0 dv above the estimated natural condition of 7.7 dv (NPS 2019a). This estimate falls at the very top of the *Moderate Concern* range.

Comparing the most recent mid-range estimate to previous NPS ARD estimates of visibility suggests that conditions may be improving at TIMU. The 5-year average has declined every year since 2009, when estimated visibility was 11.5 dv above estimated natural conditions (Figure 81).

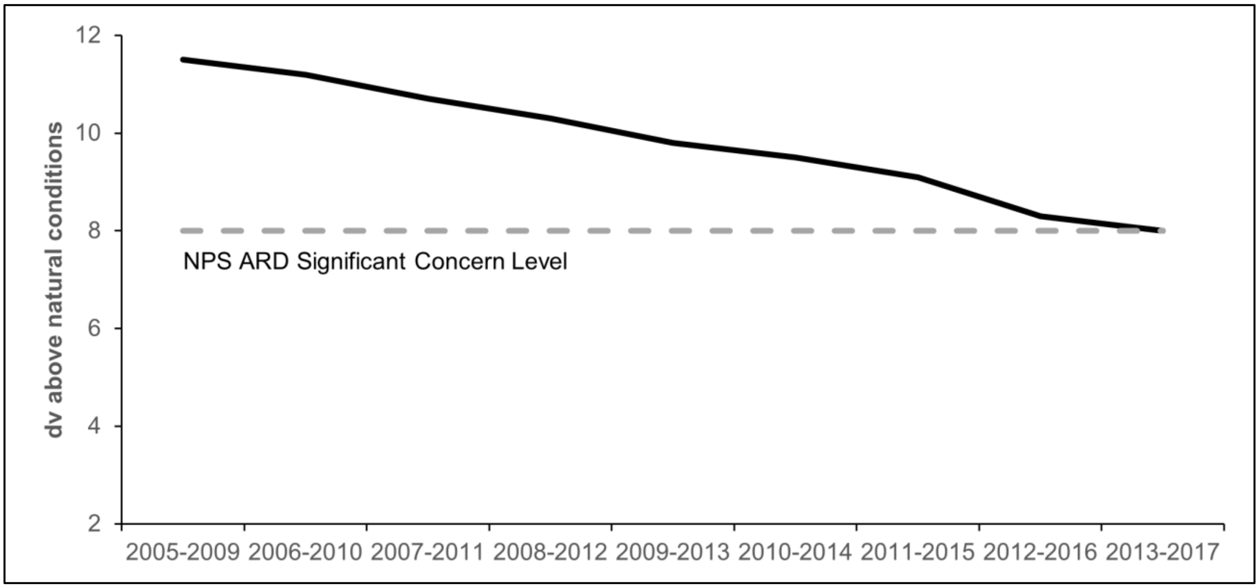

Figure 81. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at TIMU (NPS 2019a).

$PM_{2.5}$ is a major contributor to visibility impairment. Annual average 24-hour $PM_{2.5}$ concentrations are available from the Sunny Acres station just southwest of the park from 2004–2020. Annual concentrations at this station have fluctuated, but have fallen below 30 µg/m^3 in all but 2007 (Figure 82) (EPA 2020a). The EPA NAAQS for $PM_{2.5}$ uses the 3-year average 98th percentile 24-hour $PM_{2.5}$ concentration to assess human health risk. The most recent 3-year average (2017–2019) concentration for this station is 15.9 µg/m^3. This meets the EPA standard of <35 µg/m^3.

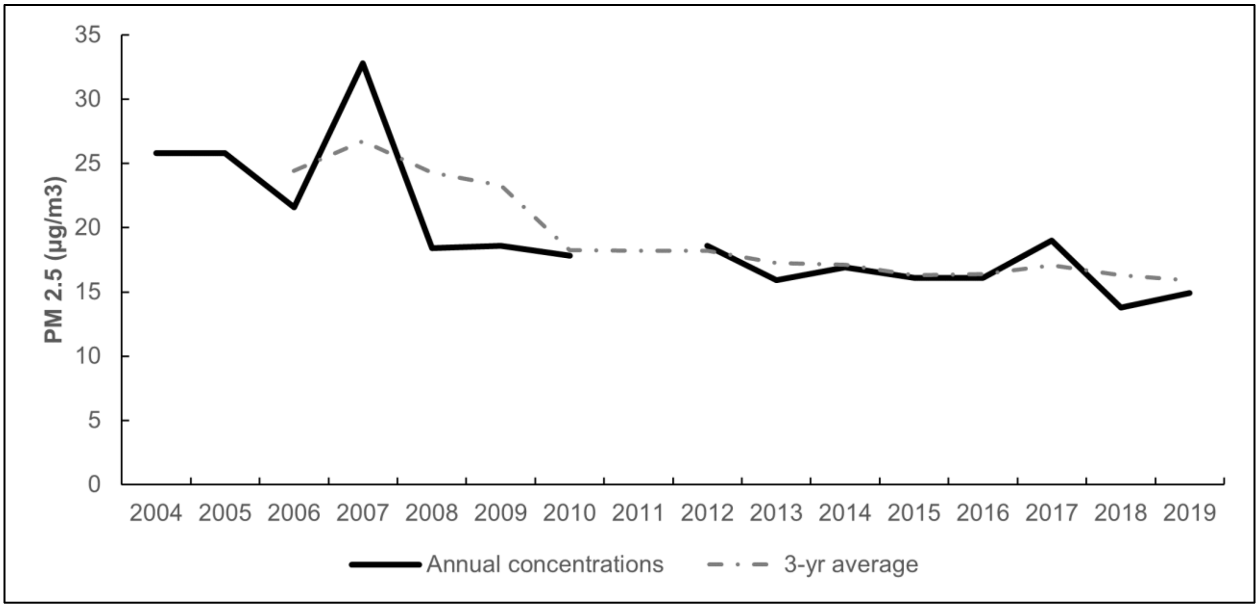

Figure 82. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) and 3-year running averages for the TIMU area (EPA 2020a). The monitoring station is located just southwest of the park in the Sunny Acres neighborhood (Site ID 12-031-0099).

Threats and Stressor Factors

Threats to TIMU's air quality include development, vehicle traffic, a local power plant, wildfires, rural trash burning, and possibly operations at Naval Station Mayport. Development and urban expansion, which typically accompany population growth, can increase emissions from gas-powered construction equipment, land clearing, and increased vehicle travel. The City of Jacksonville is currently experiencing population growth; from 2017–2018, the city experienced one of the highest overall population increases in the country (U.S. Census Bureau 2019). Since the 2010 census, Jacksonville's population has increased by nearly 11%, from approximately 822,000 to 911,500 (U.S. Census Bureau 2020).

Power plants are a major source of greenhouse gas emissions in the U.S. (EPA 2020c). The Jacksonville Electric Authority (JEA) operates a large power plant, known as the Northside Generating Station, approximately 1.4 km (0.9 mi) west of TIMU (Figure 83). According to JEA (2020), the plant utilizes a mix of natural gas, coal, fuel oil, and petroleum coke to power three large steam units and four smaller diesel-powered units. Natural gas and fuel oil are the current primary fuel sources for the larger units (JEA 2020). While considered less polluting than coal, natural gas combustion produces nitrogen oxides, carbon monoxide and carbon dioxide, VOCs, and methane (EPA 1995).

Figure 83. Locations of air quality threats and stressors relative to TIMU.

Transportation sources account for a significant portion of nitrogen oxide and VOC emissions in the U.S. and also produce some particulate pollution and sulfur dioxides (Small and Kazimi 1995). These emissions can contribute to ozone formation and impact visibility. While there are few roads within TIMU's boundaries, there is extensive motor vehicle traffic within and into and out of the City of

Jacksonville just southwest of the park (Figure 83). Jacksonville's harbor traffic and railroads may also contribute to air pollution. According to the Jacksonville Port Authority, there are 40 daily freight trains in and out of the city on three major railroads, one of which crosses through the northern portion of the park (JAXPORT 2020b). Many trains are pulled by diesel-powered locomotives, which produce exhaust that contains PM, nitrogen oxides, and carcinogens (Jaffe et al. 2014, Andersen et al. 2019). Ship traffic also produces emissions that contain PM, nitrogen oxides, sulfur oxides, and carcinogens, which can be a major contributor to air pollution over harbor areas (Sorte et al. 2020).

Naval Station Mayport, established in 1942, has become the third largest fleet concentration area in the U.S. (U.S. Navy 2020). The station has a harbor capable of accommodating 34 ships and a 2,438 m (8,000 ft) runway that can handle any aircraft operated by the Department of Defense. As with other vehicle/traffic sources, the ships and aircraft of the Naval Station may contribute to air pollution around the park.

Prescribed burning and wildfires produce air pollutants, including PM, carbon monoxide, and VOCs, which can contribute to ozone formation (Wotawa and Trainer 2000, Lee et al. 2005). Air pollution from fires typically impairs visibility and can travel long distances. For example, forest fires in Canada have been shown to impact air quality in the eastern U.S., including areas as far south as Tennessee (Wotawa and Trainer 2000, Lee et al. 2005). A large, long-lasting wildfire at Okefenokee Swamp (48 km [30 mi] northwest of TIMU) triggered air quality advisories in Jacksonville (Scanlan 2011).

Rural or backyard trash burning can emit pollutants similar to wildfires (PM, VOCs, etc.), as well as dioxins, formaldehyde, and other carcinogenic chemicals (EPA 2016f). While the burning of household/yard waste and construction material or waste is illegal in Duval County (City of Jacksonville 2020b), Jacksonville firefighters are reportedly called to illegal burns almost every week (Avanier 2019). The burning of land clearing debris from the initial clearing of vegetation from commercial properties is allowed with an open burning permit (City of Jacksonville 2020b).

Data Needs/Gaps

Monitoring air quality specifically within TIMU boundaries would provide a clearer understanding of conditions within the park. Placing monitors in different portions of the park (e.g., varying distances from Jacksonville) may provide insight into the impacts of urban development on TIMU's environmental quality.

Studies regarding the potential effects of air pollutants on park resources are also lacking. Given the concern over elevated mercury levels in the area, an in-depth assessment of mercury levels in the park's air, sediment, and organisms (e.g., plants, aquatic animals, birds) is warranted.

Overall Condition

Nitrogen Deposition

The project team assigned this measure a *Significance Level* of 3. The most recent 5-year (2013–2017) estimate for nitrogen deposition at TIMU is 2.3–2.5 kg/ha/yr (NPS 2019a), which falls in the

Moderate Concern range identified by the NPS ARD. Sullivan et al. (2011d) identified TIMU as being at high risk of nutrient enrichment from nitrogen deposition, but current levels are below the minimum ecosystem critical load for the ecoregion (Pardo et al. 2011), suggesting that sensitive vegetation elements may not currently be at risk for harmful effects. This measure is assigned a *Condition Level* of 2, indicating moderate concern.

Sulfur Deposition

Sulfur deposition was also assigned a *Significance Level* of 3. As with nitrogen, the most recent 5-year (2013–2017) estimate for sulfur wet deposition at TIMU of 2.0–2.2 kg/ha/yr (NPS 2019a) falls in the *Moderate Concern* range. Conditions appear to be improving, but this measure is assigned a *Condition Level* of 2 as well, for moderate concern.

Mercury Deposition

A *Significance Level* of 3 was assigned for mercury deposition. The 2016–2018 wet mercury deposition estimate for TIMU was in the high range (Taylor, written communication, 5 August 2020). Predicted methylmercury concentration estimates for the north Florida/south Georgia region for 2013–2015 were very high (Allen et al. 2018). Therefore, it is likely that the overall status of mercury in the area is of significant concern (*Condition Level* = 3).

Ozone

The project team also assigned this measure a *Significance Level* of 3. Ozone levels appear to have improved around TIMU over the past decade, with a most recent 5-year (2013–2017) estimate of 61.4 ppb (NPS 2019a). This also falls in the NPS ARD's *Moderate Concern* range. The 2013–2017 estimated W126 metric of 4.6 ppm-hrs, evaluating vegetation health risk, is in the *Good Condition* category (NPS 2019a). Overall, this measure is assigned a *Condition Level* of 2 for moderate concern.

Visibility

A *Significance Level* of 3 was assigned for the visibility measure. The 2013–2017 estimated visibility on mid-range days for TIMU was 8.0 dv above estimated natural conditions, or at the very top of the *Moderate Concern* category identified by the NPS ARD (NPS 2019a). Therefore, this measure is also of moderate concern and is assigned a *Condition Level* of 2.

Weighted Condition Score

The *Weighted Condition Score* for air quality at TIMU is 0.73, indicating significant concern (Table 68). Conditions for nearly all measures have improved over the past decade, resulting in an improving trend. If air quality improvements continue over the next made, this resource may drop to moderate concern.

Table 68. Current condition of air quality at TIMU.

Measures	**Significance Level**	**Condition Level**	**WCS = 0.73**
Nitrogen Deposition	3	2	–
Sulfur Deposition	3	2	–
Mercury Deposition	3	3	–
Ozone	3	2	–
Visibility	3	2	–
Overall	**–**	**–**	⬆

4.8.6 Sources of Expertise

- Denesia Cheek, NPS Regional Air Quality Coordinator
- Ksienya Taylor, NPS ARD Planning and Data Analysis

5. Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 69 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 69. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Upland Hardwood Hammocks	• Additional information on the presence and abundance of invasive plant species in these communities
	• Further research to better understand LBD and its impacts on Florida's vegetation communities
Salt Marshes	• Additional monitoring to assess changes in the sediment elevation of TIMU's salt marshes • Further study of river and creek hydrology within the park to better understand the processes that maintain TIMU's salt marshes
Herpetofauna	• Analyze previous SECN amphibian monitoring data and continue monitoring protocol
	• A park-wide reptile survey to better understand the current condition and update the park's NPSpecies list
	• Study recruitment rates of young and movement of gopher tortoises between the populations within TIMU, as well as with populations in adjacent areas
	• Continued monitoring of TIMU's gopher tortoises, particularly the high-density population at American Beach and older populations at Cedar Point and Kingsley Plantation
	• Long-term monitoring of diamondback terrapins to identify and address any population declines, potentially including locating additional nesting beaches within TIMU
	• Further study of predator impacts on diamondback terrapins, as well as effects of crabbing and potential climate change impacts
Birds	• Continuation of SECN landbird monitoring efforts to better characterize species richness, and to analyze any trends in species presence or abundance • Data collection for wading bird nesting numbers and fledging success

Table 69 (continued). Identified data gaps or needs for the featured components.

Component	**Data Gaps/Needs**
Saltwater Fish Community	• Park-wide survey or sampling, followed by regular monitoring (e.g., every 2–3 years) to identify any changes within the community
Oysters	• Regular mapping of oyster beds every 5–7 years, differentiating between live and dead reefs to track dead margins and mortality over time
	• Standardized, long-term monitoring across several estuaries to allow comparisons between populations; include oyster size structure, shell height, reef height, and oyster density
	• Repeat studies of recruitment and survival rates at TIMU and other parks to determine whether rates and patterns vary over time • Studies of species interactions involving oysters, including how these will be impacted by climate change in Northeast Florida • Genetic analysis to clarify the scale of larval export and genetic isolation among TIMU's reefs
Water Quality	• More frequent and focused sampling of water clarity and chlorophyll a to identify the locations and magnitude of increases, how they are impacting overall water quality or other park resources, and what the cause(s) may be
	• Additional monitoring for indicator bacteria, focused on areas within TIMU where septic contamination is suspected
	• The development of baselines or reference levels for salinity that are location or area-specific within the park to help detect changes in salinity over time
Air Quality	• Monitoring specifically within TIMU boundaries to provide a clearer understanding of conditions within the park and insight into the impacts of urban development on TIMU's environmental quality
	• Research into the potential effects of air pollutants (e.g., mercury, nutrients) on park resources

Many of the park's data gaps involve the need for new or continued monitoring of selected resources in order to accumulate data to assess and evaluate the condition and trends over time. This is evident from the high number of measures that could not be assigned a current condition due to either recent data gaps or a lack of regular monitoring (e.g., saltwater fish, herpetofauna, oysters). Several components would benefit from further research into how park resources are impacted by environmental changes and human activity, particularly given TIMU's proximity to human development.

5.2 Component Condition Designations

Table 70 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics and examples of how symbols are applied are located in Table 71 and Table 72). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 70) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

For featured components with available data and fewer data gaps, assigned conditions varied. Three components are considered to be of low concern: upland hardwood hammocks, salt marshes, and water quality (Table 70). Air quality is the only component of high concern, primarily due to emissions from surrounding developments (e.g., power plants, transportation, industry), particularly the City of Jacksonville. Trends could only be assigned for two components (salt marshes and air quality); the trend for salt marshes was considered to be stable, while air quality was determined to be improving.

Table 70. Summary of current condition and condition trend for featured NRCA components.

Category	Component	WCS	Condition
Biological Composition – *Ecological communities*	Upland Hardwood Hammocks	0.29	🟢
	Salt Marshes	0.33	🟢⬌
Biological Composition – *Wildlife*	Herpetofauna	N/A	◌
	Birds	N/A	◌
	Saltwater Fish Community	N/A	◌
	Oysters	N/A	◌
Environmental Quality	Water Quality	0.33	🟢
	Air Quality	0.73	🔴⬆

Table 71. Description of symbology used for individual component assessments.

Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
🟢	Resource is in Good Condition	⇧	Condition is Improving	◯	High
🟡	Resource warrants Moderate Concern	⇔	Condition is Unchanging	○	Medium
🔴	Resource warrants Significant Concern	⇩	Condition is Deteriorating	◌	Low

Table 72. Example indicator symbols and descriptions of how to interpret them in WCS tables.

Symbol Example	Verbal Description
🟢⇧	Resource is in good condition; its condition is improving; high confidence in the assessment.
🟡⇔	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
🔴	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
◌	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

5.3 Park-wide Condition Observations

Despite the variety of ecosystems within TIMU's boundaries, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park).

5.3.1 Vegetation Communities

The native vegetation communities of TIMU are vital resources for the park, providing habitat for wildlife and performing critical ecological functions, while attracting many visitors to the area. The two vegetation communities selected for inclusion in this NRCA, upland hardwood hammocks and salt marshes, are currently in good condition, although salt marshes were at the edge of the good condition range, and any small decline in conditions could shift them into the moderate concern range. TIMU’s salt marshes perform critical ecosystem functions for the region and provide vital wildlife habitat but are threatened by sea level rise, storm events, mangrove invasion, and human modification (e.g., dredging, shoreline hardening, hydrologic alterations) (Rodriguez et al. 2016, Dix et al. 2017, UNF & JU 2019).

The park’s upland hardwood hammocks also provide food and shelter for wildlife, particularly for migrating birds. Two key plant species of hammock communities are currently threatened by disease; redbay has been reduced by laurel wilt disease (Fraedrich et al. 2008) and cabbage palmetto are facing lethal bronzing disease (Bahder and Helmick 2019). These diseases, as well as invasion by non-native plant species, could alter the species composition of TIMU’s hardwood hammocks.

5.3.2 Other Biotics

Animals featured as NRCA components were herpetofauna, birds, saltwater fish, and oysters. Due to a lack of recent or consistent survey and monitoring data, current conditions could not be assigned for any of these components. Birds and amphibians, both of which can serve as indicators of ecosystem health or environmental degradation, are currently being monitored by the SECN but data analysis has not been completed to allow for condition assessment. These species are threatened by climate change (e.g., shifts in temperature and moisture regimes, as well as phenology) and habitat loss/fragmentation related to human development (Cushman 2006, Mitchell and Janzen 2010, NABCI 2010).

Fish are critical links in the aquatic food web, with some serving as prey and others as predators. Information on TIMU’s fish communities is limited, particularly in the upper reaches of tidal creeks and marshes (Dennis et al. 2001b). Since fish may serve as indicators of environmental degradation (Fausch et al. 1990), a park-wide survey followed by regular monitoring could help detect threats to the broader ecosystem.

Oysters provide important ecosystem services in estuarine communities, such as improving water quality, protecting shorelines from erosion, and providing wildlife habitat (Radabaugh et al. 2019a). Florida’s oyster beds are threatened by water quality changes, climate change/sea level rise, and boat wakes. While some studies of TIMU’s oysters are underway or have been recently completed (Randall et al. 2016, Smith 2019), regular mapping and monitoring is recommended to better understand the condition of and any changes in park oyster beds (Radabaugh et al. 2019b).

5.3.3 Environmental Quality

Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be affected substantially by the condition of air and water quality. Air quality in the TIMU area is in poor condition but showing an improving trend. Mercury deposition estimates were of the highest concern, with nitrogen and sulfur deposition, ozone levels, and visibility of moderate concern. However, these assessments are based on interpolations from regional monitoring stations, as no air quality monitoring occurs within TIMU’s boundaries. Poor air quality in the region is primarily due to emissions from surrounding developments (e.g., power plants, transportation, industry), which are outside the control of park management.

