National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Everglades National Park

Natural Resource Report NPS/EVER/NRR—2019/1991





ON THIS PAGE
Lightning strikes over a river of grass.
Photograph by: Judd Patterson taken in Everglades National Park

ON THE COVER
An osprey lands on its nest to visit a nestling.
Photograph by: Judd Patterson

Natural Resource Condition Assessment

Everglades National Park

Natural Resource Report NPS/EVER/NRR—2019/1991

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

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Many sections contain data that were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

Publisher's Note: Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions. For this report, most or all of the data discovery and analyses occurred during the period of 2014 to 2016. Thus, park conditions reported in this document pertain to that time period. Due to revised publishing requirements and/or scientific delays, this report was not published until 2019.

The Natural Resource Condition Assessment for Everglades National Park provides clear evidence of both the tremendous quantity of valuable natural resources that are present in the park and the scale of the challenges that natural resource managers must face in order to protect and preserve the condition of these natural resources for the enjoyment of future generations. Everglades National Park sits at the downstream end of what was once a 250-mile long watershed. Water once flowed uninterrupted from the headwaters of the Kissimmee River, through Lake Okeechobee, into the Everglades basin, and through to Florida Bay. The reallocation of water resources to support human development began in the 1880's with little thought about the consequences to the ecology of the region. This pattern of development continued into the 1970's, until the ecological consequences of drainage became so widespread and severe that the discussion of watershed scale restoration became an implicit and inseparable part of the discussion of continued societal and economic development.

The Okeechobee and Everglades basins are currently in the early stages of being reconnected. The restoration of the Kissimmee watershed has been extensive. Inflows into Everglades National Park are being redirected into northeastern Shark Slough, a good step towards addressing the most severe challenge that faces the park. This report provides a comprehensive assessment of what we know about the status of natural resources in Everglades National Park. The desired state of conservation for each category of natural resource is clearly defined in this report. The path toward achieving these goals is not addressed by this report; instead, the critical path toward a restored ecosystem must emerge from a broadly inclusive discussion among those stakeholders who are invested in both the social and ecological systems that are founded on the broad set of natural resources that are assessed here. This report is intended to support the broad discussion about how to achieve restoration without being prescriptive.

Every aspect of the Everglades ecosystem that was assessed in this report reveals evidence of challenges associated with human activities. This is not surprising; given the historical context that led to the establishment of EVER, the rapidly expanding human population that now exceeds 7.5 million people within 100 miles of the park boundary, and the position of the park at the downstream end of a large watershed – where cumulative impacts of upstream water diversions are most severe. The watersheds that define around 60% of the area of Everglades National Park are "worse than average", and these areas are being targeted for improvement by the Comprehensive Everglades Restoration Plan (CERP). Climate change and challenges associated with air quality are affecting all parts of the park. Exotic organisms present a profound challenge to preserving the biodiversity of the park. The native organisms present in EVER clearly thrive when consecutive years of higher-than-average rainfall occur, but multi-year improvements quickly vanish when a severe drought occurs.

This assessment clearly documents a continuing decline of prey base fish, tree islands, and seagrasses in central Florida Bay, and peat soils - as a direct consequence of low rainfall interacting with the existing design of the regional water management infrastructure. While progress has occurred, the results of this assessment are clear: **much progress remains to be accomplished** before the most severely negative ecological impacts in Everglades National Park are corrected and the natural resources present in the park are being effectively preserved "…in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (Organic Act of 1916).

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List of Terms

Estuary (noun) – The wide lower course of a river where it flows into the sea. Estuaries experience tidal flows and their water is a changing mixture of fresh and salt

Extirpate (verb) - to remove or destroy totally

Hypersaline (adjective) - body of water which exhibits levels of dissolved salts that exceed seawater (e.g., greater than 35 grams per liter)

Sound (noun) - a long broad passage of the ocean that parallels the coast and connects two waterbodies

Prologue

Publisher's note: Many sections in this report have been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." These reports were written as a requirement by the World Heritage Committee with the 2013 State of Conservation Report companion manuscript. Text, figures, and tables are similar or identical to that of the Indicators of Integrity report, and some text is also found in the State of Conservation report. The sections taken from the 2013 reports are denoted with a publisher's note in the beginning of the section.