The park’s water quality is currently in good condition, but with recent declines in water clarity (Starkey et al. 2019). Chlorophyll a and dissolved inorganic phosphorus levels are also of concern at some locations. Sites in poor condition were primarily further upstream in the park’s waterways, such as the Nassau River (Starkey et al. 2019). Elevated nutrient levels (i.e., nitrogen and phosphorus) in these upper reaches, which can increase chlorophyll a and decrease water clarity, may come from runoff or seepage of septic systems, agricultural/ livestock waste, fertilizer use, or wastewater treatment plants (Anderson 2005, UNF & JU 2019). Additionally, the increase in impervious surfaces associated with development (e.g., roads, driveways, parking lots) has intensified storm runoff, which often carries contaminants and sediment from developed areas (Anderson 2005, Shehane et al. 2005).

5.3.4 Park-wide Threats and Stressors

Several threats and stressors influence the condition of multiple resources throughout TIMU, largely related to the proximity of human development. Emissions from industry and vehicles contribute to air and water pollution, which threaten sensitive plant and animal species, such as amphibians and some fish and aquatic invertebrates (Egea-Serrano et al. 2012, Sullivan 2016). Development and the human activities associated with it contribute to habitat loss, fragmentation, and degradation (Anderson et al. 2005, Cushman 2006, FWCC 2012). Specific human activity-related threats include traffic strikes of wildlife, invasive species introductions, dredging for channel maintenance, and erosion from boat wakes (Dodd Jr. et al. 2004, Taylor and Irwin 2004, Dix et al. 2017).

Climate change and the related SLR are also major concerns for many park resources. SLR is expected to accelerate over the next century with an overall rise between 0.28–0.98 m (0.9–3.2 ft) by 2100 (IPCC 2013). While salt marshes can naturally gain elevation through accretion, if the rate of accretion does not keep up with accelerating SLR, tidal salt marshes may become permanently inundated, killing off the wetland vegetation (Hagen et al. 2013, Linhoss et al. 2015). Climate change and SLR are likely to impact water quality (e.g., temperatures, dissolved oxygen, salinity), which will, in turn, influence aquatic wildlife (Radabaugh et al. 2019a, UNF & JU 2019). Because the oxygen-holding capacity of water declines as water temperature increases, fish and aquatic invertebrates can “suffocate” as dissolved oxygen drops in warming waters (USGS 2016b). At high temperatures and/or salinity levels, oysters and other invertebrates are increasingly vulnerable to disease, parasites, and marine predators, such as carnivorous snails (Durako et al. 1988, Marcogliese 2008, Radabaugh et al. 2019b). Impacts to fish and aquatic invertebrate communities will then influence any terrestrial wildlife that rely on them as food sources, as well as human recreation (e.g., fishing, wildlife watching).

5.3.5 Overall Conclusions

While TIMU is largely dominated by estuarine systems, the park includes a range of diverse ecological communities, which support a variety of wildlife, including rare, threatened, and keystone species. This wealth of natural resources drew indigenous people and early European settlers to the region, creating the rich historical and cultural landscapes also protected by the park. These park resources offer valuable educational and recreational opportunities while providing critical ecosystem services for the region.

This NRCA serves as a review and summary of available data and literature for featured natural resources in the park. The information presented here may serve as a baseline against which any changes in condition of components in the future may be compared. Current condition could not be determined for half of the selected components due to data gaps; some of these needs are being addressed by SECN monitoring programs, which will provide valuable information for condition assessment in the near future. For resources where condition could be assessed, three were in good condition or of low concern and one (air quality) was of significant concern but with an improving trend. Understanding the condition of these resources can help managers prioritize management objectives and better focus conservation strategies to maintain the health and integrity of these ecosystems.

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Appendix A. Mammal species confirmed at TIMU

Table A-1. Mammal species confirmed at TIMU (NPS 2020b).

Scientific name	**Common name**	**Abundance**
Odocoileus virginianus	white-tailed deer	Common
Sus scrofa	feral pig	Abundant
Canis latrans	coyote	Uncommon
Urocyon cinereoargenteus	common gray fox	Common
Vulpes	red fox	Unknown
Felis catus	feral cat	Common
Lynx rufus	bobcat	Uncommon
Lontra canadensis	North American river otter	Uncommon
Mustela vison	Florida mink	Uncommon
Procyon lotor	common raccoon	Common
Tursiops truncatus	bottlenose dolphin	Common
Dasypus novemcinctus	nine-banded armadillo	Abundant
Didelphis virginiana	Virginia opossum	Common
Sylvilagus palustris	marsh rabbit	Common
Castor canadensis	American beaver	Uncommon
Neotoma floridana	eastern woodrat	Uncommon
Ochrotomys nuttalli	golden mouse	Uncommon
Oryzomys palustris	marsh rice rat	Unknown
Sigmodon hispidus	hispid cotton rat	Common
Sciurus carolinensis	eastern gray squirrel	Common
Trichechus manatus latirostris	Florida manatee	Common
Cryptotis parva	least shrew	Uncommon
Sorex longirostris	southeastern shrew	Uncommon
Scalopus aquaticus	eastern mole	Common

Appendix B. Marine invertebrates considered "probably present" at TIMU

Tabe B-1. Marine invertebrates considered "probably present" at TIMU (NPS 2020d).

Order/Group	Scientific name	Common name
Crustaceans	*Alpheus estuariensis*	snapping shrimp
	Procambarus pictus	spotted royal crayfish
	Clibanarius vittatus	thinstripe hermit
	Tozeuma carolinense	arrow shrimp
	Uca minax	red-joint fiddler
	Uca pugilator	Atlantic sand fiddler
	Palaemon floridanus	Florida grass shrimp
	Palaemonetes intermedius	brackish grass shrimp
	Palaemonetes pugio	daggerblade grass shrimp
	Palaemonetes vulgaris	common American prawn
	Farfantepenaeus aztecus	brown shrimp
	Farfantepenaeus duorarum	northern pink shrimp
	Litopenaeus setiferus	northern white shrimp
	Petrolisthes armatus	green porcelain crab
	Callinectes sapidus	blue crab
	Callinectes similis	lesser blue crab
	Acetes americanus carolinae	unnamed shrimp
	Mysidopsis bigelowi	opossum shrimp
	Neomysis americana	opossum shrimp
	Conopea galeata	commensal barnacle
	Squilla empusa	unnamed mantis shrimp
Gastropods (slugs/snails)	*Nassarius obsoletus*	mud dog whelk
	Neosimnia implicata	single-tooth simnia

Appendix C. Dragonfly and damselfly species documented at TIMU in summer 2014

Table C-1. Dragonfly and damselfly species documented at TIMU in summer 2014 (D’Amato 2015). For abundance, scarce = less than 5 sightings, rare = present on <25% of visits, uncommon = present on 25–49% of visits, common = present on 50–74% of visits, abundant = present on >75% of visits.

Insect Type	Scientific name	Common name	# of sites (out of 5)	Abundance
Dragonflies	*Tachopteryx thoreyi*	gray petaltail	1	rare
	Anax junius	common green darner	5	common
	Anax longipes	comet darner	2	rare
	Coryphaeschna ingens	regal darner	1	scarce
	Gynacantha nervosa	twilight darner	2	scarce
	Epiaeschna heros	swamp darner	1	scarce
	Libellula needhami	Needham’s skimmer	5	common
	Libellula vibrans	great blue skimmer	5	abundant
	Libellula axilena	bar-winged skimmer	2	scarce
	Erythrodiplax berenice	seaside dragonlet	1	common
	Pachydiplax longipennis	blue dasher	5	abundant
	Erythemis simplicicollis	eastern pondhawk	5	abundant
	Pantala flavescens	wandering glider	2	scarce
	Brachmesia gravida	four-spotted pennant	1	rare
	Tramea lacerata	black saddlebags	5	common/abundant
	Tramea carolina	Carolina saddlebags	5	common/abundant
	Orthemis ferruginea	roseate skimmer	3	uncommon
Damselflies	*Argia fumipennis atra*	variable dancer	2	abundant/rare
	Ischnura posita	fragile forktail	1	abundant
	Telebasis byersi	duckweed firetail	1	abundant
	Enallagma civile	familiar bluet	2	common

Appendix D. Bee species confirmed at TIMU during 2012–2013 sampling

Table D-1. Bee species confirmed at TIMU during 2012–2013 sampling (NPS 2015a).

Family	Scientific name	Notes
Family Halictidae (sweat bees)	*Agapostemon splendens*	sand-associated species
	Augochlorella aurata	found at forested and dune sites
	Epeolus carolinus	rare; kleptoparasitic larva; found only at vegetated dune site
	Halictus poeyi	found at forested and dune sites
	Lasioglossum apopkense	–
	Lasioglossum batya	–
	Lasioglossum ellisiae	–
	Lasioglossum nymphale	sand-associated species; very abundant
	Lasioglossum pectoral	–
	Lasioglossum puteulanum	–
	Lasioglossum raleighense	–
	Lasioglossum reticulatum	sand-associated species; very abundant
	Lasioglossum tarponense	sand-associated species
Family Megachilidae (leafcutter bees)	*Megachile georgica*	–
	Megachile mendica	–
	Megachile parallela	–
	Megachile pruina	sand-associated species; rare
	Megachile pseudobrevis	–
	Megachile texana	–
Family Apidae (honey, bumble, and stingless bees)	*Melissodes communis*	found at forested and dune sites
	Melissodes comptoides	found at forested and dune sites
Family Andrenidae (mining bees)	*Perdita bishoppi*	sand-associated species; found only at vegetated dune site

Appendix E. Butterflies and moths observed at TIMU during 2006

Table E-1. Butterflies and moths observed at TIMU during 2006 (Kingsley Bird Club 2007).

Insect Type	Scientific name	Common name	Month first observed
Butterflies	*Papilio glaucus*	eastern tiger swallowtail	March
	Papilio cresphontes	giant swallowtail	March
	Papilio palamedes	Palamedes swallowtail	March
	Papilio troilus	spicebush swallowtail	April
	Ascia monuste	great southern white	March
	Colias philodice	clouded sulphur	August
	Colias eurytheme	orange sulphur	September
	Phoebis sennae	cloudless sulphur	March
	Strymon melinus	gray hairstreak	July
	Parrhasius m-album	white M hairstreak	May
	Satyrium favonius	“southern” oak hairstreak	–
	Calycopis cecrops	red-banded hairstreak	–
	Atlides halesus	great purple hairstreak	–
	Brephidium exilis isophthalma	eastern pygmy-blue	April
	Heliconius charithonia	zebra (heliconian)	March
	Agraulis vanillae	gulf fritillary	March
	Phyciodes phaon	phaon crescent	March
	Polygonia interrogationis	question mark	April
	Vanessa virginiensis	American lady	April
	Vanessa atalanta	red admiral	April
	Junonia coenia	common buckeye	March
	Anartia jatrophae	white peacock	September
	Limenitis arthemis astyanax	red-spotted purple	September
	Limenitis archippus	viceroy	April
	Asterocampa clyton	tawny emperor	May
	Danaus plexippus	monarch	March
	Megisto cymela	little wood-satyr	April
	Hermeuptychia sosybius	Carolina satyr	April
	Epargyreus clarus	silver-spotted skipper	March
	Urbanus proteus	long-tailed skipper	March
	Erynnis horatius	Horace’s duskywing	May
	Erynnis zarucco	Zarucco duskywing	March

Table E-1 (continued). Butterflies and moths observed at TIMU during 2006 (Kingsley Bird Club 2007).

Insect Type	Scientific name	Common name	Month first observed
Butterflies (continued)	*Pyrgus communis*	common checkered-skipper	August
	Pyrgus oileus	tropical checkered-skipper	August
	Hylephila phyleus	fiery skipper	May
	Polites vibex	whirlabout	April
	Wallengrenia otho	southern broken-dash	April
	Lerodea eufala	Eufala skipper	May
	Lerema accius	clouded skipper	April
	Panoquina panoquin	salt marsh skipper	March
Moths	*Hypercompe scribonia*	giant leopard moth	March
	Amphion floridensis	Nessus sphinx	April
	Malacosoma americanum	eastern tent caterpillar moth	April
	Antheraea polyphemus	polyphemus moth	July
	Actias luna	luna moth	September
	Syntomeida epilais	polka dot wasp moth	September

Appendix F. Location of islands surveyed

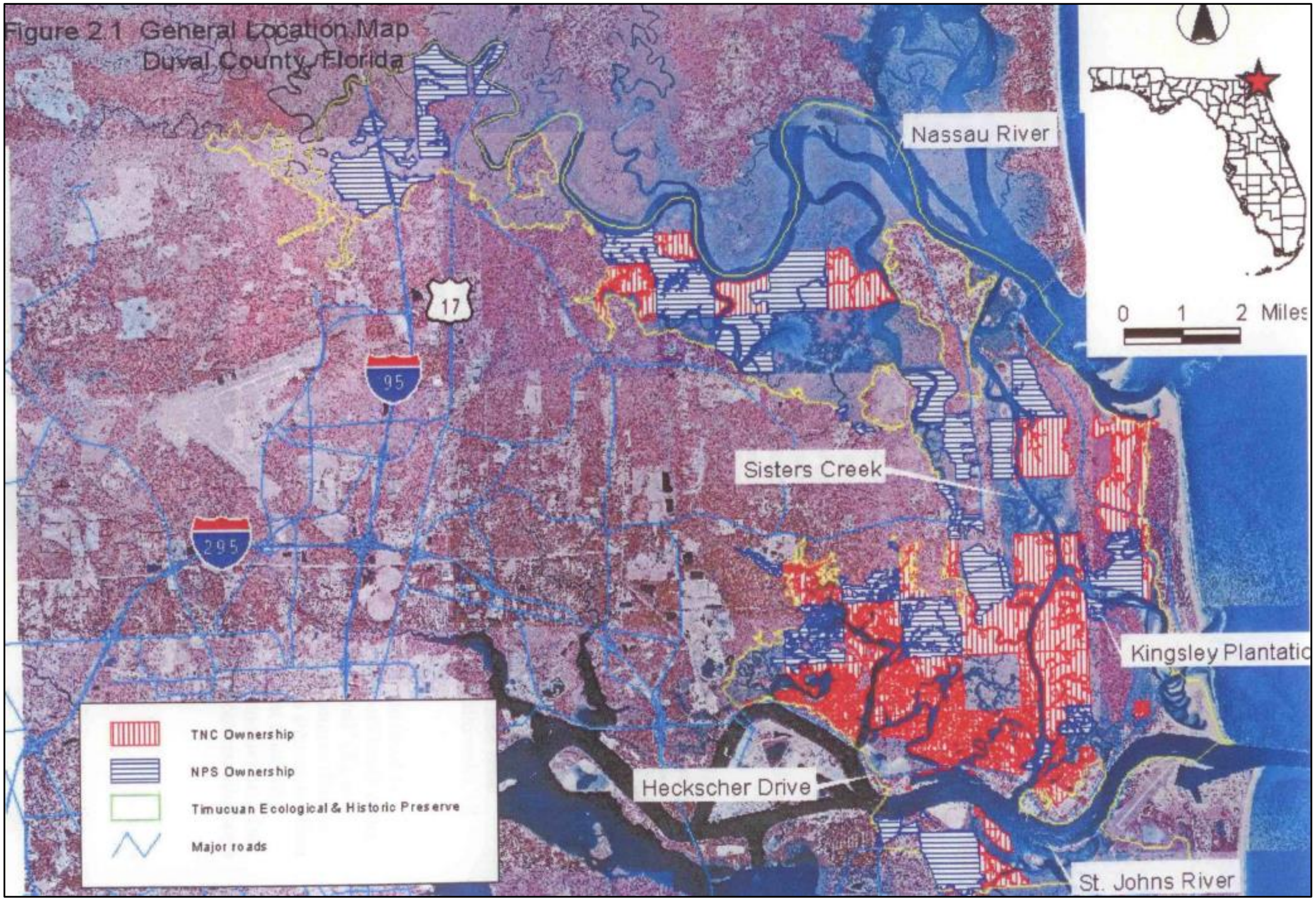

Figure F-1. Location of islands surveyed by McClung (2004). Red patterned areas were owned by TNC and blue areas were owned by NPS at the time (reproduced from McClung 2004). SomeTNC properties have since been transferred to NPS ownership (Steven Kidd, written comm., Nov. 2020).

Appendix G. Plant species documented in TIMU's hardwood hammock communities

Table G-1. Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Acer rubrum	red maple	–	–	–	–	x
Agarista populifolia	Florida hobblebush	–	–	–	–	x
Albizia julibrissin [a]	mimosa	–	x	–	–	–
Amorpha fruticosa	false indigo bush	–	–	–	x	–
Ampelopsis arborea	peppervine	x	–	–	–	–
Amphicarpaea bracteata	American hogpeanut	–	–	x	–	–
Andropogon glomeratus	bushy bluestem	–	x	–	–	–
Andropogon virginicus	broomsedge bluestem	–	x	–	–	–
Aralia spinosa	devil's walkingstick	–	x	x	–	–
Arisaema dracontium	green dragon	–	–	–	–	x
Aristida stricta	pineland threeawn; wiregrass	–	x	–	–	–
Aristolochia serpentaria	Virginia snakeroot	–	–	x	–	x
Asclepias tomentosa	tuba milkweed	–	–	x	–	–
Asimina parviflora	smallflower pawpaw	–	–	x	–	x
Asplenium platyneuron	ebony spleenwort	–	–	–	–	x
Baccharis halimifolia	eastern baccharis	–	x	–	x	–
Bacopa monnieri	herb-of-grace	–	–	x	–	–
Bidens bipinnata	Spanish needles	–	–	x	–	x
Bidens pilosa	hairy beggarticks	–	–	x	–	–
Bignonia capreolata	crossvine	x	–	x	x	x
Borrichia frutescens	bushy seaside tansy	–	–	–	x	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Bromus catharticus [a]	rescuegrass	–	–	x	–	–
Callicarpa americana	American beautyberry	–	x	x	x	x
Campsis radicans	trumpet creeper	–	–	–	x	–
Cardamine hirsuta [a]	hairy bittercress	–	–	x	–	–
Carex sp.	sedge	–	x	–	–	x
Carphephorus paniculatus	hairy chaffhead	–	x	–	–	–
Carpinus caroliniana	American hornbeam	–	x	–	–	x
Carya cordiformis	bitternut hickory	–	–	–	–	x
Carya glabra	pignut hickory	x	x	x	x	x
Castanea pumila	chinkapin	–	–	–	–	x
Celtis laevigata	sugar hackberry	–	x	–	x	x
Centrosema virginianum	spurred butterfly pea	–	x	–	–	–
Ceratiola ericoides	sand heath	–	–	–	–	x
Chasmanthium laxum var. *sessiliflorum*	longleaf woodoats	x	–	x	x	x
Citrus sp.	citrus	–	–	–	–	x
Citrus × *aurantium* [a]	sour orange	–	–	x	–	–
Clematis catesbyana	satincurls	–	–	–	–	x
Cnidoscolus urens var. *stimulosus*	finger rot	–	–	–	x	x
Cocculus carolinus	Carolina coralbead	–	–	x	–	–
Commelina sp.	dayflower	–	–	–	–	x
Commelina caroliniana [a]	Carolina dayflower	–	–	x	–	–
Conoclinium coelestinum	blue mistflower	–	–	x	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Conyza canadensis var. *canadensis*	Canadian horseweed	–	–	x	–	–
Coreopsis gladiata	coastal plain tickseed	–	x	–	–	–
Cornus asperifolia	toughleaf dogwood	–	–	–	–	x
Cornus foemina	swamp dogwood	x	–	–	x	–
Crataegus uniflora	dwarf hawthorn	–	x	–	–	–
Cyperus esculentus [a]	yellow nutgrass	–	–	x	–	–
Cyperus odoratus	fragrant flatsedge	–	–	x	–	–
Cyperus retrorsus	pine barren flatsedge	–	x	–	–	–
Desmodium glabellum	Dillenius' ticktrefoil	–	–	x	–	–
Dichanthelium sp.	witchgrass	–	x	–	–	x
Dichanthelium commutatum	variable panicgrass	–	–	x	–	x
Diospyros virginiana	common persimmon	–	x	–	x	–
Eclipta prostrata	false daisy	–	–	x	–	–
Elephantopus nudatus	smooth elephantsfoot	–	–	x	–	x
Erechtites hieraciifolius	American burnweed	–	–	–	–	x
Erythrina herbacea	eastern coralbean	–	x	–	x	x
Euonymus americanus	strawberry bush	–	–	x	–	x
Euphorbia cyathophora	fire on the mountain	–	–	x	–	–
Euthamia graminifolia	flat-top goldentop	–	x	–	–	–
Fatoua villosa [a]	hairy crabweed	–	–	x	–	–
Fimbristylis sp.	fimbristylis	–	x	–	–	–
Forestiera segregata	Florida swampprivet	–	x	–	–	–
Fraxinus americana	white ash	–	–	–	–	x

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Galactia elliottii	Elliott's milkpea	–	–	x	x	x
Galium circaezans	licorice bedstraw	–	–	–	–	x
Galium hispidulum	coastal bedstraw	–	–	x	–	–
Gamochaeta pensylvanica	Pennsylvania everlasting	–	–	x	–	–
Gaylussacia dumosa	dwarf huckleberry	–	–	–	x	–
Gaylussacia nana	confederate huckleberry	–	–	–	–	x
Gelsemium sempervirens	evening trumpetflower	–	–	–	–	x
Gonolobus suberosus var. *suberosus*	angularfruit milkvine	–	x	–	–	–
Hamamelis virginiana	American witchhazel	–	–	x	–	x
Hydrocotyle bonariensis	largeleaf pennywort	–	x	–	–	–
Ilex ambigua	Carolina holly	–	–	x	–	x
Ilex cassine	dahoon	–	x	–	–	–
Ilex glabra	inkberry	–	–	x	–	–
Ilex opaca	American holly	–	x	–	x	x
Ilex vomitoria	yaupon	x	x	x	x	x
Ipomoea sp.	morning-glory	–	–	–	x	x
Ipomoea cordatotriloba	tievine	–	–	x	–	–
Ipomoea pandurata	man-of-the-earth	–	–	x	–	–
Iva sp.	marshelder	–	x	–	x	–
Juncus roemerianus	needlegrass rush	–	x	–	–	–
Juniperus virginiana var. *silicicola*	southern redcedar	x	x	–	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Juniperus virginiana (may include *J. virginiana* var. *silicola*)	eastern redcedar	–	–	x	x	x
Lantana camara [a]	lantana	–	x	–	–	–
Licania michauxii	gopher apple	–	–	–	–	x
Liquidambar styraciflua	sweetgum	x	x	–	x	x
Liriope spicata [a]	creeping liriope	–	–	x	–	–
Lonicera japonica [a]	Japanese honeysuckle	–	x	–	–	–
Lonicera sempervirens	trumpet honeysuckle	–	–	–	–	x
Ludwigia peruviana [a]	Peruvian primrosewillow	–	–	x	–	–
Lygodium japonicum [a]	Japanese climbing fern	–	–	x	–	–
Lyonia ferruginea	rusty staggerbush	–	x	–	x	x
Lyonia lucida	fetterbush lyonia	–	–	–	–	x
Lyonia mariana	Piedmont staggerbush	–	–	x	–	–
Magnolia grandiflora	southern magnolia	x	x	x	–	x
Matelea sp.	milkvine	–	–	–	x	x
Melanthera nivea	snow squarestem	–	–	x	–	–
Melothria pendula	Guadeloupe cucumber	–	–	x	–	x
Mikania scandens	climbing hempvine	–	–	x	x	x
Mitchella repens	partridgeberry	–	–	–	–	x
Monotropa uniflora	Indianpipe	–	–	–	–	x
Morella cerifera	wax myrtle	x	x	x	x	x
Morus rubra	red mulberry	–	–	x	x	x
Muhlenbergia capillaris	hairawn muhly	–	x	–	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU’s hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Oplismenus hirtellus	basketgrass	–	–	x	x	x
Opuntia pusilla	cockspur pricklypear	–	x	–	–	–
Opuntia stricta	erect prickypear cactus	–	x	–	–	–
Orthosia scoparia	leafless swallow-wort	–	–	–	–	x
Osmanthus americanus	devilwood	–	x	–	x	x
Osmunda cinnamomea	cinnamon fern	–	–	x	–	–
Osmunda regalis var. *spectabilis*	royal fern	–	–	x	–	–
Panicum anceps	beaked panicgrass	–	–	x	–	–
Panicum virgatum	switchgrass	–	x	–	–	–
Parthenocissus quinquefolia	Virginia creeper	x	–	x	x	x
Paspalum sp.	paspalum grass	–	x	–	–	–
Paspalum setaceum	thin paspalum	–	–	x	–	–
Paspalum urvillei [a]	Vasey’s grass	–	–	x	–	–
Passiflora incarnata	purple passionflower	–	–	–	x	–
Passiflora lutea	yellow passionflower	–	–	x	–	x
Persea borbonia	redbay	–	x	x	x	x
Phoradendron leucarpum	oak mistletoe	–	–	x	–	–
Phytolacca americana	American pokeweed	–	x	–	x	x
Pinus elliotti	slash pine	–	x	–	–	x
Pinus palustris	longleaf pine	–	x	–	–	–
Pinus taeda	loblolly pine	–	–	–	x	x
Piptochaetium avenaceum	blackseed needlegrass	–	–	x	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Pleopeltis polypodioides var. *michauxiana*	resurrection fern	–	–	x	–	x
Polygonum (Persicaria) hydropiperoides	swamp smartweed	–	–	x	–	–
Polygonum punctatum	dotted smartweed	–	–	x	–	–
Prunus caroliniana	Carolina laurelcherry	–	–	–	x	x
Prunus serotina	black cherry	x	x	x	x	x
Prunus umbellata	hog plum	–	–	–	–	x
Psychotria nervosa	Seminole balsamo	–	–	x	–	x
Ptelea trifoliata	common hoptree	–	–	–	–	x
Pteridium aquilinum	bracken fern	–	x	–	–	x
Quercus chapmanii	Chapman's oak	–	x	–	x	x
Quercus geminata	sand live oak	–	x	x	x	x
Quercus hemisphaerica	Darlington oak	–	x	x	–	x
Quercus laurifolia	laurel oak	–	x	–	x	–
Quercus myrtifolia	myrtle oak	–	x	–	x	x
Quercus nigra	water oak	x	x	–	–	x
Quercus virginiana	live oak	x	x	x	x	x
Rhus copallinum	winged sumac	–	x	–	–	x
Rhynchospora fascicularis	fascicled beaksedge	–	–	x	–	–
Rubus sp.	blackberry	–	–	–	x	x
Rubus trivialis	southern dewberry	–	–	–	–	x
Ruellia caroliniensis	Carolina wild petunia	–	–	x	x	x
Sabal minor	dwarf palmetto	–	x	–	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Sabal palmetto	cabbage palmetto	x	x	x	x	x
Sabatia brevifolia	shortleaf rose gentian	–	–	–	–	x
Salvia lyrata	lyreleaf sage	–	–	x	–	–
Sambucus nigra ssp. *canadensis*	American black elderberry	–	–	–	x	–
Sanicula canadensis	Canadian blacksnakeroot	–	–	x	–	–
Sapindus saponaria	wingleaf soapberry	–	–	x	–	x
Scleria sp.	nutrush	–	–	–	–	x
Scleria triglomerata	whip nutrush	x	–	–	–	–
Serenoa repens	saw palmetto	–	x	x	x	x
Setaria sp.	bristlegrass	–	x	–	–	–
Sideroxylon lycioides	buckthorn bully	–	–	–	–	x
Sideroxylon tenax	tough bully	–	x	x	x	x
Smallanthus uvedalia	hairy leafcup	–	–	x	–	x
Smilax sp.	greenbrier	x	–	–	–	–
Smilax auriculata	earleaf greenbrier	–	–	–	x	x
Smilax bona-nox	saw greenbrier	–	–	x	x	x
Smilax glauca	cat greenbrier	–	–	x	–	x
Smilax pumila	sarsparilla vine	–	–	x	x	x
Smilax rotundifolia	roundleaf greenbrier	–	–	–	–	x
Smilax tamnoides	bristly greenbrier	–	–	x	–	–
Solanum americanum	American black nightshade	–	–	x	–	x
Solidago fistulosa	pinebarren goldenrod	–	x	–	–	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Solidago odora ssp. *chapmanii*	Chapman's goldenrod	–	–	x	–	–
Sonchus oleraceus [a]	common sowthistle	–	–	x	–	–
Sporobolus indicus [a]	smut grass	–	–	x	–	–
Sporobolus virginicus	seashore dropseed	–	x	–	–	–
Stachys floridana	Florida hedgenettle	–	–	x	–	–
Strophostyles helvola	amberique-bean	–	–	–	–	x
Styrax grandifolius	bigleaf snowbell	–	x	–	–	x
Symplocos tinctoria	sweetleaf	–	x	–	x	x
Taraxacum officinale [a]	common dandelion	–	–	x	–	–
Tilia americana	American basswood	–	–	–	–	x
Tillandsia recurvata	ballmoss	–	–	x	–	x
Tillandsia usneoides	Spanish moss	x	–	x	–	x
Toxicodendron radicans	eastern poison ivy	x	–	x	x	x
Tradescantia ohiensis	Ohio spiderwort	–	–	–	–	x
Tragia urens	wavyleaf noseburn	–	–	x	–	–
Tridens flavus var. *flavus*	purpletop tridens	–	–	x	–	–
Vaccinium arboreum	sparkleberry	x	x	x	–	x
Vaccinium corymbosum	highbush blueberry	x	–	x	–	x
Vaccinium myrsinites	shiny blueberry	–	–	–	x	x
Vaccinium stamineum	deerberry	–	–	x	x	x
Verbesina virginica	white crownbeard	–	–	x	–	x
Vernonia gigantea	giant ironweed	–	x	x	–	x
Vitis sp.	grape	x	x	–	x	–

[a] Non-native species.

Table G-1 (continued). Plant species documented in TIMU's hardwood hammock communities by various studies over time.

Scientific name	Common name	COJ (1998)	McClung (2004)	Zomlefer et al. (2007)	SECN 2009 data (Byrne et al. 2012b)	SECN 2019 data (NPS 2020f)
Vitis aestivalis	summer grape	–	–	x	x	x
Vitis rotundifolia	muscadine	–	–	x	x	x
Vitis vulpina	frost grape	–	–	–	–	x
Woodwardia areolata	netted chainfern	–	–	x	–	–
Youngia japonica [a]	oriental false hawksbeard	–	–	x	–	x
Yucca aloifolia	aloe yucca	–	x	–	–	–

[a] Non-native species.

Appendix H. Plant species documented in TIMU's salt marshes

Table H-1. Plant species documented in TIMU's salt marshes by various studies over time.

Scientific name	Common name	NPS 1996 (1984 sampling)	COJ (1998)	Steinway-Rodkin & Montague (2004)	Zomlefer et al. (2007)
Ambrosia artemisiifolia	annual ragweed	–	–	–	x
Ampelaster carolinianus	climbing aster	–	–	x	–
Atriplex cristata	crested saltbush	–	–	–	x
Baccharis halimifolia	eastern baccharis	x	x	x	x
Batis maritima	turtleweed	x	x	x	x
Bolboschoenus robustus	sturdy bulrush	–	–	x	–
Borrichia frutescens	bushy seaside tansy	x	–	x	–
Chenopodium album	lambsquarters	–	–	–	x
Cladium jamaicense	Jamaica swamp sawgrass	–	–	x	–
Cynanchum angustifolium	gulf coast swallow-wort	–	x	–	x
Desmodium paniculatum	panicledleaf ticktrefoil	–	–	–	x
Distichlis spicata	saltgrass	x	x	x	x
Dysphania ambrosioides [a]	Mexican tea	–	–	–	x
Eleocharis sp.	spikerush	–	–	x	–
Fimbristylis spadicea	marsh fimbry	–	–	x	–
Hydrocotyle sp.	pennywort	–	–	x	–
Ipomoea sagittata	saltmarsh morning-glory	–	–	x	–
Iva frutescens	bigleaf sumpweed	x	x	–	x
Juncus effusus	common rush	–	–	x	–
Juncus roemerianus	needlegrass rush	x	x	x	x
Lilaeopsis carolinensis	Carolina grasswort	–	–	x	–
Limonium carolinianum	Carolina sealavender	x	x	x	x

[a] Non-native species.

Table H-1 (continued). Plant species documented in TIMU's salt marshes by various studies over time.

Scientific name	Common name	NPS 1996 (1984 sampling)	COJ (1998)	Steinway-Rodkin & Montague (2004)	Zomlefer et al. (2007)
Lycium carolinianum	Carolina desert-thorn	–	x	–	x
Lythrum lineare	wand lythrum	–	–	x	–
Melica mutica	twoflower melicgrass	–	–	–	x
Opuntia stricta	erect pricklypear	–	–	–	x
Panicum virgatum	switchgrass	–	–	–	x
Rumex hastatulus	heartwing dock	–	–	–	x
Salicornia virginica	Virginia glasswort	x	x	–	–
Sarcocornia perennis	chickenclaws	–	–	x	x
Scirpus sp.	bulrush	–	–	x	–
Sesuvium sp.	seapurslane	–	–	x	–
Sesuvium portulacastrum	shoreline seapurslane	x	x	–	x
Solidago sempervirens	seaside goldenrod	–	–	x	x
Spartina alterniflora	smooth cordgrass	x	x	x	x
Spartina bakeri	sand cordgrass	–	–	x	–
Spartina cynosuroides	big cordgrass	x	–	x	–
Spartina patens	saltmeadow cordgrass	x	x	–	x
Suaeda linearis	annual seepweed	x	–	–	x
Symphyotrichum tenuifolium	saltmarsh aster	–	–	x	–
Tetragonia tetragonioides [a]	New Zealand spinach	–	–	–	x
Typha angustifolia	narrowleaf cattail	x	–	–	–
Vicia acutifolia	fourleaf vetch	–	–	x	–

[a] Non-native species.

Appendix I. Provisional RSET elevation change data for SECN sampling sites at TIMU

Provisional RSET elevation change data for SECN sampling sites at TIMU (Tables I-1 to I6; NPS 2020e). See Figure 19 for sampling locations. Note that TIMU65 was only re-sampled in 2016, not 2017 or 2018. Change was not calculated for directions where measurement angles differed by ≥9°. Due to the low number of sampling periods, large gaps between sampling periods, and inconsistent sampling, it is not recommended that these data be used for planning purposes.

Table I-1. Mean elevation change (mm), April 2015–June 2018.

Station	Direction 1	Direction 2	Direction 3	Direction 4	Mean
TIMU01C	−1.9 [a]	−6.1 [a]	−13.8	−6.1	**−7.0**

[a] Angle of the sampling arm differed by 3–8° between sampling visit.

Table I-2. Mean elevation change (mm), May 2015–June 2018.

Station	Direction 1	Direction 2	Direction 3	Direction 4	Mean
TIMU20A	18.0 [a]	−81.6 [a]	25.5 [a]	23.7 [a]	**−3.6**
TIMU20B	41.3 [a]	33.6 [a]	59.4	68.9	**50.8**
TIMU20C	29.3 [a]	18.0	–	9.8 [a]	**19.0**

[a] Angle of the sampling arm differed by 3–8° between sampling visit.

Table I-3. Mean elevation change (mm), May 2015–June 2016.

Station	Direction 1	Direction 2	Direction 3	Direction 4	Mean
TIMU65A	−1.1	−6.6 [a]	−4.3 [a]	−2.0 [a]	**−3.5**
TIMU65B	−3.4 [a]	−4.7	−4.9 [a]	−4.9 [a]	**−4.5**
TIMU65C	−9.3 [a]	4.3	−3.2 [a]	4.6 [a]	**−0.9**

[a] Angle of the sampling arm differed by 3–8° between sampling visit.

Table I-4. Mean elevation change (mm) since April 2015.

Station	Direction 1		Direction 2		Direction 3		Direction 4		Mean	
	June 2017	June 2018	June 2017	June 2018	June 2017	June 2018	June 2017	June 2018	June 2017	June 2018
TIMU27A	−2.7 [a]	−7.4 [a]	10.4	0.1 [a]	6.0	−8.1 [a]	−3.1 [a]	−7.9 [a]	**1.5**	**−5.8**
TIMU27B	–	–	–	–	−37.8 [a]	–	–	–	**–**	**–**

[a] Angle of the sampling arm differed by 3–8° between sampling visits.

Table I-5. Mean elevation change (mm) since May 2015.

Station	Direction 1		Direction 2		Direction 3		Direction 4		Mean	
	July 2017	**June 2018**	**July 2017**	**June 2018**	**July 2017**	**June 2018**	**July 2017**	**June 2018**	**July 2017**	**June 2018**
TIMU54A	9.0	18.1	10.2 [a]	45.6	9.5 [a]	17.2 [a]	−0.3 [a]	1.8 [a]	**7.1**	**20.7**
TIMU54B	–	40.9 [a]	44.0 [a]	47.3 [a]	33.9 [a]	48.4 [a]	26.4 [a]	37.8 [a]	**34.8**	**43.6**
TIMU54C	32.1 [a]	36.0 [a]	37.1 [a]	39.4	–	–	24.7 [a]	20.3 [a]	**31.3**	**31.9**

[a] Angle of the sampling arm differed by 3–8° between sampling visits.

Table I-6. Mean elevation change (mm) since April 2015.

Station	Direction 1		Direction 2		Direction 3		Direction 4		Mean	
	August 2017	**July 2018**	**August 2017**	**July 2018**	**August 2017**	**July 2018**	**August 2017**	**July 2018**	**August 2017**	**July 2018**
TIMU78A	–	4.5 [a]	40.4 [a]	20.8 [a]	−5.4 [a]	−1.0	–	3.6	**17.5**	**7.0**
TIMU78B	13.4 [a]	–	15.6 [a]	14.6 [a]	–	13.7 [a]	7.7 [a]	8.1	**12.2**	**12.1**
TIMU78C	10.0	3.5 [a]	1.4	3.8	7.2 [a]	9.2	–	–	**6.2**	**5.5**

[a] Angle of the sampling arm differed by 3–8° between sampling visits.