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." 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 Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- 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.

Chapter 2: Introduction and Resource Setting

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2.1. Enabling legislation, Legal Foundation, and Park Establishment Timeline

The Everglades National Park (referred to subsequently as EVER, Everglades NP, ENP, or the park) was authorized on May 30, 1934. The Public Law (48 Statute 816) that effected this action is entitled "An Act To provide for the establishment of the Everglades National Park in the state of Florida and for other purposes." Actual dedication of the 460,000 acres of park lands with legally designated boundaries did not occur until 1947. The Great Depression, World War II, and the process of arriving at a fair value of the lands that were owned by private individuals were challenges that required resolution prior to formal establishment. An expansion of the boundaries to cover 1.4 million acres occurred by 1958, and the "Everglades National Park Protection and Expansion Act of 1989" (Public Law 101-229) added approximately 109,600 acres to the park 41 years later. The lands incorporated in the most recent expansion are known as the "East Everglades Addition Lands" or alternatively as "northeastern Shark Slough" and define the northeastern corner of the park.

The Everglades National Park is the first national park intended foremost to protect biology. Over 100 units of the NPS existed prior to the authorization of Everglades in 1934, but those units were largely singled out for protection under the desire to safeguard geologic curiosities, sweeping vistas, and resources of historic or cultural value. Harry Truman identified the biological value of the Everglades during the address that dedicated the Everglades National Park on December 6, 1947:

> *"In this park we shall preserve tarpon and trout, pompano, bear, deer, crocodiles and alligators--and rare birds of great beauty. We shall protect hundreds of all kinds of wildlife which might otherwise soon be extinct…*
>
> *These are the people's parks, owned by young and old, by those in the cities and those on the farms. Most of them are ours today because there were Americans many years ago who exercised vision, patience, and unselfish devotion in the battle for conservation.*
>
> *Each national park possesses qualities distinctive enough to make its preservation a matter of concern to the whole Nation. Certainly, this Everglades area has more than its share of features unique to these United States. Here are no lofty peaks seeking the sky, no mighty glaciers or rushing streams wearing away the uplifted land. Here is land, tranquil in its quiet beauty, serving not as the source of water but as the last receiver of it. To its natural abundance we owe the spectacular plant and animal life that distinguishes this place from all others in the country"* (Truman 1947).

Conservation and protection of the unique organisms, the vast expanse of wetland, and the wilderness value of the area have been the predominate themes associated with Everglades National Park. These themes were captured first in the enabling legislation drafted in 1934:

> *"The said area or areas shall be permanently reserved as a wilderness, and no development of the project or plan for the entertainment of visitors shall be undertaken which will interfere with the preservation intact of the unique flora and fauna and the essential primitive natural conditions now prevailing in this area."* (Public Law 48 Stat 816, section 4)

As the boundaries of the park were expanded, the focus of preservation and protection were reiterated. Section 103 of the "Everglades National Park Protection and Expansion Act of 1989" (Public Law 101-229) advises the Secretary of the Interior to:

> *"…utilize such other statutory authority as may be available to him for the preservation of wildlife and natural resources as he deems necessary to carry out the purposes of this Act."*

and proceeds to identify protection of the ecosystem as a key aspect of park administration:

> *"The Secretary shall manage the park in order to maintain the natural abundance, diversity, and ecological integrity of native plants and animals, as well as the behavior of native animals, as a part of their ecosystem."* (Public Law 101-229)

2.1.1. Wilderness

Everglades National Park contains the Marjory Stoneman Douglas Wilderness Area – the largest contiguous area designated as wilderness east of the Mississippi River (Draft Everglades National Park General Management Plan 2013). The concept of Wilderness was identified in the enabling legislation for EVER (referenced above). Congress formally defined wilderness in 1964 through the Wilderness Act (Public Law 88-577):

> *"(c) A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."*

Fourteen years later (1978), Public Law 95-625 officially designated "approximately 1,296,500 acres…to be known as the Everglades Wilderness."