Appendix J. Bird species that have been documented in TIMU

Table J-1. Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	**Scientific Name**	**NPS (2020d)**	**CBC**	**eBird [a]**	**TNC (1996)**	**Jones (1998)**	**Byrne et al. (2011) (SECN)**	**Conservation Status**
Acadian Flycatcher	*Empidonax virescens*	X	–	X	X	–	X	–
Alder Flycatcher	*Empidonax alnorum*	X	–	–	–	–	–	–
American Avocet	*Recurvirostra americana*	X	X	X	–	–	–	–
American Bittern	*Botaurus lentiginosus*	X	X	X	–	–	–	–
American Black Duck	*Anas rubripes*	X	X	–	–	–	–	–
American Coot	*Fulica americana*	X	X	X	–	–	–	–
American Crow	*Corvus brachyrhynchos*	X	X	X	X	X	X	–
American Golden Plover	*Pluvialis dominica*	X	–	–	–	–	–	–
American Goldfinch	*Carduelis tristis*	X	X	X	–	–	–	–
American Kestrel	*Falco sparverius*	X	X	X	–	–	–	–
American Oystercatcher	*Haematopus palliatus*	X	X	X	X	–	–	ST
American Pipit	*Anthus rubescens*	X	X	X	–	–	–	–
American Redstart	*Setophaga ruticilla*	X	X	X	X	–	–	–
American Robin	*Turdus migratorius*	X	X	X	–	X	–	–
American Swallow-tailed Kite	*Elanoides forficatus*	X	–	–	–	–	–	–
American White Pelican	*Pelecanus erythrorhynchos*	X	X	X	–	–	–	–
American Wigeon	*Anas americana*	X	X	–	–	–	–	–
American Woodcock	*Scolopax minor*	X	X	X	–	–	–	–
Anhinga	*Anhinga anhinga*	X	X	X	–	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Arctic Tern	*Sterna paradisaea*	X	–	–	–	–	–	–
Bachman's Sparrow	*Aimophila aestivalis*	X	X	–	–	–	–	–
Baird's Sandpiper	*Calidris bairdii*	X	–	–	–	–	–	–
Bald Eagle	*Haliaeetus leucocephalus*	X	X	X	–	–	–	–
Baltimore Oriole	*Icterus galbula*	X	X	X	–	–	–	–
Bank Swallow	*Riparia riparia*	X	–	–	X	–	–	–
Barn Owl	*Tyto alba*	X	X	–	–	–	–	–
Barn Swallow	*Hirundo rustica*	X	X	X	X	–	–	–
Barred Owl	*Strix varia*	X	X	X	–	–	X	–
Bar-tailed Godwit	*Limosa lapponica*	X	–	–	–	–	–	–
Bay-breasted Warbler	*Dendroica castanea*	X	–	X	–	–	–	–
Bell's Vireo	*Vireo bellii*	X	–	–	–	–	–	–
Belted Kingfisher	*Megaceryle alcyon*	X	X	X	X	X	–	–
Black Rail	*Laterallus jamaicensis*	–	X	–	–	–	–	–
Black Scoter	*Melanitta nigra*	X	X	–	–	–	–	–
Black Skimmer	*Rynchops niger*	X	X	X	X	–	–	ST
Black Tern	*Chlidonias niger*	X	–	–	–	–	–	–
Black Vulture	*Coragyps atratus*	X	X	X	X	X	–	–
Black-and-White Warbler	*Mniotilta varia*	X	X	X	X	X	–	–
Black-bellied Plover	*Pluvialis squatarola*	X	X	X	X	–	–	–
Black-bellied Whistling-Duck	*Dendrocygna autumnalis*	–	–	X	–	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Black-billed Cuckoo	*Coccyzus erythropthalmus*	X	–	X	X	–	–	–
Blackburnian Warbler	*Dendroica fusca*	X	X	X	–	–	–	–
Black-Crowned Night-Heron	*Nycticorax nycticorax*	X	X	X	X	–	–	–
Black-headed Gull	*Larus ridibundus*	X	X	–	–	–	–	–
Black-necked Stilt	*Himantopus mexicanus*	X	X	X	–	–	–	–
Blackpoll Warbler	*Dendroica striata*	X	–	X	X	–	–	–
Black-throated Blue Warbler	*Dendroica caerulescens*	X	X	X	X	–	–	–
Black-throated Green Warbler	*Dendroica virens*	X	X	X	–	–	–	–
Blue Grosbeak	*Guiraca caerulea*	X	–	X	X	–	X	–
Blue Jay	*Cyanocitta cristata*	X	X	X	X	X	X	–
Blue-gray Gnatcatcher	*Polioptila caerulea*	X	X	X	X	–	X	–
Blue-headed Vireo	*Vireo solitarius*	X	X	X	–	–	–	–
Blue-winged Teal	*Anas discors*	X	X	X	–	X	–	–
Blue-winged Warbler	*Vermivora pinus*	X	–	X	–	–	–	–
Boat-tailed Grackle	*Quiscalus major*	X	X	X	X	–	–	–
Bobolink	*Dolichonyx oryzivorus*	X	–	X	X	–	–	–
Bonaparte’s Gull	*Larus philadelphia*	X	X	X	–	–	–	–
Brant	*Branta bernicla*	–	X	–	–	–	–	–
Brewer’s Blackbird	*Euphagus cyanocephalus*	–	X	–	–	–	–	–
Bridled Tern	*Sterna anaethetus*	X	–	–	–	–	–	–
Broad-winged Hawk	*Buteo platypterus*	X	X	X	–	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Bronzed Cowbird	*Molothrus aeneus*	X	–	–	–	–	–	–
Brown Creeper	*Certhia americana*	–	X	–	–	–	–	–
Brown Pelican	*Pelecanus occidentalis*	X	X	X	X	X	–	–
Brown Thrasher	*Toxostoma rufum*	X	X	X	X	–	X	–
Brown-headed Cowbird	*Molothrus ater*	X	X	X	X	–	–	–
Brown-headed Nuthatch	*Sitta pusilla*	X	X	X	–	–	–	–
Buff-breasted Sandpiper	*Tryngites subruficollis*	X	–	X	–	–	–	–
Bufflehead	*Bucephala albeola*	X	X	–	–	–	–	–
Bullock’s Oriole	*Icterus bullockii*	–	X	–	–	–	–	–
Burrowing Owl	*Athene cunicularia*	–	X	–	–	–	–	ST
Cabot’s Tern	*Thalasseus acuflavidus*	–	X	–	–	–	–	–
Canada Goose	*Branta canadensis*	X	X	X	–	–	X	–
Canada Warbler	*Wilsonia canadensis*	X	X	X	–	–	–	–
Canvasback	*Aythya valisineria*	X	X	–	–	–	–	–
Cape May Warbler	*Dendroica tigrina*	X	–	X	X	–	–	–
Carolina Chickadee	*Poecile carolinensis*	X	X	X	X	X	X	–
Carolina Wren	*Thryothorus ludovicianus*	X	X	X	X	X	X	–
Caspian Tern	*Sterna caspia*	X	X	X	X	–	–	–
Cattle Egret	*Bubulcus ibis*	X	X	X	X	–	–	–
Cave Swallow	*Petrochelidon fulva*	X	–	–	–	–	–	–
Cedar Waxwing	*Bombycilla cedrorum*	X	X	X	X	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Cerulean Warbler	*Dendroica cerulea*	X	–	–	–	–	–	–
Chestnut-sided Warbler	*Dendroica pensylvanica*	X	–	X	–	–	–	–
Chimney Swift	*Chaetura pelagica*	X	–	X	X	–	–	–
Chipping Sparrow	*Spizella passerina*	X	X	X	–	–	–	–
Chuck-Will's-Widow	*Caprimulgus carolinensis*	X	X	X	X	–	X	–
Clapper Rail	*Rallus longirostris*	X	X	X	X	–	X	–
Clay-colored Sparrow	*Spizella pallida*	X	X	–	–	–	–	–
Cliff Swallow	*Petrochelidon pyrrhonota*	X	X	X	–	–	–	–
Common Eider	*Somateria mollissima*	–	X	–	–	–	–	–
Common Gallinule	*Gallinula galeata*	–	X	X	–	–	–	–
Common Goldeneye	*Bucephala clangula*	X	X	–	–	–	–	–
Common Grackle	*Quiscalus quiscula*	X	X	X	X	–	X	–
Common Ground Dove	*Columbina passerina*	X	–	X	X	–	–	–
Common Loon	*Gavia immer*	X	X	X	–	–	–	–
Common Merganser	*Mergus merganser*	–	X	X	–	–	–	–
Common Moorhen	*Gallinula chloropus*	X	–	–	–	X	X	–
Common Nighthawk	*Chordeiles minor*	X	X	X	–	–	–	–
Common Redpoll	*Acanthis flammea*	–	X	–	–	–	–	–
Common Tern	*Sterna hirundo*	X	X	X	–	–	–	–
Common Yellowthroat	*Geothlypis trichas*	X	X	X	X	X	X	–
Connecticut Warbler	*Oporornis agilis*	X	–	X	–	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Cooper's Hawk	*Accipiter cooperii*	X	X	X	X	–	–	–
Cory's Shearwater	*Calonectris diomedea*	X	X	–	–	–	–	–
Curlew Sandpiper	*Calidris ferruginea*	X	–	–	–	–	–	–
Dark-eyed Junco	*Junco hyemalis*	X	X	X	–	–	–	–
Dickcissel	*Spiza americana*	–	X	–	–	–	–	–
Double-crested Cormorant	*Phalacrocorax auritus*	X	X	X	X	X	–	–
Downy Woodpecker	*Picoides pubescens*	X	X	X	X	X	X	–
Dunlin	*Calidris alpina*	X	X	X	–	–	–	–
Eared Grebe	*Podiceps nigricollis*	–	X	–	–	–	–	–
Eastern Bluebird	*Sialia sialis*	X	X	X	–	–	–	–
Eastern Kingbird	*Tyrannus tyrannus*	X	X	X	–	–	–	–
Eastern Meadowlark	*Sturnella magna*	X	X	X	–	–	–	–
Eastern Phoebe	*Sayornis phoebe*	X	X	X	–	X	X	–
Eastern Screech Owl	*Megascops asio*	X	X	–	X	–	X	–
Eastern Towhee	*Pipilo erythrophthalmus*	X	X	X	X	X	X	–
Eastern Wood-pewee	*Contopus virens*	X	–	X	–	–	–	–
Eurasian Collared Dove	*Streptopelia decaocto*	X	X	X	–	–	–	–
Eurasian Wigeon	*Anas penelope*	–	X	–	–	–	–	–
European Starling	*Sturnus vulgaris*	X	X	X	X	–	–	–
Evening Grosbeak	*Hesperiphona vespertina*	–	X	–	–	–	–	–
Field Sparrow	*Spizella pusilla*	X	X	–	–	–	–	–

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Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Fish Crow	*Corvus ossifragus*	X	X	X	X	X	X	–
Florida Scrub-Jay	*Aphelocoma coerulescens*	–	X	–	–	–	–	FT, ST
Forster’s Tern	*Sterna forsteri*	X	X	X	X	X	–	–
Fox Sparrow	*Passerella iliaca*	X	X	–	–	–	–	–
Franklin’s Gull	*Larus pipixcan*	X	–	–	–	–	–	–
Fulvous Whistling-Duck	*Dendrocygna bicolor*	–	X	–	–	–	–	–
Gadwall	*Anas strepera*	X	X	–	–	–	–	–
Glaucous Gull	*Larus hyperboreus*	X	X	–	–	–	–	–
Glossy Ibis	*Plegadis falcinellus*	X	X	X	–	–	–	–
Golden Eagle	*Aquila chrysaetos*	–	–	–	–	–	–	–
Golden-crowned Kinglet	*Regulus satrapa*	X	X	X	–	–	–	–
Golden-winged Warbler	*Vermivora chrysoptera*	X	–	X	–	–	–	–
Grasshopper Sparrow	*Ammodramus savannarum*	X	X	–	–	–	–	–
Gray Catbird	*Dumetella carolinensis*	X	X	X	X	–	X	–
Gray Kingbird	*Tyrannus dominicensis*	X	–	X	–	–	–	–
Gray-cheeked Thrush	*Catharus minimus*	X	X	X	–	–	–	–
Great Black-backed Gull	*Larus marinus*	X	X	X	–	–	–	–
Great Blue Heron	*Ardea herodias*	X	X	X	X	X	X	–
Great Cormorant	*Phalacrocorax carbo*	–	X	–	–	–	–	–
Great Crested Flycatcher	*Myiarchus crinitus*	X	–	X	X	–	X	–
Great Egret	*Ardea alba*	X	X	X	X	X	X	–

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Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Great Horned Owl	*Bubo virginianus*	X	X	X	–	–	–	–
Greater Scaup	*Aythya marila*	X	X	–	–	–	–	–
Greater Yellowlegs	*Tringa melanoleuca*	X	X	X	–	–	–	–
Green Heron	*Butorides virescens*	X	X	X	X	–	–	–
Green-winged Teal	*Anas crecca*	X	X	X	–	–	–	–
Gull-billed Tern	*Sterna nilotica*	X	X	X	X	–	–	–
Hairy Woodpecker	*Leuconotopicus villosus*	–	X	–	–	–	–	–
Harlequin Duck	*Histrionicus histrionicus*	–	X	–	–	–	–	–
Henslow’s Sparrow	*Ammodramus henslowii*	X	X	–	–	–	–	–
Hermit Thrush	*Catharus guttatus*	X	X	X	X	X	–	–
Herring Gull	*Larus argentatus*	X	X	X	–	–	–	–
Hooded Merganser	*Lophodytes cucullatus*	X	X	X	–	X	–	–
Hooded Warbler	*Wilsonia citrina*	X	–	X	–	–	–	–
Horned Grebe	*Podiceps auritus*	X	X	X	–	–	–	–
Horned Lark	*Eremophila alpestris*	X	X	–	–	–	–	–
House Finch	*Carpodacus mexicanus*	X	X	X	–	–	X	–
House Sparrow	*Passer domesticus*	X	X	X	–	–	–	–
House Wren	*Troglodytes aedon*	X	X	X	X	–	–	–
Iceland Gull	*Larus glaucoides*	X	X	–	–	–	–	–
Indian Peafowl	*Pavo cristatus*	–	–	X	–	–	–	–
Indigo Bunting	*Passerina cyanea*	X	X	X	X	–	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Kentucky Warbler	*Oporornis formosus*	X	–	X	X	–	–	–
Killdeer	*Charadrius vociferus*	X	X	X	X	X	–	–
King Rail	*Rallus elegans*	X	X	–	–	–	–	–
Lapland Longspur	*Calcarius lapponicus*	X	X	–	–	–	–	–
Lark Sparrow	*Chondestes grammacus*	X	X	X	–	–	–	–
Laughing Gull	*Larus atricilla*	X	X	X	X	–	X	–
Le Conte’s Sparrow	*Ammodramus leconteii*	X	X	–	–	–	–	–
Leach’s Storm Petrel	*Oceanodroma leucorhoa*	X	–	–	–	–	–	–
Least Bittern	*Ixobrychus exilis*	X	X	–	–	–	–	–
Least Flycatcher	*Empidonax minimus*	X	–	–	–	–	–	–
Least Sandpiper	*Calidris minutilla*	X	X	X	–	–	–	–
Least Tern	*Sterna antillarum*	X	X	X	X	–	–	ST
Lesser Black-backed Gull	*Larus fuscus*	X	X	X	–	–	–	–
Lesser Scaup	*Aythya affinis*	X	X	X	–	–	–	–
Lesser Yellowlegs	*Tringa flavipes*	X	X	X	–	X	–	–
Lincoln’s Sparrow	*Melospiza lincolnii*	X	X	–	–	–	–	–
Little Blue Heron	*Egretta caerulea*	X	X	X	X	X	X	ST
Loggerhead Shrike	*Lanius ludovicianus*	X	X	X	–	–	–	–
Long-billed Curlew	*Numenius americanus*	X	X	–	–	–	–	–
Long-billed Dowitcher	*Limnodromus scolopaceus*	X	X	–	–	–	–	–
Long-tailed Duck	*Clangula hyemalis*	X	X	–	–	–	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Long-tailed Jaeger	*Stercorarius longicaudus*	X	–	–	–	–	–	–
Louisiana Waterthrush	*Seiurus motacilla*	X	–	X	–	–	–	–
Magnificent Frigatebird	*Fregata magnificens*	X	–	X	–	–	–	–
Magnolia Warbler	*Dendroica magnolia*	X	X	X	–	–	–	–
Mallard	*Anas platyrhynchos*	X	X	X	–	–	–	–
Marbled Godwit	*Limosa fedoa*	X	X	X	–	–	–	–
Marsh Wren	*Cistothorus palustris*	X	X	X	X	–	–	–
Merlin	*Falco columbarius*	X	X	X	–	–	–	–
Mississippi Kite	*Ictinia mississippiensis*	X	–	X	–	–	–	–
Monk Parakeet	*Myiopsitta monachus*	X	X	–	–	–	–	–
Mottled Duck	*Anas fulvigula*	X	X	X	–	–	–	–
Mourning Dove	*Zenaida macroura*	X	X	X	X	X	X	–
Mourning Warbler	*Geothlypis philadelphia*	–	X	–	–	–	–	–
Muscovy Duck	*Cairina moschata*	X	X	X	–	–	–	–
Nashville Warbler	*Vermivora ruficapilla*	X	–	X	–	–	–	–
Nelson’s Sharp-tailed Sparrow	*Ammodramus nelsoni*	X	X	X	–	–	–	–
Northern Bobwhite	*Colinus virginianus*	X	X	X	X	–	X	–
Northern Cardinal	*Cardinalis cardinalis*	X	X	X	X	X	X	–
Northern Flicker	*Colaptes auratus*	X	X	X	X	–	–	–
Northern Gannet	*Morus bassanus*	X	X	X	–	–	–	–
Northern Harrier	*Circus cyaneus*	X	X	X	X	X	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Northern Mockingbird	*Mimus polyglottos*	X	X	X	X	X	X	–
Northern Parula	*Parula americana*	X	X	X	X	–	X	–
Northern Pintail	*Anas acuta*	X	X	–	–	–	–	–
Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	X	–	X	–	–	–	–
Northern Saw-whet Owl	*Aegolius acadicus*	–	X	–	–	–	–	–
Northern Shoveler	*Anas clypeata*	X	X	X	–	–	–	–
Northern Waterthrush	*Seiurus noveboracensis*	X	X	X	X	–	–	–
Orange-crowned Warbler	*Vermivora celata*	X	X	X	–	X	–	–
Orchard Oriole	*Icterus spurius*	X	–	X	X	–	–	–
Osprey	*Pandion haliaetus*	X	X	X	X	X	X	–
Ovenbird	*Seiurus aurocapillus*	X	–	X	X	–	X	–
Pacific Loon	*Gavia pacifica*	–	X	–	–	–	–	–
Painted Bunting	*Passerina ciris*	X	X	X	X	–	–	–
Palm Warbler	*Dendroica palmarum*	X	X	X	X	–	–	–
Parasitic Jaeger	*Stercorarius parasiticus*	X	X	–	–	–	–	–
Pectoral Sandpiper	*Calidris melanotos*	X	–	X	–	–	–	–
Peregrine Falcon	*Falco peregrinus*	X	X	X	–	–	–	–
Philadelphia Vireo	*Vireo philadelphicus*	X	–	X	–	–	–	–
Pied-Billed Grebe	*Podilymbus podiceps*	X	X	X	–	–	–	–
Pileated Woodpecker	*Dryocopus pileatus*	X	X	X	X	X	X	–
Pine Siskin	*Carduelis pinus*	X	X	–	–	–	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Pine Warbler	*Dendroica pinus*	X	X	X	X	–	X	–
Piping Plover	*Charadrius melodus*	X	X	X	–	–	–	FT, ST
Pomarine Jaeger	*Stercorarius pomarinus*	X	X	–	–	–	–	–
Prairie Warbler	*Dendroica discolor*	X	X	X	X	–	X	–
Prothonotary Warbler	*Protonotaria citrea*	X	X	X	X	–	–	–
Purple Finch	*Carpodacus purpureus*	X	X	–	–	–	–	–
Purple Gallinule	*Porphyrio martinica*	–	X	–	–	–	–	–
Purple Martin	*Progne subis*	X	X	X	–	–	–	–
Purple Sandpiper	*Calidris maritima*	X	X	–	–	–	–	–
Razorbill	*Alca torda*	–	X	–	–	–	–	–
Red Junglefowl	*Gallus gallus*	–	–	X	–	–	–	–
Red Knot	*Calidris canutus*	X	X	X	–	–	–	FT (rufa ssp)
Red Phalarope	*Phalaropus fulicaria*	X	–	–	–	–	–	–
Red-bellied Woodpecker	*Melanerpes carolinus*	X	X	X	X	X	X	–
Red-breasted Merganser	*Mergus serrator*	X	X	X	–	–	–	–
Red-breasted Nuthatch	*Sitta canadensis*	X	X	X	–	–	–	–
Red-cockaded Woodpecker	*Leuconotopicus borealis*	–	X	–	–	–	–	FE, ST
Red-crowned Parrot	*Amazona viridigenalis*	–	X	–	–	–	–	–
Reddish Egret	*Egretta rufescens*	X	X	X	–	–	–	ST
Red-eyed Vireo	*Vireo olivaceus*	X	–	X	X	–	X	–
Redhead	*Aythya americana*	X	X	–	–	–	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Red-headed Woodpecker	*Melanerpes erythrocephalus*	X	X	X	X	X	–	–
Red-necked Grebe	*Podiceps grisegena*	–	X	–	–	–	–	–
Red-necked Phalarope	*Phalaropus lobatus*	X	–	–	–	–	–	–
Red-shouldered Hawk	*Buteo lineatus*	X	X	X	–	X	X	–
Red-tailed Hawk	*Buteo jamaicensis*	X	X	X	X	–	–	–
Red-throated Loon	*Gavia stellata*	X	X	–	–	–	–	–
Red-winged Blackbird	*Agelaius phoeniceus*	X	X	X	X	X	X	–
Ring-billed Gull	*Larus delawarensis*	X	X	X	–	–	–	–
Ring-necked Duck	*Aythya collaris*	X	X	X	–	X	–	–
Ring-necked Pheasant	*Phasianus colchicus*	–	X	–	–	–	–	–
Rock Dove	*Columba livia*	X	X	X	X	–	–	–
Roseate Spoonbill	*Ajaia ajaja*	X	X	X	–	–	–	ST
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	X	–	X	–	–	–	–
Rough-legged Hawk	*Buteo lagopus*	–	X	–	–	–	–	–
Royal Tern	*Sterna maxima*	X	X	X	–	–	–	–
Ruby-crowned Kinglet	*Regulus calendula*	X	X	X	–	X	X	–
Ruby-throated Hummingbird	*Archilochus colubris*	X	X	X	–	–	–	–
Ruddy Duck	*Oxyura jamaicensis*	X	X	X	–	–	–	–
Ruddy Turnstone	*Arenaria interpres*	X	X	X	–	–	–	–
Rusty Blackbird	*Euphagus carolinus*	X	X	–	–	–	–	–
Sabine’s Gull	*Xema sabini*	X	–	–	–	–	–	–

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Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Saltmarsh Swamp-tailed Sparrow	*Ammodramus caudacutus*	X	X	X	–	–	–	–
Sanderling	*Calidris alba*	X	X	X	–	–	–	–
Sandhill Crane	*Grus canadensis*	X	X	X	–	–	–	ST
Sandwich Tern	*Sterna sandvicensis*	X	X	X	–	–	–	–
Savannah Sparrow	*Passerculus sandwichensis*	X	X	X	X	–	–	–
Scarlet Tanager	*Piranga olivacea*	X	–	X	–	–	–	–
Scissor-tailed Flycatcher	*Tyrannus forficatus*	X	–	–	–	–	–	–
Seaside Sparrow	*Ammodramus maritimus*	X	X	X	X	–	–	ST
Sedge Wren	*Cistothorus platensis*	X	X	X	–	–	–	–
Semipalmated Plover	*Charadrius semipalmatus*	X	X	X	X	–	–	–
Semipalmated Sandpiper	*Calidris pusilla*	X	X	X	X	–	–	–
Sharp-shinned Hawk	*Accipiter striatus*	X	X	X	–	–	–	–
Shiny Cowbird	*Molothrus bonariensis*	X	–	–	–	–	–	–
Short-billed Dowitcher	*Limnodromus griseus*	X	X	X	X	–	–	–
Short-eared Owl	*Asio flammeus*	X	X	–	–	–	–	–
Short-tailed Hawk	*Buteo brachyurus*	–	–	X	–	–	–	–
Smooth-billed Ani	*Crotophaga ani*	–	X	–	–	–	–	–
Snail Kite	*Rostrhamus sociabilis*	–	X	–	–	–	–	–
Snow Bunting	*Plectrophenax nivalis*	X	X	–	–	–	–	–
Snow Goose	*Chen caerulescens*	X	X	–	–	–	–	–
Snowy Egret	*Egretta thula*	X	X	X	X	X	X	–

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Common Name	**Scientific Name**	**NPS (2020d)**	**CBC**	**eBird [a]**	**TNC (1996)**	**Jones (1998)**	**Byrne et al. (2011) (SECN)**	**Conservation Status**
Snowy Owl	*Bubo scandiacus*	–	X	–	–	–	–	–
Snowy Plover	*Charadrius alexandrinus*	X	X	–	–	–	–	ST
Solitary Sandpiper	*Tringa solitaria*	X	X	X	–	–	–	–
Solitary Vireo	*Vireo solitarius*	–	–	–	X	X	–	–
Song Sparrow	*Melospiza melodia*	X	X	X	–	–	–	–
Sooty Tern	*Sterna fuscata*	X	–	–	–	–	–	–
Sora	*Porzana carolina*	X	X	X	–	–	–	–
Spotted Sandpiper	*Actitis macularia*	X	X	X	X	X	–	–
Stilt Sandpiper	*Calidris himantopus*	X	X	–	–	–	–	–
Summer Tanager	*Piranga rubra*	X	X	X	X	–	X	–
Surf Scoter	*Melanitta perspicillata*	X	X	–	–	–	–	–
Swallow-tailed Kite	*Elanoides forficatus*	–	–	X	–	–	–	–
Swainson’s Hawk	*Buteo swainsoni*	–	X	–	–	–	–	–
Swainson’s Thrush	*Catharus ustulatus*	X	X	X	–	–	–	–
Swainson’s Warbler	*Limnothlypis swainsonii*	X	–	–	–	–	–	–
Swamp Sparrow	*Melospiza georgiana*	X	X	X	X	–	–	–
Tennessee Warbler	*Vermivora peregrina*	X	–	X	–	–	–	–
Tree Swallow	*Tachycineta bicolor*	X	X	X	X	–	–	–
Tricolored Heron	*Egretta tricolor*	X	X	X	X	–	–	ST
Tropical Kingbird	*Tyrannus melancholicus*	X	–	–	–	–	–	–
Tufted Titmouse	*Baeolophus bicolor*	X	X	X	X	X	X	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Turkey Vulture	*Cathartes aura*	X	X	X	X	X	–	–
Upland Sandpiper	*Bartramia longicauda*	X	–	–	–	–	–	–
Veery	*Catharus fuscescens*	X	X	X	–	–	–	–
Vesper Sparrow	*Pooecetes gramineus*	X	X	–	–	–	–	–
Virginia Rail	*Rallus limicola*	X	X	–	–	–	–	–
Warbling Vireo	*Vireo gilvus*	X	–	X	–	–	–	–
Western Kingbird	*Tyrannus verticalis*	X	X	–	–	–	–	–
Western Sandpiper	*Calidris mauri*	X	X	X	–	–	–	–
Western Tanager	*Piranga ludoviciana*	X	X	X	–	–	–	–
Whimbrel	*Numenius phaeopus*	X	X	X	X	–	–	–
Whip-Poor-Will	*Caprimulgus vociferus*	X	X	X	–	–	–	–
White Ibis	*Eudocimus albus*	X	X	X	X	X	X	–
White-breasted Nuthatch	*Buteo swainsoni*	–	X	–	–	–	–	–
White-crowned Sparrow	*Zonotrichia leucophrys*	X	X	–	–	–	–	–
White-eyed Vireo	*Vireo griseus*	X	X	X	X	–	X	–
White-rumped Sandpiper	*Calidris fuscicollis*	X	–	–	–	–	–	–
White-throated Sparrow	*Zonotrichia albicollis*	X	X	X	–	–	–	–
White-winged Dove	*Zenaida asiatica*	X	X	–	–	–	–	–
White-winged Scoter	*Melanitta fusca*	X	X	–	–	–	–	–
Wild Turkey	*Meleagris gallopavo*	X	X	X	–	–	–	–
Willet	*Catoptrophorus semipalmatus*	X	X	X	X	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Willow Flycatcher	*Empidonax traillii*	X	–	X	–	–	–	–
Wilson's Phalarope	*Phalaropus tricolor*	X	–	–	–	–	–	–
Wilson's Plover	*Charadrius wilsonia*	X	X	X	–	–	–	–
Wilson's Snipe	*Gallinago delicata*	X	X	X	–	–	–	–
Wilson's Storm-Petrel	*Oceanites oceanicus*	X	–	–	–	–	–	–
Wilson's Warbler	*Wilsonia pusilla*	X	X	X	–	–	–	–
Winter Wren	*Troglodytes troglodytes*	X	X	–	–	X	–	–
Wood Duck	*Aix sponsa*	X	X	X	X	X	–	–
Wood Stork	*Mycteria americana*	X	X	X	X	X	–	FT, ST
Wood Thrush	*Hylocichla mustelina*	X	X	X	X	–	–	–
Worm-eating Warbler	*Helmitheros vermivorus*	X	X	X	X	–	–	–
Yellow Warbler	*Dendroica petechia*	X	X	X	–	–	–	–
Yellow-bellied Flycatcher	*Empidonax flaviventris*	X	–	–	–	–	–	–
Yellow-bellied Sapsucker	*Sphyrapicus varius*	X	X	X	–	–	–	–
Yellow-billed Cuckoo	*Coccyzus americanus*	X	–	X	X	–	X	–
Yellow-breasted Chat	*Icteria virens*	X	X	X	X	–	X	–
Yellow-crowned Night-Heron	*Nyctanassa violacea*	X	X	X	X	–	–	–
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	–	X	–	–	–	–	–
Yellow-rumped Warbler	*Dendroica coronata*	X	X	X	X	X	–	–
Yellow-throated Vireo	*Vireo flavifrons*	X	X	X	–	–	–	–

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Table J-1 (continued). Bird species that have been documented in TIMU by the various surveys and inventory efforts. X= confirmed species, FE = federally endangered, FT = federally threatened, ST = state threatened. CBC Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Common Name	Scientific Name	NPS (2020d)	CBC	eBird [a]	TNC (1996)	Jones (1998)	Byrne et al. (2011) (SECN)	Conservation Status
Yellow-throated Warbler	*Dendroica dominica*	X	X	X	X	X	X	–
Confirmed		**312**	**281**	**235**	**108**	**49**	**50**	**355**

[a] eBird results include species documented at Kingsley Plantation, Cedar Point, the Theodore Roosevelt Area, and Fort Caroline and are current through August 2020.

Appendix K. Bird species detected in various areas of TIMU

Table K-1. Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A "P" indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Acadian Flycatcher	X	X	–	X	–
American Avocet	X	–	–	X	–
American Bittern	X	–	–	X	–
American Coot	X	X	–	X	–
American Crow	X	X	X	X	X
American Goldfinch	X	X	X	X	X
American Kestrel	X	X	X	X	–
American Oystercatcher	X	X	X	–	X
American Pipit	X	–	X	–	–
American Redstart	X	X	X	X	X
American Robin	X	X	X	X	X
American White Pelican	X	X	X	X	X
American Woodcock	X	–	X	–	–
Anhinga	X	X	X	X	X
Bald Eagle	X	X	X	X	X
Baltimore Oriole	X	X	–	–	–
Bank Swallow	X	X	X	P	–
Barn Swallow	X	X	X	X	P
Barred Owl	X	X	X	X	X
Bay-breasted Warbler	X	–	X	X	–
Belted Kingfisher	X	X	X	X	X
Black Skimmer	X	X	–	X	X
Black Vulture	X	X	X	X	X
Black-and-white Warbler	X	X	X	X	X
Black-bellied Plover	X	X	X	X	–
Black-bellied Whistling-Duck	X	X	–	–	–
Black-billed Cuckoo	X	–	X	–	–
Blackburnian Warbler	X	X	X	X	–
Black-crowned Night-Heron	X	X	X	X	X
Black-necked Stilt	X	–	–	X	–
Blackpoll Warbler	X	X	X	X	X
Black-throated Blue Warbler	X	X	X	X	X

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A "P" indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Black-throated Green Warbler	X	X	–	X	X
Blue Grosbeak	X	X	X	X	–
Blue Jay	X	X	X	X	X
Blue-gray Gnatcatcher	X	X	X	X	X
Blue-headed Vireo	X	X	X	X	X
Blue-winged Teal	X	X	X	X	–
Blue-winged Warbler	X	X	P	X	–
Boat-tailed Grackle	X	X	X	X	X
Bobolink	X	X	X	X	X
Bonaparte's Gull	X	X	X	X	X
Broad-winged Hawk	X	X	X	–	–
Brown Pelican	X	X	X	X	X
Brown Thrasher	X	X	X	X	X
Brown-headed Cowbird	X	X	X	X	X
Brown-headed Nuthatch	X	–	X	X	–
Buff-breasted Sandpiper	X	X	–	–	–
Canada Goose	X	X	X	X	X
Canada Warbler	X	–	–	P	–
Cape May Warbler	X	X	X	X	X
Carolina Chickadee	X	X	X	X	X
Carolina Wren	X	X	X	X	X
Caspian Tern	X	X	–	X	X
Cattle Egret	X	X	X	X	X
Cedar Waxwing	X	X	P	X	X
Chestnut-sided Warbler	X	X	X	X	–
Chimney Swift	X	X	X	X	X
Chipping Sparrow	X	X	X	–	X
Chuck-will's-widow	X	X	X	X	–
Clapper Rail	X	X	X	X	X
Cliff Swallow	X	–	–	P	–
Common Gallinule	X	X	X	X	X
Common Grackle	X	X	X	X	X
Common Ground Dove	X	X	X	X	X
Common Loon	X	P	–	P	–
Common Merganser	X	X	–	–	–

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A “P” indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Common Nighthawk	X	X	P	X	–
Common Tern	X	X	–	–	–
Common Yellowthroat	X	X	X	X	X
Connecticut Warbler	X	–	–	P	–
Cooper’s Hawk	X	X	X	X	X
Dark-eyed Junco	X	X	–	–	–
Double-crested Cormorant	X	X	X	P	X
Downy Woodpecker	X	X	X	X	X
Dunlin	X	X	X	X	–
Eastern Bluebird	X	X	X	X	X
Eastern Kingbird	X	P	X	X	X
Eastern Meadowlark	X	X	–	–	–
Eastern Phoebe	X	X	X	X	X
Eastern Screech-Owl	X	X	X	X	–
Eastern Towhee	X	X	X	X	X
Eastern Whip-poor-will	X	X	X	X	–
Eastern Wood-Pewee	X	X	X	X	X
Eurasian Collared-Dove	X	X	–	–	–
European Starling	X	X	–	X	X
Fish Crow	X	X	X	X	X
Forster’s Tern	X	X	X	X	X
Glossy Ibis	X	X	–	X	–
Golden-crowned Kinglet	X	X	X	–	–
Golden-winged Warbler	X	X	X	P	–
Gray Catbird	X	X	X	X	X
Gray Kingbird	X	X	–	X	–
Gray-cheeked Thrush	X	X	–	X	X
Great Black-backed Gull	X	X	–	–	–
Great Blue Heron	X	X	X	X	X
Great Crested Flycatcher	X	X	X	X	X
Great Egret	X	X	X	X	X
Great Horned Owl	X	X	X	X	X
Greater Yellowlegs	X	X	X	P	X
Green Heron	X	X	X	X	X
Green-winged Teal	X	–	X	–	–

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A "P" indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Gull-billed Tern	X	X	–	–	–
Hermit Thrush	X	P	X	P	X
Herring Gull	X	X	X	X	X
Hooded Merganser	X	X	X	X	X
Hooded Warbler	X	X	X	X	X
Horned Grebe	X	X	–	X	–
House Finch	X	X	X	X	X
House Sparrow	X	X	–	X	–
House Wren	X	X	X	X	X
Indian Peafowl	X	X	–	–	–
Indigo Bunting	X	X	X	X	X
Kentucky Warbler	X	X	–	–	–
Killdeer	X	X	X	X	X
Lark Sparrow	X	X	–	–	–
Laughing Gull	X	X	X	X	X
Least Sandpiper	X	X	X	X	P
Least Tern	X	X	X	X	X
Lesser Black-backed Gull	X	X	–	–	X
Lesser Scaup	X	–	–	–	X
Lesser Yellowlegs	X	X	X	X	–
Little Blue Heron	X	X	X	X	X
Loggerhead Shrike	X	X	–	–	–
Louisiana Waterthrush	X	X	X	X	–
Magnificent Frigatebird	X	X	–	–	–
Magnolia Warbler	X	X	X	X	P
Mallard	X	X	X	X	X
Marbled Godwit	X	X	–	–	–
Marsh Wren	X	X	X	X	X
Merlin	X	X	X	X	–
Mississippi Kite	X	–	–	X	X
Mottled Duck	X	–	X	X	–
Mourning Dove	X	X	X	X	X
Muscovy Duck	X	X	–	–	–
Nashville Warbler	X	P	–	P	–
Nelson's Sharp-tailed Sparrow	X	X	–	P	–

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A "P" indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Northern Bobwhite	X	–	X	–	–
Northern Cardinal	X	X	X	X	X
Northern Flicker	X	X	X	X	X
Northern Gannet	X	X	–	–	–
Northern Harrier	X	X	X	X	X
Northern Mockingbird	X	X	X	X	X
Northern Parula	X	X	X	X	X
Northern Rough-winged Swallow	X	X	–	X	–
Northern Shoveler	X	–	–	X	–
Northern Waterthrush	X	X	X	X	P
Orange-crowned Warbler	X	X	X	X	X
Orchard Oriole	X	X	–	–	–
Osprey	X	X	X	X	X
Ovenbird	X	X	X	X	X
Painted Bunting	X	X	X	X	X
Palm Warbler	X	X	X	X	X
Pectoral Sandpiper	X	X	X	–	–
Peregrine Falcon	X	X	X	P	–
Philadelphia Vireo	X	X	–	–	–
Pied-billed Grebe	X	X	X	X	–
Pileated Woodpecker	X	X	X	X	X
Pine Warbler	X	X	X	X	X
Piping Plover	X	X	–	–	–
Prairie Warbler	X	X	X	X	X
Prothonotary Warbler	X	X	–	X	–
Purple Martin	X	X	X	X	X
Red Junglefowl (Domestic type)	X	–	X	–	–
Red Knot	X	X	–	–	–
Red-bellied Woodpecker	X	X	X	X	X
Red-breasted Merganser	X	P	X	X	X
Red-breasted Nuthatch	X	X	–	–	–
Reddish Egret	X	X	X	X	–
Red-eyed Vireo	X	X	X	X	X
Red-headed Woodpecker	X	X	X	X	X
Red-shouldered Hawk	X	X	X	X	X

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A "P" indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	eBird	Kingsley Plantation	Cedar Point	Theodore Roosevelt	Fort Caroline
Red-tailed Hawk	X	X	X	X	X
Red-winged Blackbird	X	X	X	X	X
Ring-billed Gull	X	X	X	X	X
Ring-necked Duck	X	X	–	X	–
Rock Dove	X	X	X	X	X
Roseate Spoonbill	X	X	X	X	P
Rose-breasted Grosbeak	X	X	X	P	–
Royal Tern	X	X	X	X	X
Ruby-crowned Kinglet	X	X	X	X	X
Ruby-throated Hummingbird	X	X	X	X	X
Ruddy Duck	X	–	–	–	X
Ruddy Turnstone	X	X	–	–	X
Saltmarsh Sharp-tailed Sparrow	X	–	X	X	–
Sanderling	X	X	X	X	–
Sandhill Crane	X	–	–	X	–
Sandwich Tern	X	X	P	–	–
Savannah Sparrow	X	X	–	X	X
Scarlet Tanager	X	P	X	X	–
Seaside Sparrow	X	X	X	X	–
Sedge Wren	X	–	X	X	X
Semipalmated Plover	X	X	X	X	–
Semipalmated Sandpiper	X	X	X	X	–
Sharp-shinned Hawk	X	X	X	X	X
Short-billed Dowitcher	X	X	X	X	–
Short-tailed Hawk	X	–	–	X	–
Snowy Egret	X	X	X	X	X
Solitary Sandpiper	X	–	–	X	P
Song Sparrow	X	X	X	X	X
Sora	X	–	–	X	–
Spotted Sandpiper	X	X	X	X	X
Summer Tanager	X	X	X	X	X
Swainson's Thrush	X	X	X	X	P
Swallow-tailed Kite	X	X	X	X	X
Swamp Sparrow	X	X	X	X	X
Tennessee Warbler	X	X	X	X	–

Table K-1 (continued). Bird species detected in various areas of TIMU, as reported by the eBird online portal (results obtained from https://ebird.org/). A “P” indicates that photographic evidence has been submitted and approved on the eBird portal.

Species	**eBird**	**Kingsley Plantation**	**Cedar Point**	**Theodore Roosevelt**	**Fort Caroline**
Tree Swallow	X	X	X	X	X
Tricolored Heron	X	X	X	X	X
Tufted Titmouse	X	X	X	X	X
Turkey Vulture	X	X	X	X	X
Veery	X	X	–	X	X
Warbling Vireo	X	X	–	–	–
Western Sandpiper	X	X	–	X	X
Western Tanager	X	–	X	–	–
Whimbrel	X	X	X	–	–
White Ibis	X	X	X	X	X
White-eyed Vireo	X	X	X	X	X
White-throated Sparrow	X	X	X	X	X
Wild Turkey	X	–	X	X	–
Willet	X	X	X	X	X
Willow Flycatcher	X	X	–	–	–
Wilson’s Plover	X	X	–	X	–
Wilson’s Snipe	X	–	–	X	–
Wilson’s Warbler	X	X	–	–	–
Wood Duck	X	X	–	X	X
Wood Stork	X	X	X	X	X
Wood Thrush	X	X	X	P	X
Worm-eating Warbler	X	X	X	X	X
Yellow Warbler	X	X	X	X	X
Yellow-bellied Sapsucker	X	X	X	X	X
Yellow-billed Cuckoo	X	X	–	X	X
Yellow-breasted Chat	X	X	–	–	–
Yellow-crowned Night-Heron	X	X	–	X	–
Yellow-rumped Warbler	X	X	X	X	X
Yellow-throated Vireo	X	X	X	X	X
Yellow-throated Warbler	X	X	X	X	X
Totals	**237**	**209**	**169**	**192**	**140**

Appendix L. Bird species observed in the Cedar Point and Theodore Roosevelt areas of TIMU

Table L-1. Bird species observed in the Cedar Point and Theodore Roosevelt areas of TIMU by Jones and Jones (1998).

Species	Cedar Point	T. Roosevelt
American Crow	–	X
American Robin	X	–
Belted Kingfisher	X	–
Black Vulture	X	–
Black-and-white Warbler	–	X
Blue Jay	X	–
Blue-winged Teal	–	X
Brown Pelican	X	–
Carolina Chickadee	–	X
Carolina Wren	X	X
Common Moorhen	–	X
Common Yellowthroat	X	–
Double-crested Cormorant	X	X
Downy Woodpecker	–	X
Eastern Phoebe	X	–
Eastern Towhee	X	–
Fish Crow	–	X
Forster’s Tern	X	–
Great Blue Heron	X	X
Great Egret	X	X
Grey Catbird	X	–
Hermit Thrush	X	X
Hooded Merganser	X	–
Killdeer	X	–
Lesser Yellowlegs	X	–
Little Blue Heron	X	X
Mourning Dove	–	X
Northern Cardinal	X	X
Northern Harrier	X	–
Northern Mockingbird	X	–
Orange-crowned Warbler	X	–
Osprey	X	–
Pileated Woodpecker	X	X

Table L-1 (continued). Bird species observed in the Cedar Point and Theodore Roosevelt areas of TIMU by Jones and Jones (1998).

Species	**Cedar Point**	**T. Roosevelt**
Red-bellied Woodpecker	X	X
Red-headed Woodpecker	–	X
Red-shouldered Hawk	X	–
Red-winged Blackbird	X	–
Ring-necked Duck	–	X
Ruby-crowned Kinglet	X	X
Snowy Egret	X	–
Solitary Vireo	X	X
Spotted Sandpiper	X	–
Tufted Titmouse	X	X
Turkey Vulture	X	X
White Ibis	X	X
Winter Wren	X	X
Wood Duck	X	–
Wood Stork	X	X
Yellow-rumped Warbler	X	X
Yellow-throated Warbler	–	X
Species Richness	**39**	**28**

Appendix M. Saltwater fish species documented at TIMU

Table M-1. Saltwater fish species documented at TIMU (NPS 2020d). / = captured just upstream of TIMU (Locations C, D, or E—see Figure 42) by Tagatz (1967), NC = not captured by Tagatz (1967) but documented in the SJR previously.