The current status of Everglades National Park is profoundly shaped by the dominant historical themes of patient conservation, restoration, and wilderness. During the 13-year period between authorization (1934) and establishment (1947), a "Wildlife Reconnaissance" report (Beard 1938) was developed to document the climatic and physical context of the proposed park. In his report, Daniel Beard identified some of the issues that have become enduring management concerns in the region (e.g., extreme fire behavior, shifts in water patterns due to canal building) and became the park's first Superintendent.

2.1.2. Other important laws, projects, and international recognition

There is a long list of laws, projects, and international conventions that drive natural resource management in EVER. The Endangered Species Act (1973), the Fishery Conservation and Management Act (1976), the Clean Water Act (1972), and the Clean Air Act (1970) provide important legal frameworks for focusing collaborative monitoring with the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the US Fish and Wildlife Service (USFWS). The Central and Southern Florida Project established the regional system of water management infrastructure as a result of a series of Congressional actions - called River and Harbor Acts - between 1948 and 1974. These projects have been modified on an ongoing basis through Water Resource Development Acts (the USFWS maintains a website of the original text of these Congressional actions). This regional network of canals and levees has been instrumental in making large areas of the region suitable for agriculture and economic development. The Comprehensive Everglades Restoration Plan (hereafter referred to as CERP) is the current legal and political framework for reconciling the various laws, economic interests, and cultural values that have strong influence over the condition of the park.

The Everglades is recognized worldwide for its biological value. The Convention on Wetlands of International Importance (known as the Ramsar convention) is the only global environmental treaty that addresses wetlands specifically, and it lists the Everglades among the world's prized wetlands. UNESCO - the United Nations Educational, Scientific, and Cultural Organization – is another international organization that has identified Everglades National Park as biologically important. UNESCO identifies the park as a World Heritage Site and an International Biosphere Reserve. For all of the laws, recognition, and extensive discussions about how best to restore the Everglades ecosystem, the Organic Act of 1916 – which established the National Park Service – simply and effectively states the management goal of the National Park Service:

> *"The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."* (16 U.S.C. l, 2, 3, and 4)

When one reviews the number of legal frameworks that are used to support management decisions in the park it is clear just how challenging it has become to meet the simple, enduring goal of leaving an area "…unimpaired for the enjoyment of future generations".

2.1.3. Restoration

The restoration of the Greater Everglades Ecosystem is an essential task that defines much of the administrative function and fulfills the legal foundation of the Everglades National Park. Section 104 of the Everglades National Park Protection and Expansion Act of 1989 identifies key areas that are adjacent to the Everglades Addition Lands where modifications can be made through a process that includes the Secretary of the Army, the Governor of Florida, and the South Florida Water Management District. The Water Resources Development Act of 2000 provides the legal context for these actions, and the specific plan is commonly referred to as the Comprehensive Everglades Restoration Plan (or CERP).

The ecological functions of South Florida have been massively altered by the Army Corps of Engineers in cooperation with the state of Florida. Water diversions across basins, channelizing water flow into canals, draining areas to allow development and establishing flood control structures are now common actions in the region. These practices can have the unintended consequence of delivering nutrient enriched agricultural runoff water to natural areas, and driving the rapid deterioration of areas that were previously part of one of the largest continuous wetland in the western hemisphere. The CERP seeks to establish a new balance between natural protection and urban or agricultural development, and addresses the entire Everglades watershed, which includes Big Cypress National Preserve, Everglades National Park, Loxahatchee National Wildlife Refuge, and many other wilderness areas managed by the state of Florida. Much has been written about the CERP that will not be repeated in this NRCA, but aspects of the CERP that have affected the park, or are soon-to-be-established, are essential to this report.

2.2. Geography, Climate, and Biological Properties of Everglades National Park

2.2.1. Geography

A meaningful description of the geography of Everglades National Park includes a consideration of three different aspects of the area. First there is the park itself: its size, shape, and contours. Second is the mosaic of landscapes in which EVER is embedded through shared boundaries and overland corridors. Third is the broad regional context that is influenced by biogeography: coarse scale climate patterns (e.g., temperate vs. tropical), and the narrow peninsula that extends southward from a temperate continent into a warm Caribbean sea just north of the Tropic of Cancer. The first two aspects of geography (location and surrounding areas) are easily identified with maps and summary tables, while the third (broad regional context) requires a blended discussion of the relationship of geography with climate and ecology.