Scientific name	Common name	NPS (2020d)	Tagatz (1967)
Albula vulpes	bonefish	x	–
Achirus lineatus	lined sole	x	x
Alosa mediocris	bonejack; hickory shad	x	NC
Anchoa hepsetus	striped anchovy	x	x
Anchoa lyolepis	dusky anchovy	–	x
Anchoa mitchilli	bay anchovy	x	x
Ancylopsetta ommata	ocellated flounder	–	x
Anguilla rostrata	American eel	x	/
Archosargus probatocephalus	sheepshead	x	x
Ariopsis felis	hardhead catfish	x	x
Astroscopus y-graecum	southern stargazer	x	x
Bagre marinus	gafftopsail catfish	x	/
Bairdiella chrysoura	silver perch	x	x
Bathygobius soporator	frillfin goby	x	NC
Brevoortia smithi	yellowfin menhaden	x	x
Brevoortia tyrannus	Atlantic menhaden	x	x
Caranx crysos	blue runner	x	–
Caranx hippos	crevalle jack	x	x
Carcharhinus leucas	bull shark	x	–
Carcharhinus limbatus	blacktip shark	x	–
Centropomus undecimalis	common snook	x	NC
Centropristis philadelphica	rock sea bass	–	x
Centropristis striata	black sea bass	x	x
Chaetodipterus faber	Atlantic spadefish	x	x
Chasmodes bosquianus	striped blenny	x	x
Chilomycterus schoepfii	burrfish, porcupinefish	x	/
Chloroscombrus chrysurus	Atlantic bumper	x	x
Citharichthys macrops	spotted whiff	x	–
Citharichthys spilopterus	bay whiff	x	x
Ctenogobius boleosoma	darter goby	x	x
Ctenogobius shufeldti	freshwater goby	x	x
Cynoscion arenarius	sand seatrout	x	–
Cynoscion nebulosus	spotted seatrout	x	/

Table M-1 (continued). Saltwater fish species documented at TIMU (NPS 2020d). / = captured just upstream of TIMU (Locations C, D, or E—see Figure 42) by Tagatz (1967), NC = not captured by Tagatz (1967) but documented in the SJR previously.

Scientific name	Common name	NPS (2020d)	Tagatz (1967)
Cynoscion nothus	silver seatrout	x	–
Cynoscion regalis	weakfish, gray trout	x	x
Cyprinodon variegatus	sheepshead minnow	x	/
Dasyatis americana	southern stingray	x	NC
Dasyatis sabina	Atlantic stingray	x	x
Dasyatis say	bluntnose stingray	x	–
Diapterus auratus	Irish pompano	x	/
Dorosoma cepedianum	gizzard shad	x	/
Dorosoma petenense	threadfin shad	x	NC
Elops saurus	ladyfish	x	x
Etropus crossotus	fringed flounder	x	x
Eucinostomus argenteus	spotfin mojarra	x	x
Eucinostomus gula	silver jenny	x	x
Eucinostomus jonesii	slender mojarra	x	–
Eugerres plumieri	striped mojarra	x	/
Floridichthys carpio	ocellated killifish	x	–
Fundulus confluentus	marsh killifish	x	x
Fundulus heteroclitus	mummichog	x	x
Fundulus majalis	striped killifish	x	x
Fundulus similis	longnose killifish	–	x
Gambusia affinis	mosquitofish	x	/
Gambusia holbrooki	eastern mosquitofish	x	–
Gobiesox strumosus	skilletfish	x	x
Gobioides broussonnetii	violet goby	x	x
Gobionellus hastatus	sharptail goby	x	/
Gobiosoma bosc	naked goby	x	x
Gobiosoma ginsburgi	seaboard goby	x	–
Gobiosoma robustum	code goby	x	/
Harengula jaguana	scaled sardine	x	–
Hippocampus erectus	lined seahorse	x	x
Hippocampus zosterae	dwarf seahorse	x	–
Hypsoblennius hentz	feather blenny	–	x
Hypsoblennius ionthas	freckled blenny	x	x
Lagodon rhomboides	pinfish	x	x
Larimus fasciatus	banded drum	x	–

Table M-1 (continued). Saltwater fish species documented at TIMU (NPS 2020d). / = captured just upstream of TIMU (Locations C, D, or E—see Figure 42) by Tagatz (1967), NC = not captured by Tagatz (1967) but documented in the SJR previously.

Scientific name	Common name	NPS (2020d)	Tagatz (1967)
Leiostomus xanthurus	spot	x	x
Lobotes surinamensis	tripletail	x	–
Lucania parva	rainwater killifish	x	–
Lutjanus griseus	gray snapper	x	x
Lutjanus synagris	lane snapper	x	–
Membras martinica	rough silverside	x	x
Menidia beryllina	tidewater silverside	x	x
Menidia menidia	Atlantic silverside	x	x
Menidia peninsulae	tidewater silverside	x	–
Menticirrhus americanus	southern kingfish	x	/
Menticirrhus littoralis	Gulf kingfish	x	–
Menticirrhus saxatilis	northern kingfish	x	–
Microgobius gulosus	clown goby	x	/
Microgobius thalassinus	green goby	x	x
Micropogonias undulatus	Atlantic croaker	x	x
Morone saxatilis	striped bass	x	–
Mugil cephalus	striped or black mullet	x	x
Mugil curema	white mullet	x	x
Mycteroperca microlepis	charcoal belly, gag	x	x
Myrophis punctatus	speckled worm eel	x	–
Oligoplites saurus	leatherjack	x	x
Ophichthus gomesii	shrimp eel	x	–
Ophidion josephi	crested cusk-eel	–	x
Opisthonema oglinum	Atlantic thread herring	x	x
Opsanus tau	oyster toadfish	x	x
Orthopristis chrysoptera	pigfish	x	x
Paralichthys albigutta	gulf flounder	x	x
Paralichthys dentatus	summer flounder, fluke	x	x
Paralichthys lethostigma	southern flounder	x	x
Peprilus paru	harvestfish	–	x
Poecilia latipinna	sailfin molly	x	/
Pogonias cromis	black drum	x	x
Pomatomus saltatrix	bluefish	x	x
Prionotus carolinus	northern searobin	x	–
Prionotus evolans	striped searobin	x	–

Table M-1 (continued). Saltwater fish species documented at TIMU (NPS 2020d). / = captured just upstream of TIMU (Locations C, D, or E—see Figure 42) by Tagatz (1967), NC = not captured by Tagatz (1967) but documented in the SJR previously.

Scientific name	Common name	NPS (2020d)	Tagatz (1967)
Prionotus scitulus	leopard searobin	x	x
Prionotus tribulus	bighead searobin	x	x
Rhizoprionodon terraenovae	Atlantic sharpnose shark	x	–
Sciaenops ocellatus	red drum	x	x
Scomberomorus maculatus	Atlantic Spanish mackerel	x	x
Selene setapinnis	Atlantic moonfish	–	x
Selene vomer	lookdown	x	x
Sphoeroides maculatus	northern puffer	x	x
Sphoeroides nephelus	southern puffer	x	–
Sphoeroides spengleri	bandtail puffer	–	x
Sphyrna lewini	scalloped hammerhead	–	x
Sphyrna tiburo	bonnethead	x	–
Sphyraena barracuda	barracuda	–	x
Stellifer lanceolatus	star drum	x	x
Stephanolepis hispidus	planehead filefish	x	x
Strongylura marina	Atlantic needlefish	x	x
Strongylura timucu	longjaw; timucu	x	–
Symphurus plagiusa	blackcheek tonguefish	x	x
Syngnathus floridae	dusky pipefish	x	–
Syngnathus fuscus	northern pipefish	x	/
Syngnathus louisianae	chain pipefish	x	x
Syngnathus scovelli	Gulf pipefish	x	x
Synodus foetens	inshore lizardfish	x	x
Trachinotus carolinus	Florida pompano	x	–
Trachinotus falcatus	permit	x	/
Trichiurus lepturus	Atlantic cutlassfish	x	x
Trinectes maculatus	hogchoker	x	x
Urophycis floridana	southern hake	–	x
Urophycis regia	spotted hake	–	x

Appendix N. Additional graphs of fish indices of abundance for the Lower SJR

Figures N1 through N6 show fish indices of abundance by species and age class.

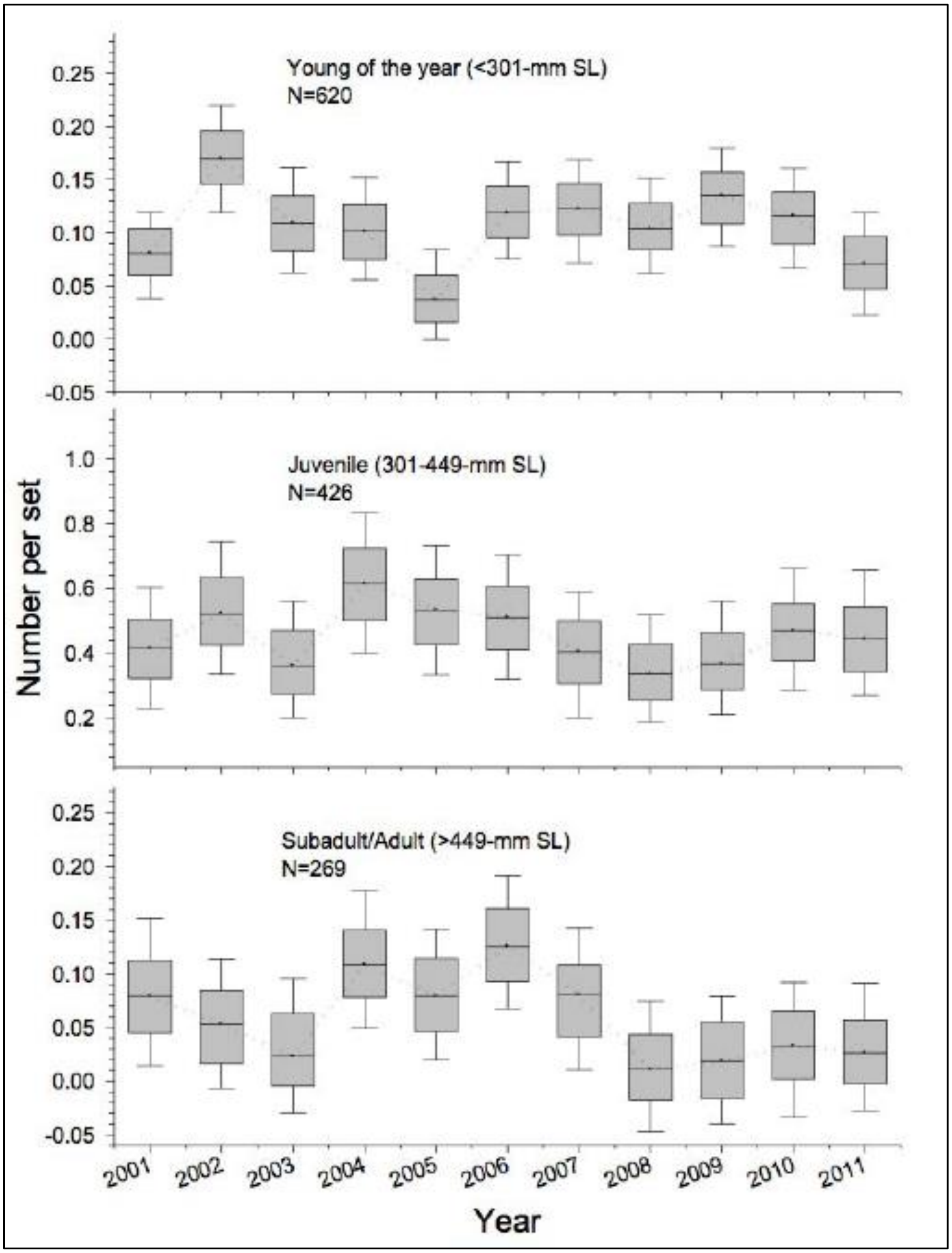

Figure N-1. Number of young of the year, juveniles, and subadults/adults of red drum caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012). The N value indicates the total number of sets completed for the time period.

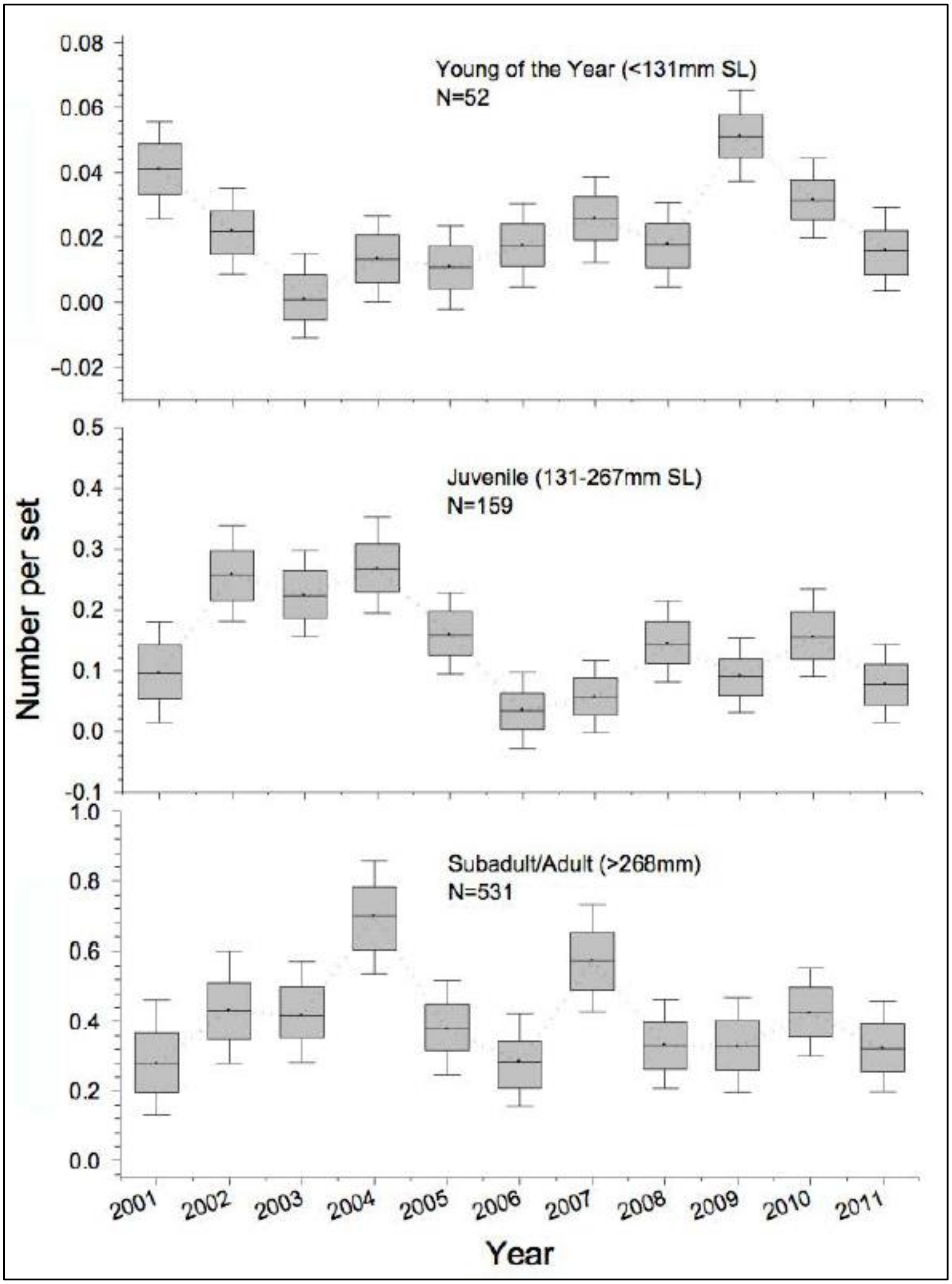

Figure N-2. Number of young of the year, juveniles, and subadults/adults of sheepshead caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012).

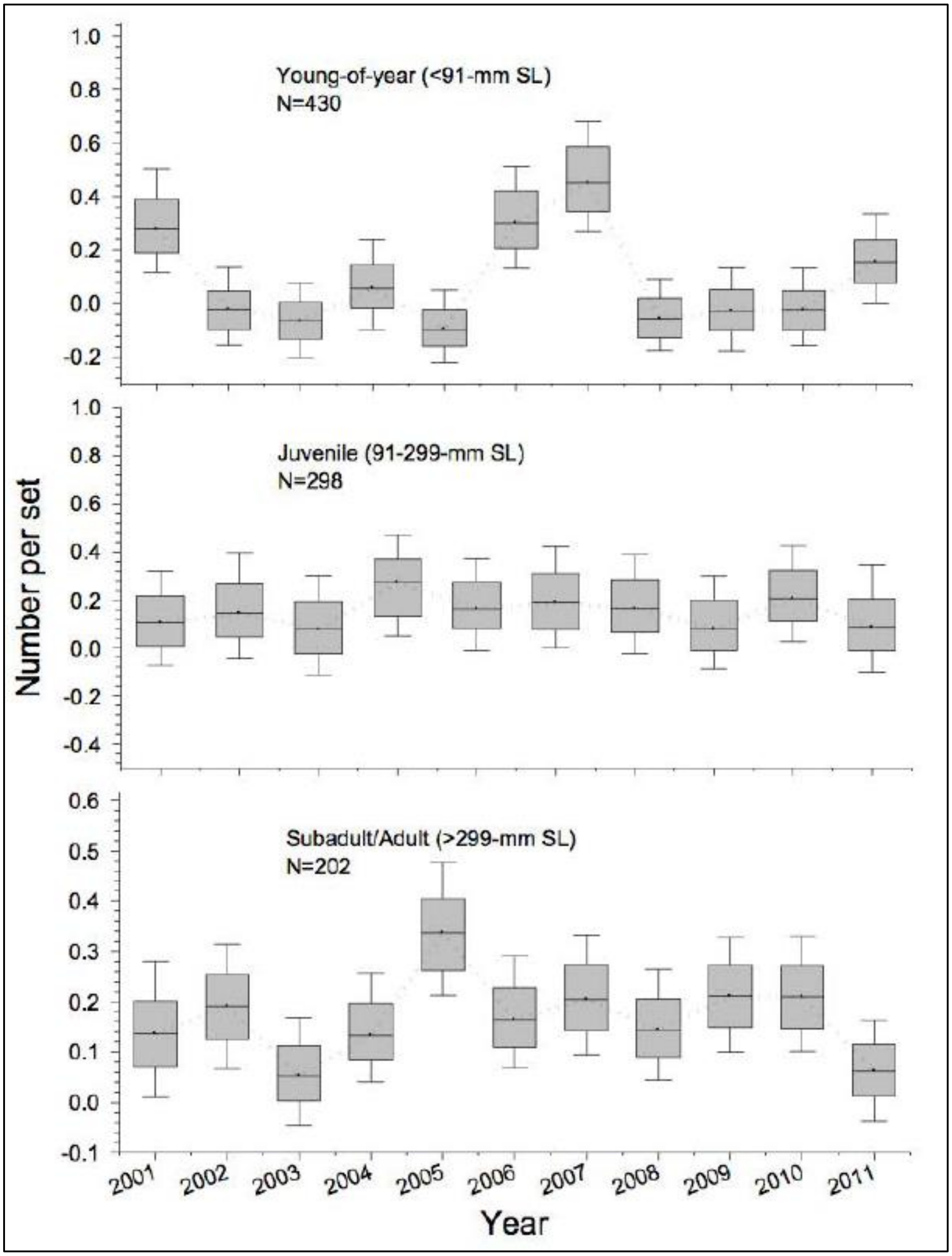

Figure N-3. Number of young of the year, juveniles, and subadults/adults of spotted seatrout caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012).