Everglades National Park covers over 1,506,000 acres (2,353 square miles) of southern Florida, with 1,530 square miles of land and 823 square miles of marine areas under protection (Figure 2.1). The marine portions of EVER are mostly shallow coastal zones. Marine zones begin in the northwestern corner of EVER, just east of the 10,000 islands area on the west coast of Florida and follow the

shoreline south to include Cape Sable - once south of Cape Sable the breadth of the marine protected area expands to over 28 miles from the coast and becomes estuarine throughout much of Florida Bay. The terrestrial portion of EVER is larger than the land area of Rhode Island, and is predominately a combination of freshwater wetlands, coastal saline marsh, and mangrove forest. EVER is contiguous with Big Cypress National Preserve, and the combined area of the NPS lands is nearly 2.3 million acres (3,541 square miles), an area larger than either Delaware or Puerto Rico. EVER is part of the Everglades Protection Area (consists of Water Conservation Area [WCA] 1, WCA2, WCA3), and together these wildlife management units cover 4,887 square miles, an area slightly larger than Connecticut. The Everglades Protection Area is a broad, flat floodplain, and the 10 feet of elevation change across the entire expanse of EVER is typical of the larger watershed which features ~14 feet of elevation change over the nearly 80 mile distance from the southern rim of Lake Okeechobee to the northern boundary of Florida Bay. This translates to an almost imperceptible slope of a few inches per mile as one travels from the northeastern corner of the park to the southwestern corner. Overlaid on this gradual sloping contour are irregular patterns of local elevation changes up to 3 feet that are recognizable due to clear shifts in vegetation.

Everglades National Park is connected to several other areas that are managed to support natural resources (Figure 2.2). These areas are owned by the state of Florida, the U.S. Federal Government, county governments, sovereign tribal nations, and non-governmental organizations (like the Nature Conservancy and Audubon Society, Table 2.1). The Florida Panther National Wildlife Refuge (41 mi^2), Fakahatchee Strand Preserve State Park (123 mi^2), and Picayune Strand State Forest (116 mi^2) define the western edges of this patchwork of managed areas. Rookery Bay National Marine Estuary Reserve (137 mi^2), Collier-Seminole State Park (11.4 mi^2), and Ten Thousand Islands National Wildlife Refuge (NWR) (54 mi^2) connect this western frontier to the shoreline and estuaries of the Gulf of Mexico. The northern boundary of the managed patchwork is defined by the Holey Land (55 mi^2) and Rotenberger (45 mi^2) Wildlife Management Areas (WMAs), Everglades Agricultural Area Lands (~82 mi^2 of land designated for future flow equalization basins, storm water treatment area expansion, and potentially other wildlife supporting uses), the existing storm water treatment areas (74 mi^2), and a portion of the River of Grass Lands located in Hendry County (~30 mi^2). The southern and eastern frontier of the core natural area is bounded by two wildlife management areas southeast of Everglades National Park: Southern Glades WMA (46 mi^2) and South Dade Wetlands (73 mi^2). Buffer lands are interspersed along the eastern boundary of the wildlife management areas (89 mi^2). In this broadly defined patchwork of managed areas, the Everglades National Park is a central feature of a nearly continuous 6,913 mi^2 expanse of lands and marine areas that are managed with some aspect of natural resource management in mind. A more exhaustive list of wildlife areas is available from the Florida Natural Area Inventory. An extraction of the preserved lands south of Lake Okeechobee identifies over 8,500 mi^2 of land and marine areas identified as natural areas (Figure 2.2). The acquisition of this network of protected lands, bays, and marine preserves is a tremendous achievement, and while many of South Florida's natural resources are in precarious conditions, the future for this region could yield many broadly shared, positive environmental developments among species (including humans) if this large set of preserved areas are managed together to effectively nurture ecological functions.