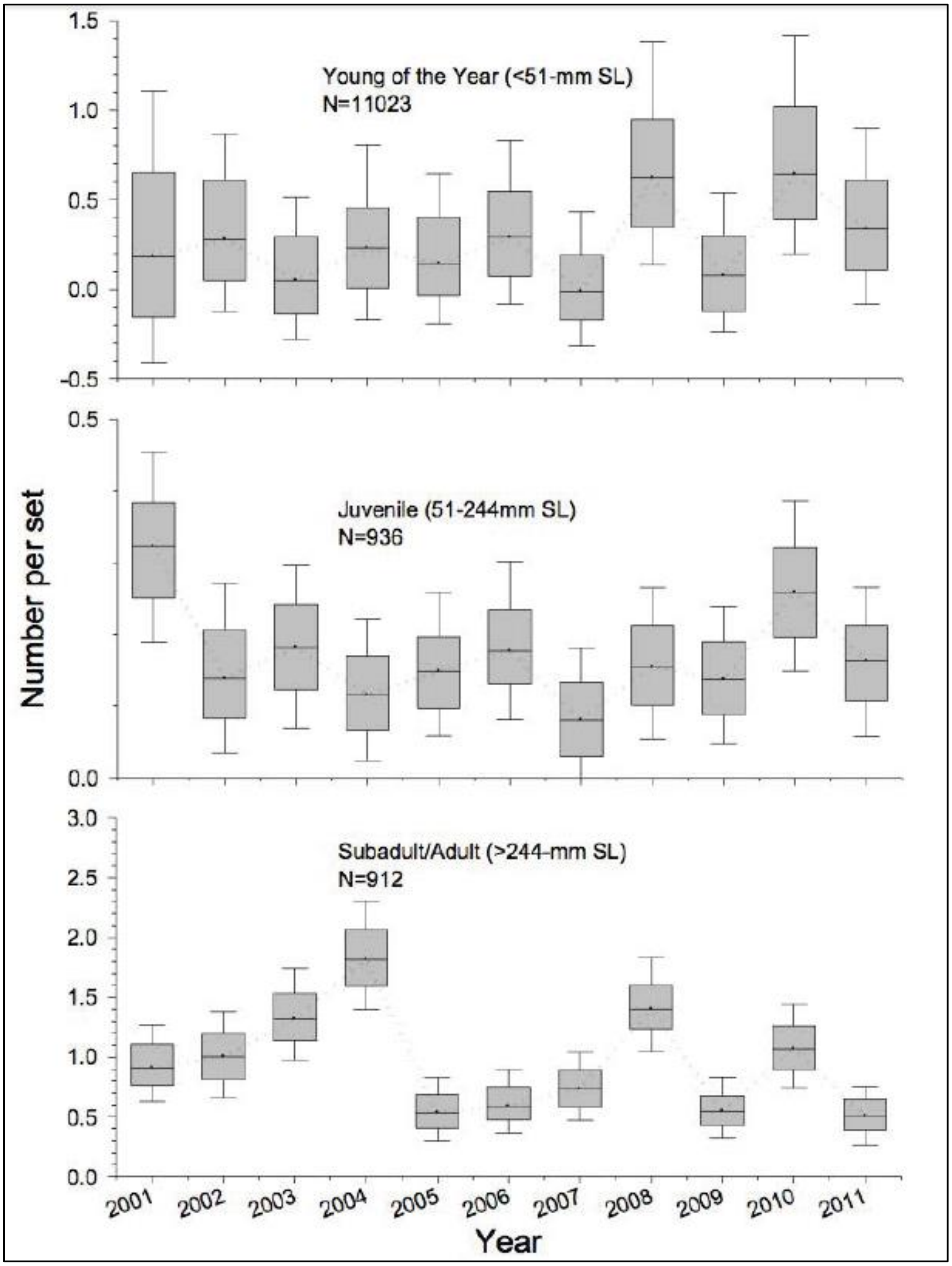

Figure N-4. Number of young of the year, juveniles, and subadults/adults of striped mullet caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012).

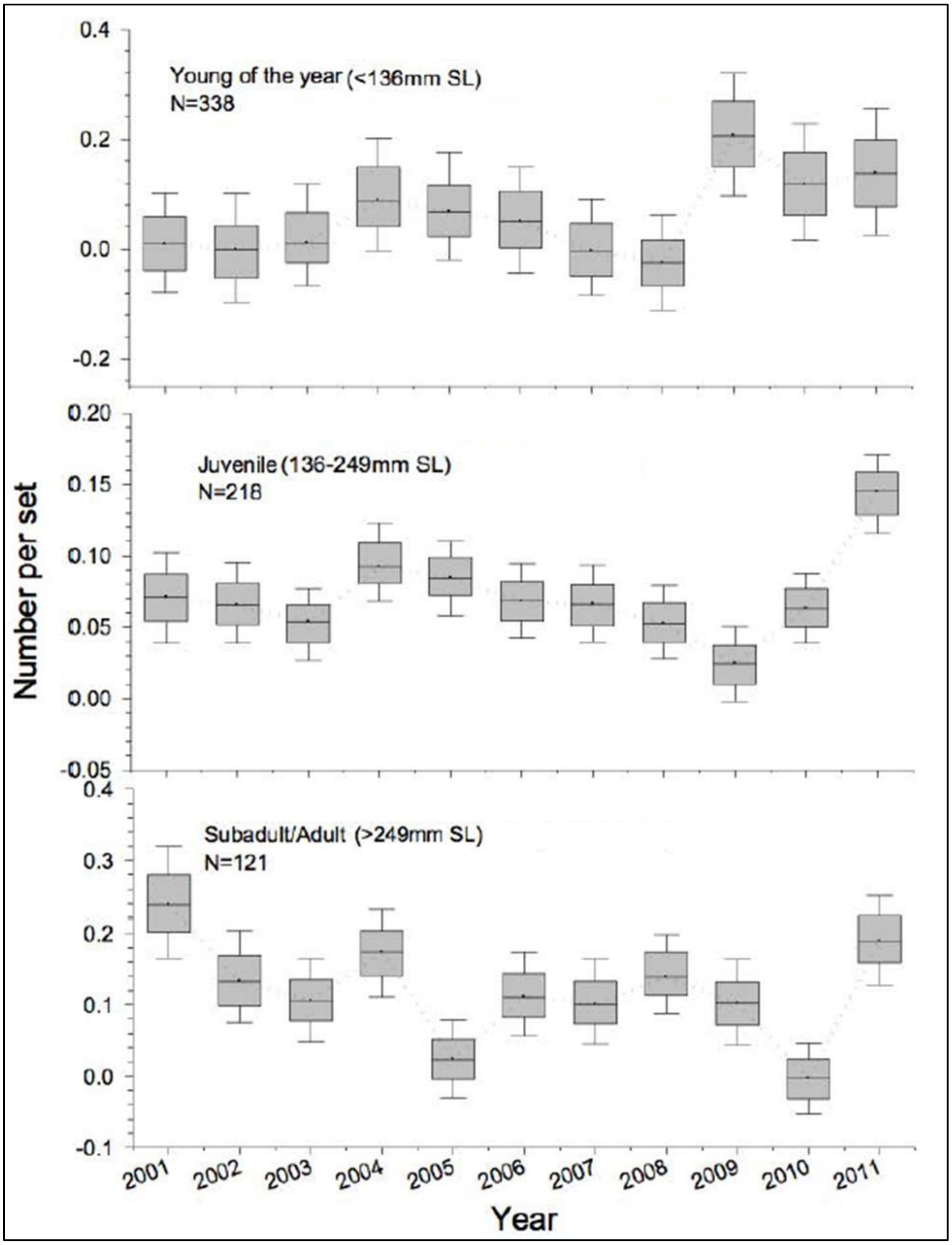

Figure N-5. Number of young of the year, juveniles, and subadults/adults of southern flounder caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012).

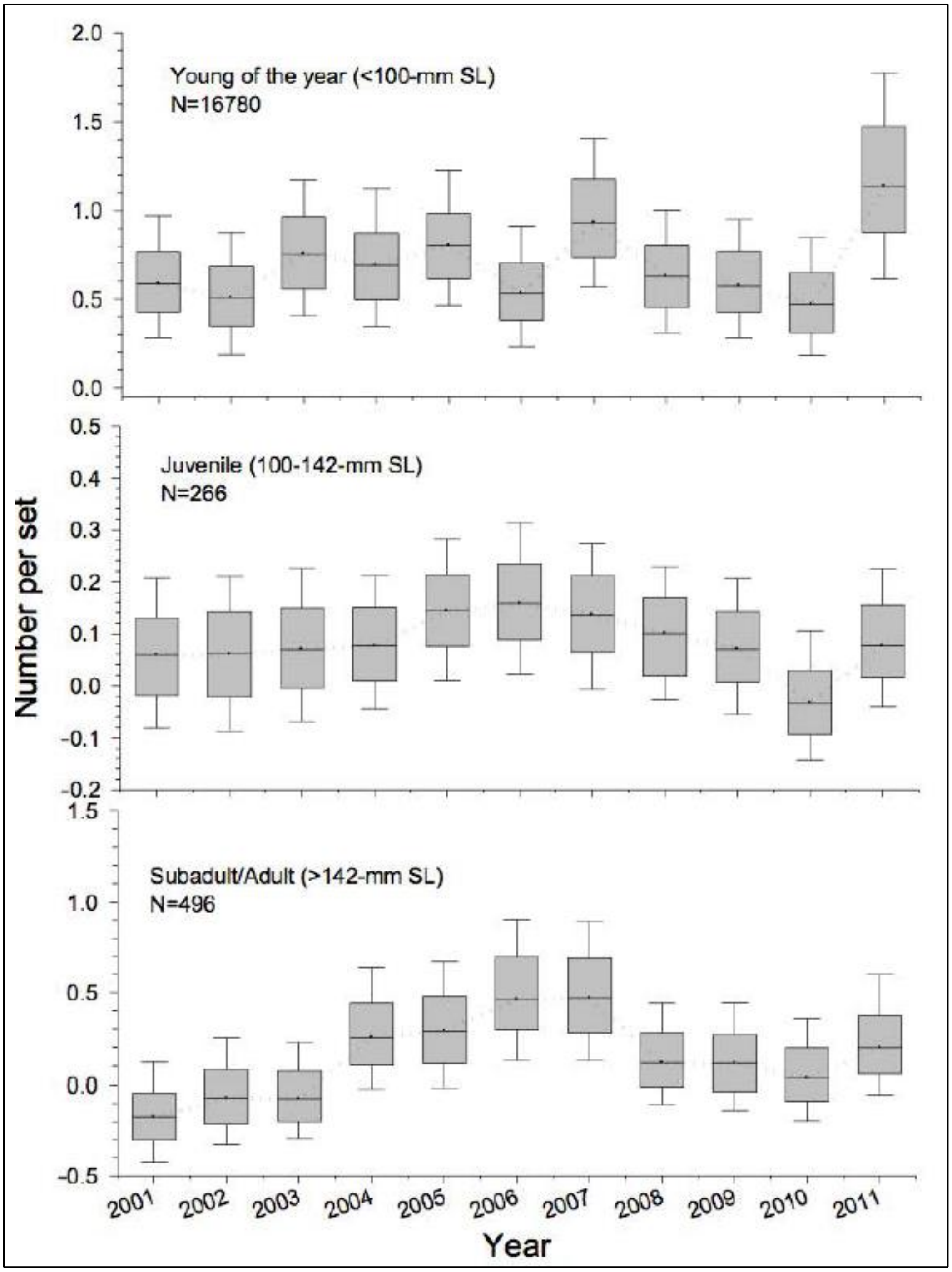

Figure N-6. Number of young of the year, juveniles, and subadults/adults of Atlantic croaker caught within the lower basin of the St. Johns River from 2001–2011 (reproduced from UNF and JU 2012).

Appendix O. City of Jacksonville water quality monitoring results, 2012–2016

Figures O-1 through O-15 show water quality monitoring results. Source: Rinehart et al. 2013, Wright and Mockus 2015, and Hynds and Starkey 2019.

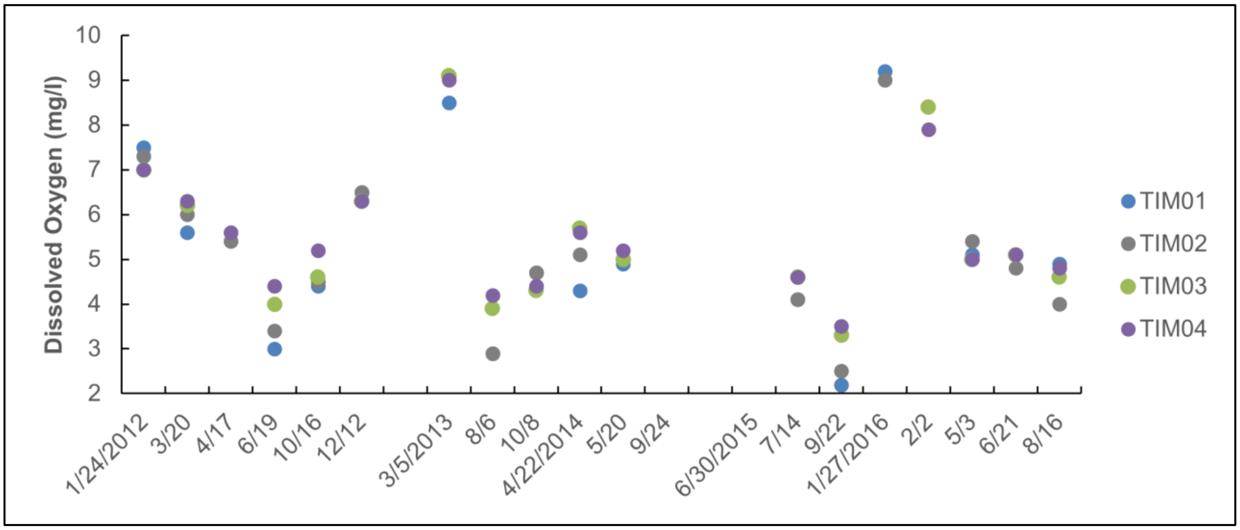

Figure O-1. Dissolved oxygen observations at TIMU stations, 2012–2016 (poor condition <2 mg/l, good condition >5 mg/l). For station locations, see Figure 65.

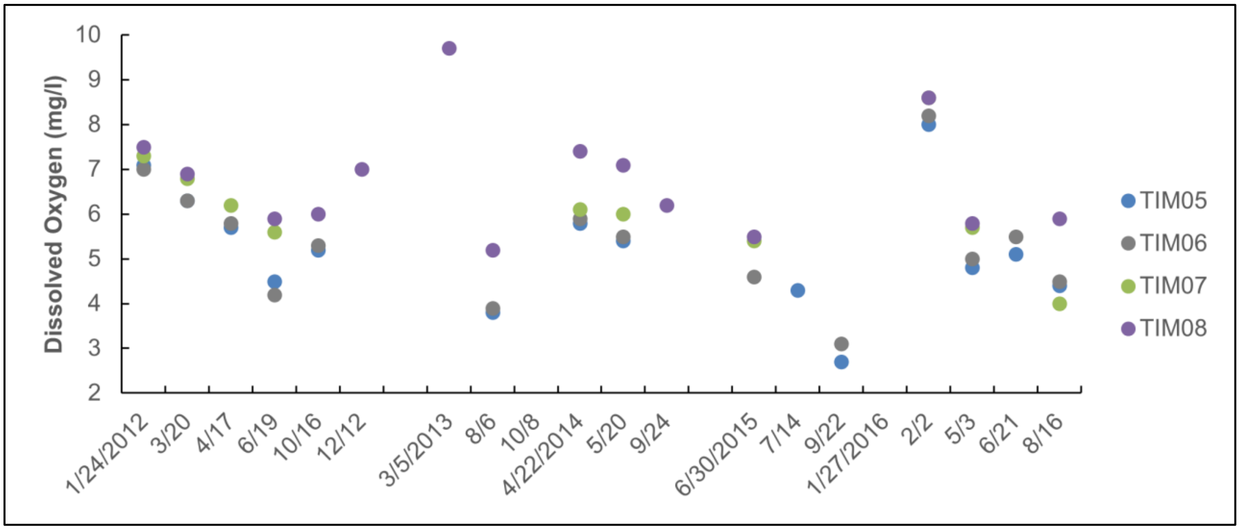

Figure O-2. Dissolved oxygen observations at TIMU stations, 2012–2016 (poor condition <2 mg/l, good condition >5 mg/l). For station locations, see Figure 65.

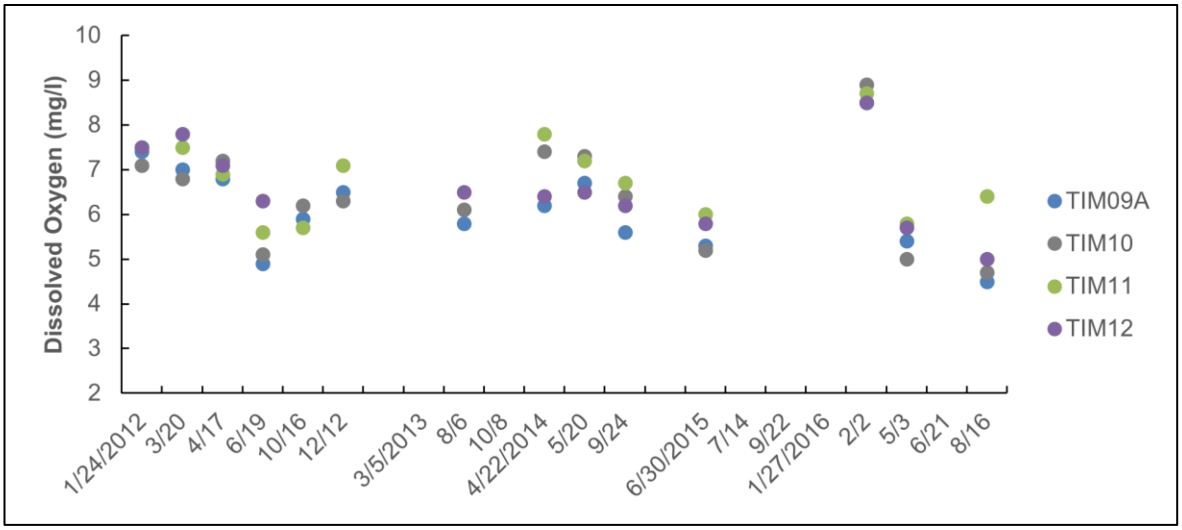

Figure O-3. Dissolved oxygen observations at TIMU stations, 2012–2016 (poor condition <2 mg/l, good condition >5 mg/l). For station locations, see Figure 65.

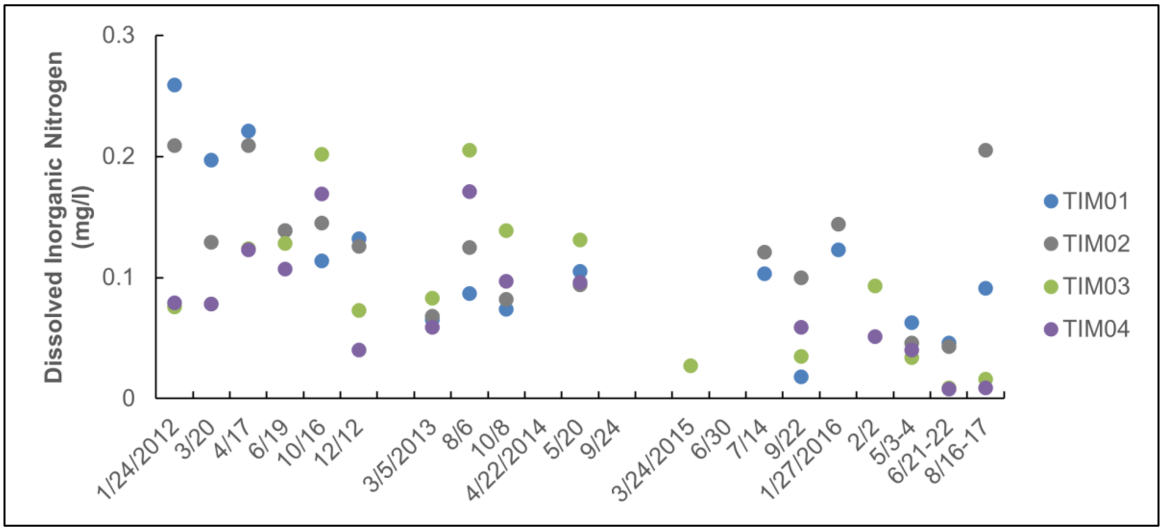

Figure O-4. Dissolved inorganic nitrogen observations at TIMU stations, 2012–2016 (poor condition >0.5 mg/l, good condition <0.1 mg/l).

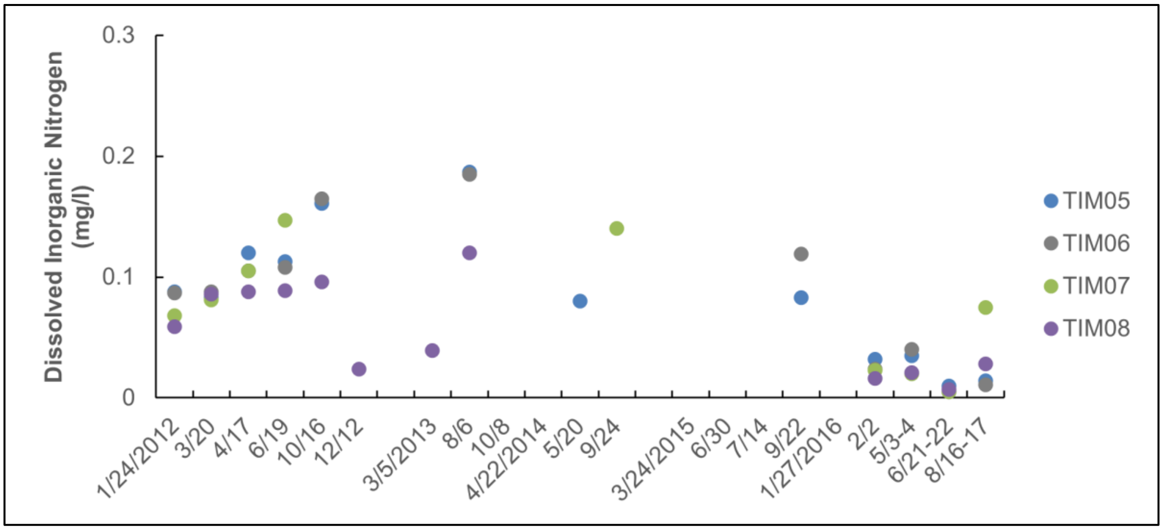

Figure O-5. Dissolved inorganic nitrogen observations at TIMU stations, 2012–2016 (poor condition >0.5 mg/l, good condition <0.1 mg/l).