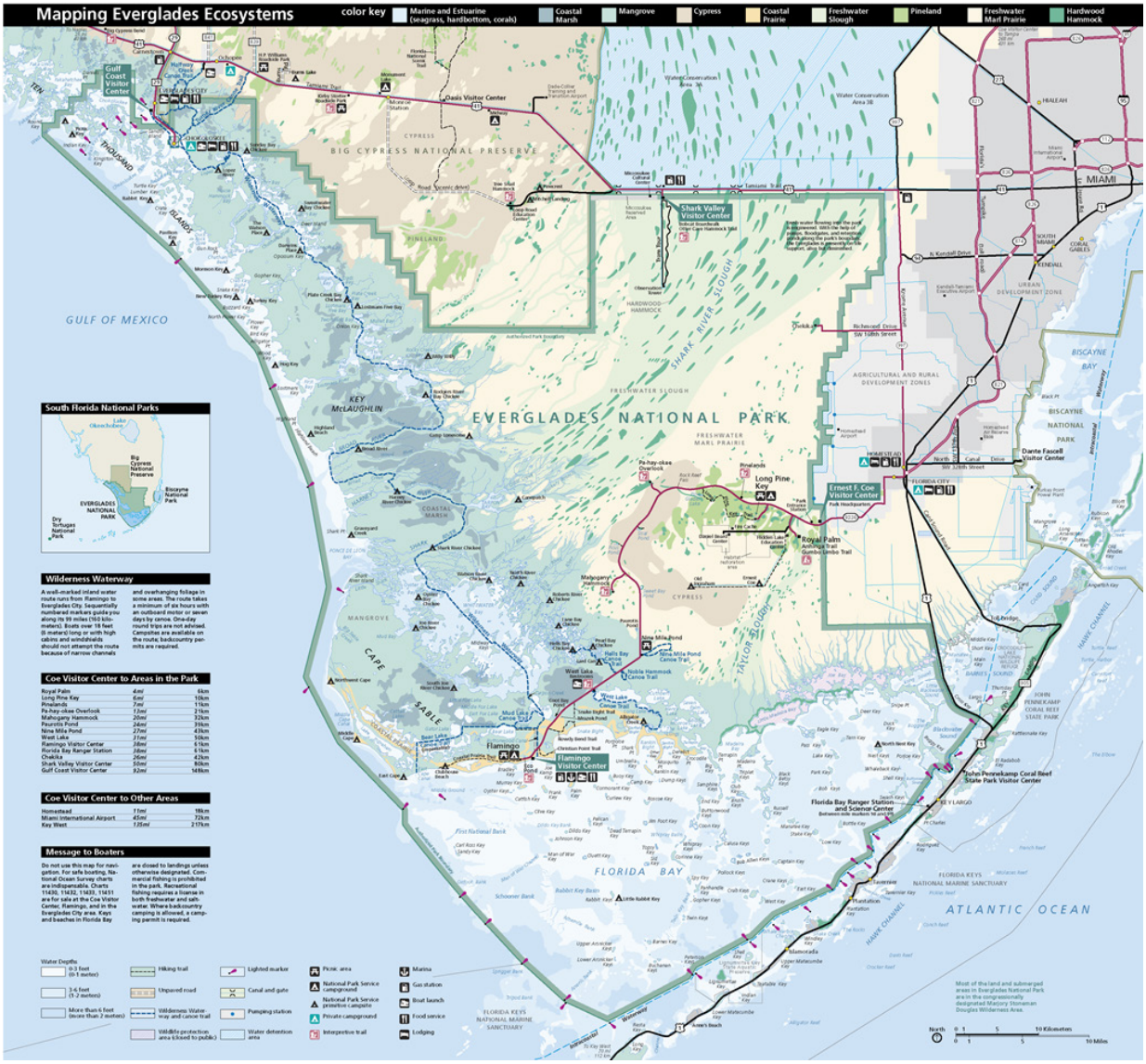


Figure 2.1. A general depiction of the geographical and ecological features of Everglades National Park. This map is reprinted with the permission of the National Park Service, and is part of the “Harpers Ferry” series of maps that are shared with visitors to many National Parks.

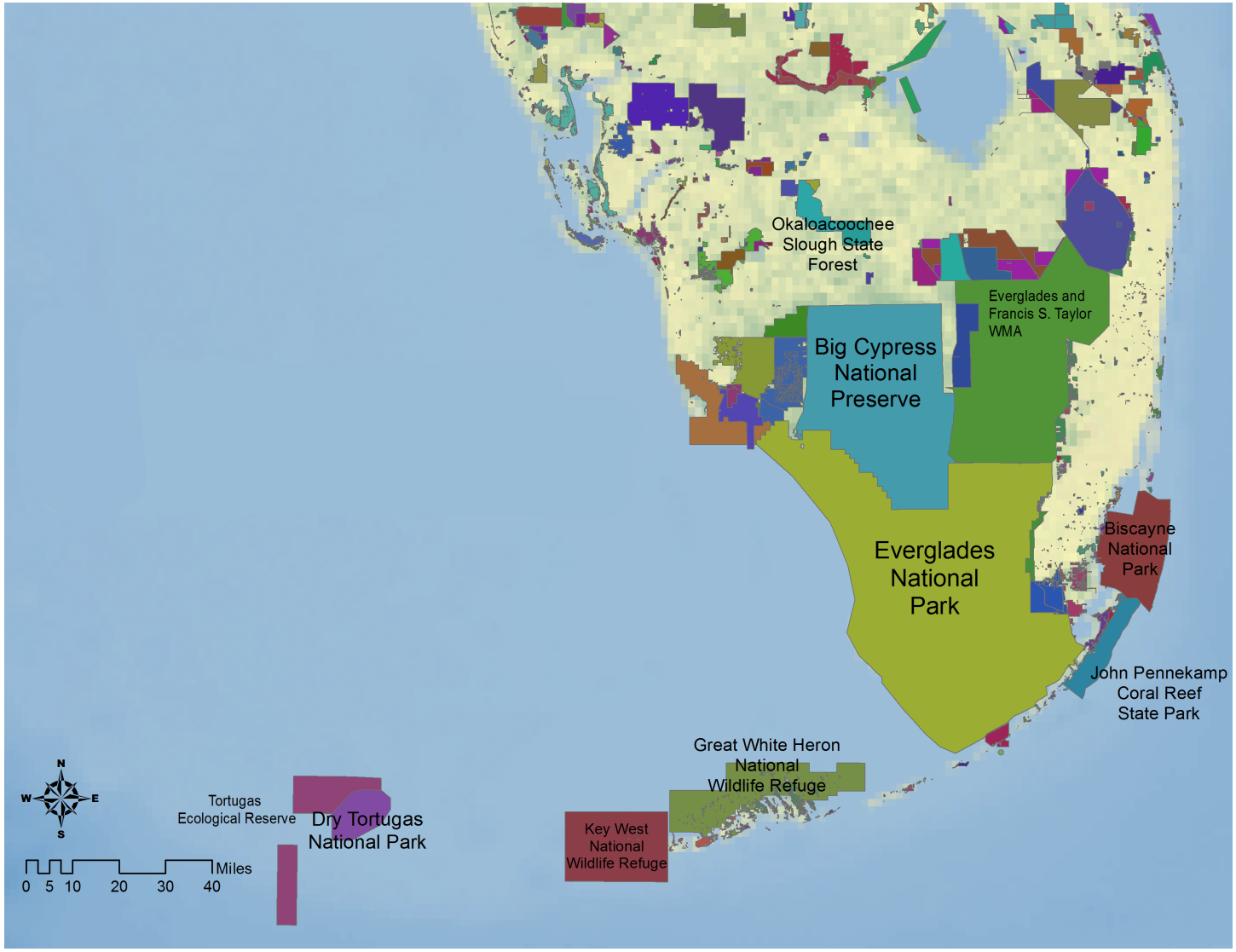


Figure 2.2. Areas in southern Florida where natural resource management is a priority for the owners. Over 8,500 square miles of land, coastal, and marine areas are identified in this figure. The information represented here was aggregated by the Florida Natural Areas Inventory (FNAI) and includes areas managed by municipalities, the state of Florida, and the U.S. Federal Government.

Table 2.1. Natural areas of southern Florida that are part of the same watershed as Everglades National Park. Areas listed in order of size.