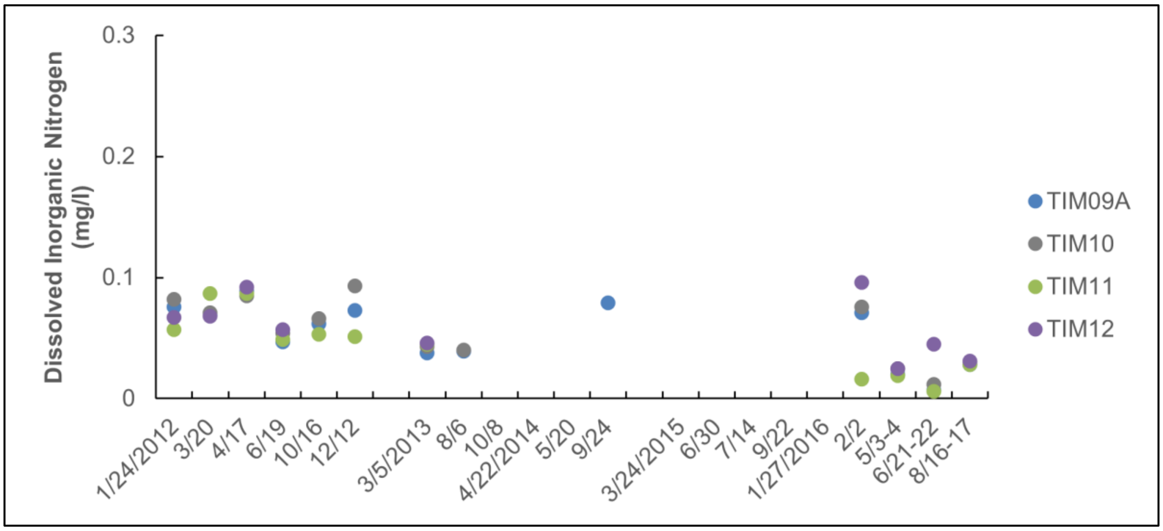

Figure O-6. Dissolved inorganic nitrogen observations at TIMU stations, 2012–2016 (poor condition >0.5 mg/l, good condition <0.1 mg/l).

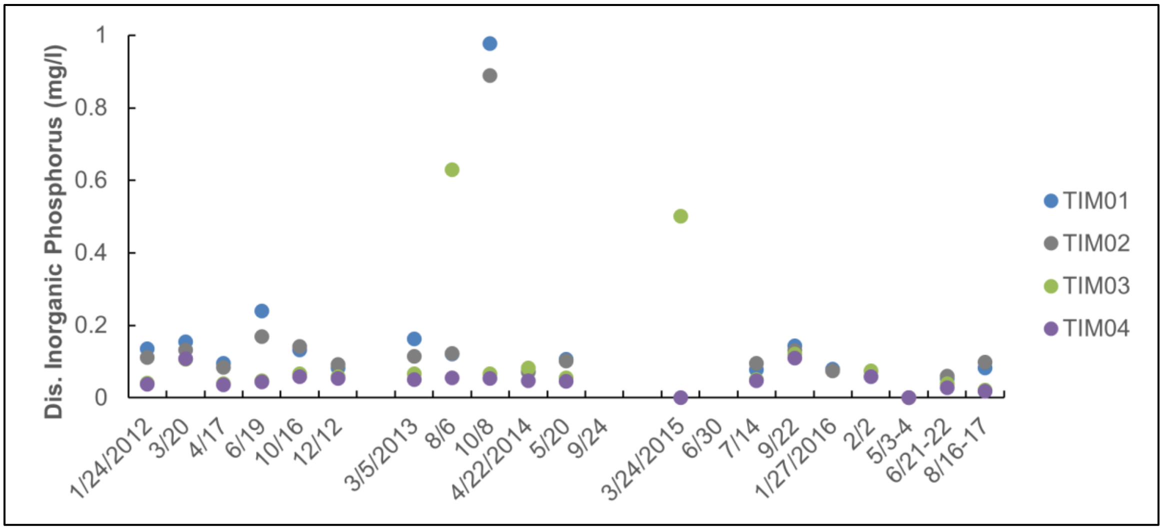

Figure O-7. Dissolved inorganic phosphorus observations at TIMU stations, 2012–2016 (poor condition >0.05 mg/l, good condition <0.01 mg/l).

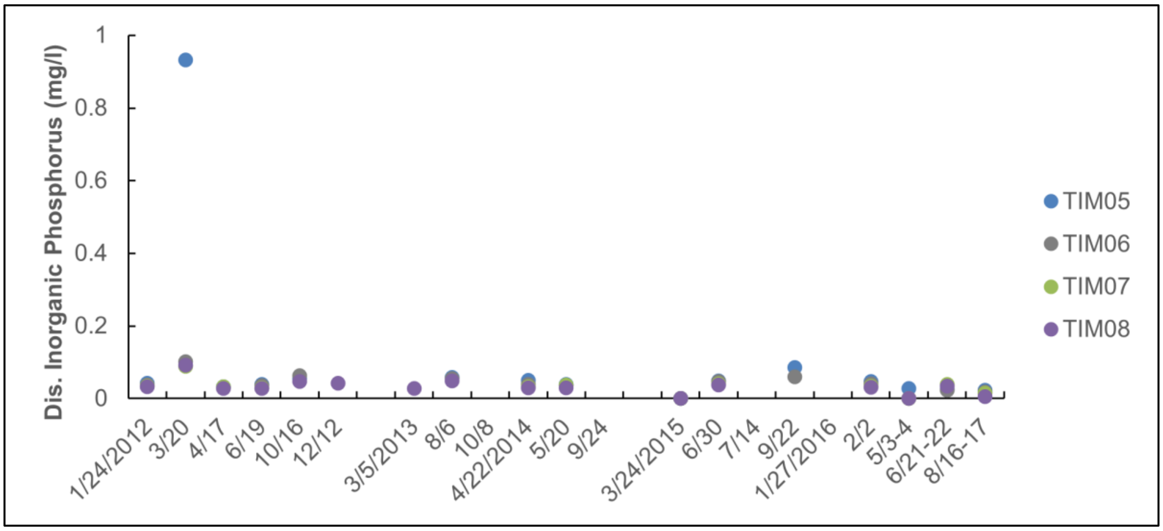

Figure O-8. Dissolved inorganic phosphorus observations at TIMU stations, 2012–2016 (poor condition >0.05 mg/l, good condition <0.01 mg/l).

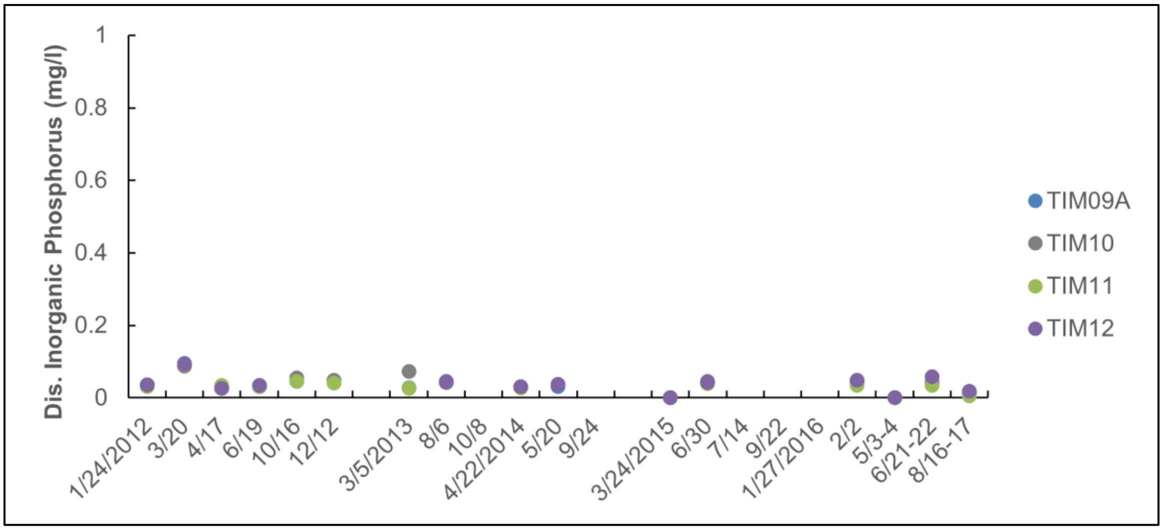

Figure O-9. Dissolved inorganic phosphorus observations at TIMU stations, 2012–2016 (poor condition >0.05 mg/l, good condition <0.01 mg/l).

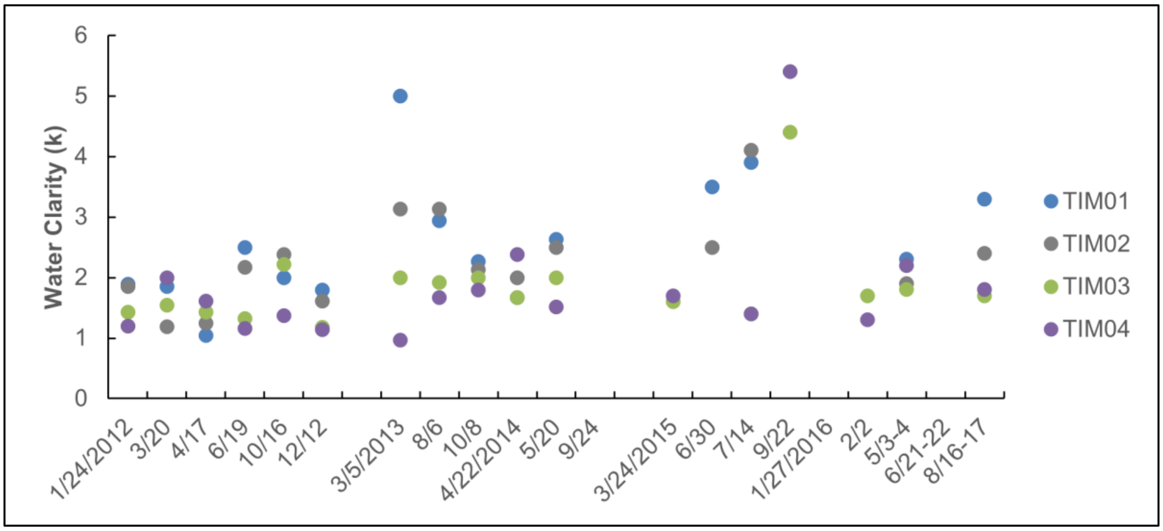

Figure O-10. Water clarity observations at TIMU stations, 2012–2016. For station locations, see Figure 65 (poor condition >2.30, good condition <1.61).

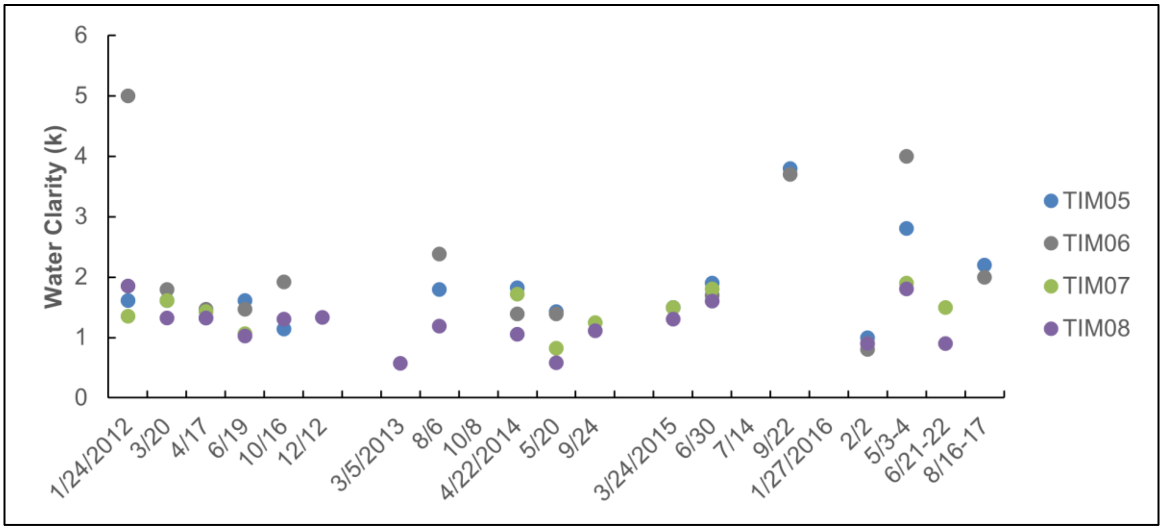

Figure O-11. Water clarity observations at TIMU stations, 2012–2016. For station locations, see Figure 65 (poor condition >2.30, good condition <1.61).

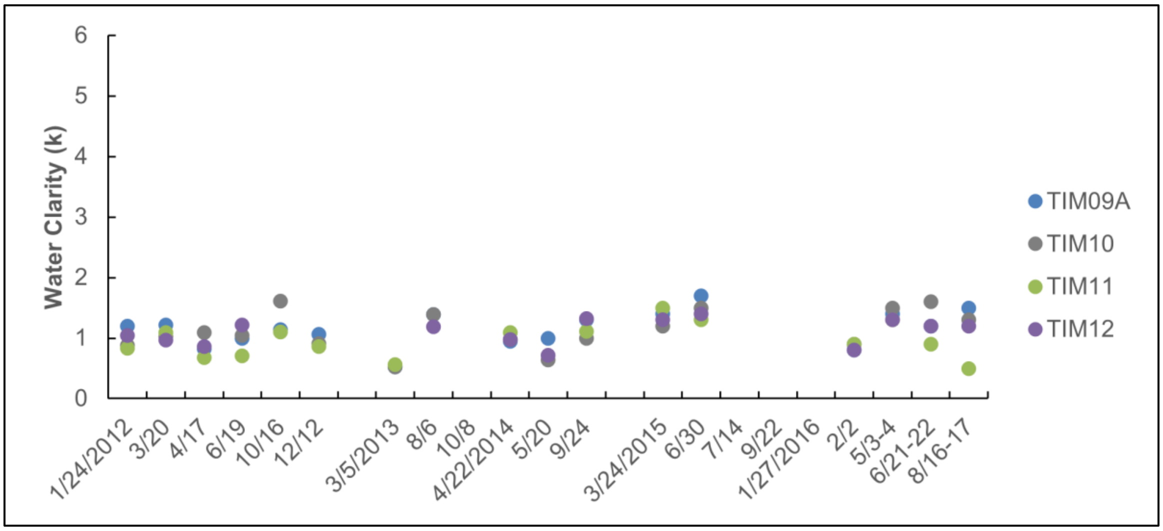

Figure O-12. Water clarity observations at TIMU stations, 2012–2016. For station locations, see Figure 65 (poor condition >2.30, good condition <1.61).

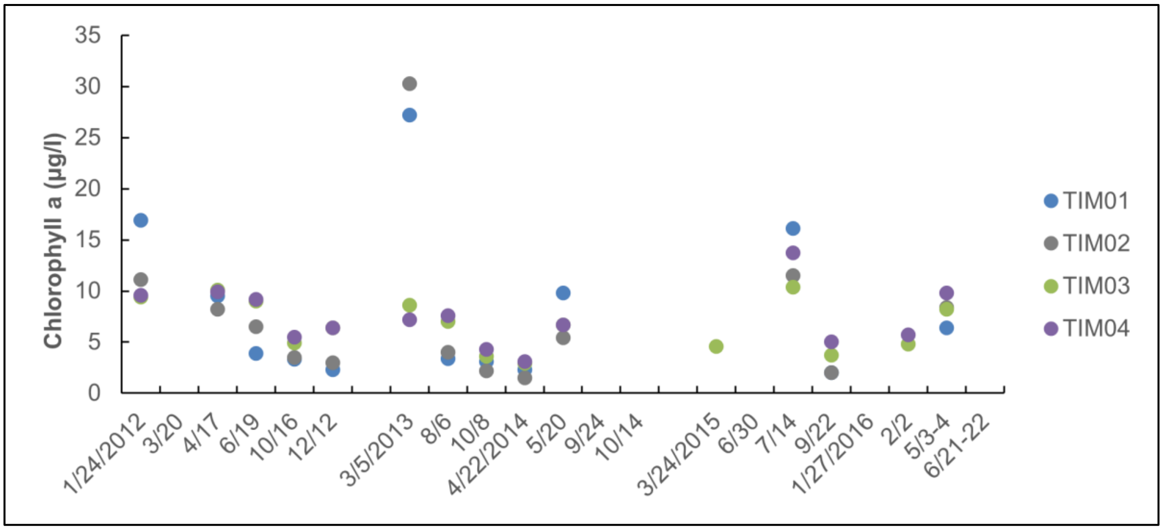

Figure O-13. Chlorophyll a observations at TIMU stations, 2012–2016 (poor condition >20 µg/l, good condition <5 µg/l).

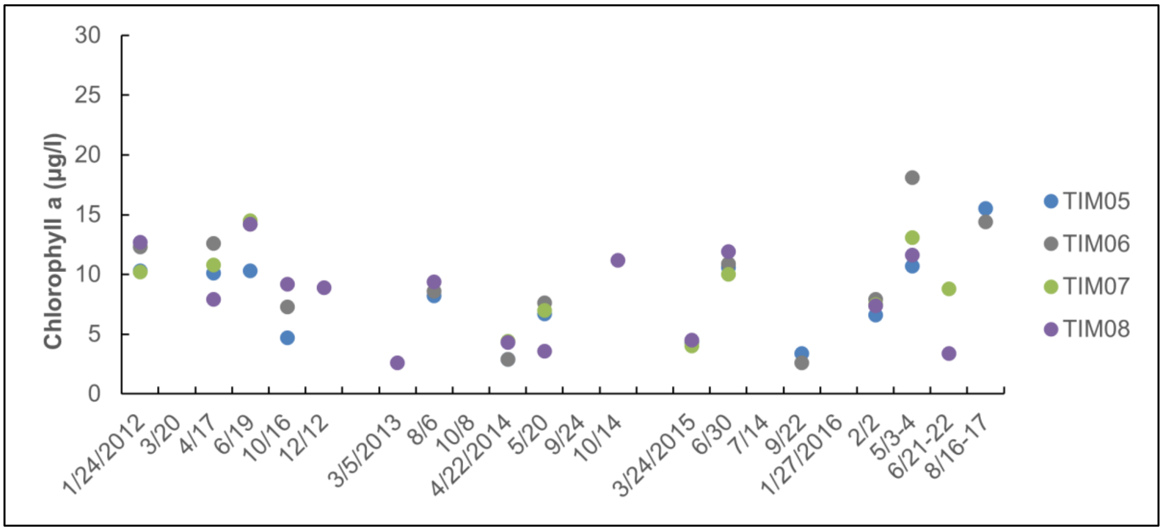

Figure O-14. Chlorophyll a observations at TIMU stations, 2012–2016 (poor condition >20 µg/l, good condition <5 µg/l).

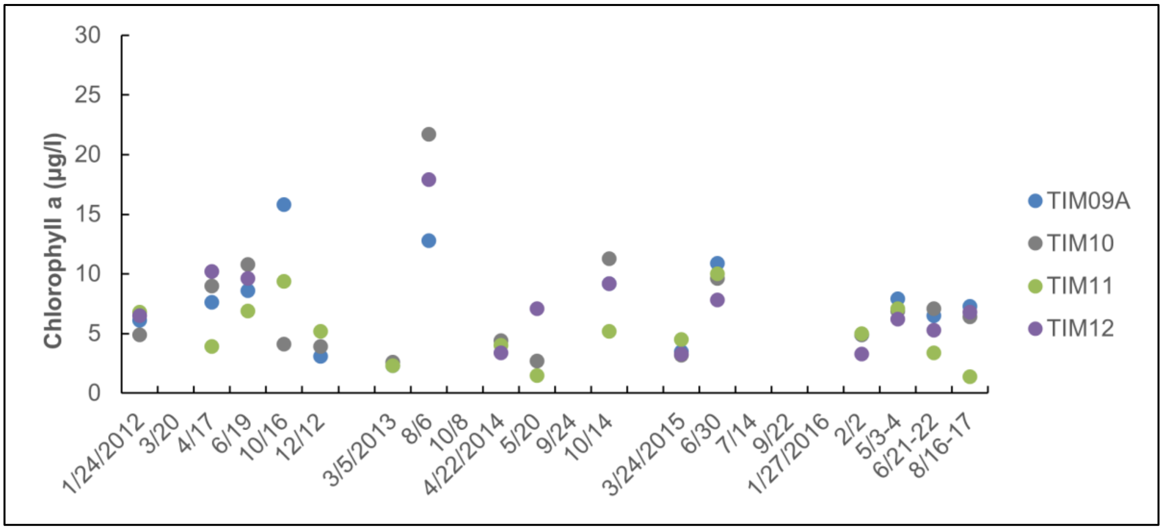

Figure O-15. Chlorophyll a observations at TIMU stations, 2012–2016 (poor condition >20 µg/l, good condition <5 µg/l).

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