Name	Area (mi^2)	Land Owner	Land Manager
Everglades National Park	2,353	U.S. DOI, National Park Service	National Park Service
Big Cypress National Preserve	1,139	U.S. DOI, National Park Service	National Park Service
Everglades and Francis S. Taylor WMA (WCA2 and WCA3)	1,052	SFWMD[a]	FL FWCC[c]
Loxahatchee National Wildlife Refuge	220	U.S. DOI, Fish and Wildlife Service	U.S. Fish and Wildlife Service
Miccosukee Indian Reservation	123	Miccosukee Indian Tribe	SFWMD[a]/Miccosukee
Fakahatchee Strand Preserve State Park	121	Florida DEP[d]	FL DEP, Div. of Rec. and Parks[e]
Picayune Strand State Forest	116	Florida DEP[d]	FDACS, FFS[f]
East Coast Buffer Lands	89	SFWMD[a]	SFWMD[a]
Big Cypress Seminole Indian Res.	85	Seminole Indian Nation	Seminole Indian Nation
South Dade Wetlands	73	Miami-Dade County	Miami-Dade DERM EEL[b]
Holey Land WMA	56	Florida DEP[d]	FL FWCC[c]
Rotenberger WMA	48	Florida DEP[d]	FL FWCC[c]
Southern Glades WMA	47	SFWMD[a]	SFWMD[a]
Florida Panther National Wildlife Refuge	41	U.S. DOI, Fish and Wildlife Service	U.S. Fish and Wildlife Service

[a] SFWMD: South Florida Water Management District;

[b] Miami-Dade DERM EEL Program: Miami-Dade Department of Environmental Resource Management Environmentally Endangered Lands Program;

[c] FL FWCC: Florida Fish and Wildlife Conservation Commission;

[d] Florida DEP: Trustees of the Internal Improvement Trust Fund was established in 1855 and are now a component of Florida's Department of Environmental Protection (FDEP) (source http://digitalcollections.fiu.edu/iif/about.htm visited 3/15/2013);

[e] FL DEP, Div. of Rec. and Parks : FL Department of Environmental Protection, Div. of Recreation and Parks;

[f] FDACS, FFS: Florida Department of Agriculture and Consumer Services – Florida Forest Service (a division within FDACS).

2.2.2. Climate

The southern tip of the Florida peninsula defines the transition from the seasonally cold, temperate, North America to the subtropical Caribbean (Figure 2.3). Snow is an extraordinarily rare occurrence in the park, and temperatures fall below freezing less than a few days per decade. Offshore breezes drive the predominant climate pattern in the region. These breezes reduce summer temperatures along the coast and ensure predictable daily rainfall pattern in the interior during the summer season (Byers and Rodebush 1948). Everglades National Park has received ~55.6 in of rain per year on average over the last 10 years, with ~44.5 in falling during the six month long wet season: May 1 – October 31, and ~12 in falling during the six month long dry season: November 1 – April 30 (sources: http://www.gohydrology.org/p/rain.html, accessed July 15, 2013, and Royal Palm rainfall station in EVER). Regular rainfall during the summer months combines with periodic tropical storm systems and flat topography to produce an expansive region of seasonally flooded, humid environments during the wet season (Figure 2.4). Annual rainfall amounts vary from 37–85 in annually (based on the 60 year record from Royal Palm hammock), so the dry seasons that occur each year can vary quite a bit in severity. Temperatures reported from Florida City (a municipality near EVER) normally range from 54˚ to 90˚ F, and rarely exceed 94˚ F or fall below 44˚ F. Muggy conditions prevail from mid-March through mid-December, when relative humidity regularly exceeds 90%.

Tropical storms and hurricanes can occur any year, and eleven hurricanes have impacted southern Florida since 1980 (Floyd 1987, Andrew 1992, Erin 1995, Georges 1998, Irene 1999, Charley 2004, Frances 2004, Jeanne 2004, Katrina 2005, Rita 2005, and Wilma 2005 – more information available from NOAA website). Six of these eleven hurricanes made landfall in a 2-year period (2004–2005). Hurricanes and tropical storms can deliver very different amounts of wind and rain, and differences among storm impacts account for some of the large between-year differences in rainfall received in the region.

One can generally describe the climate of Everglades' as sub-tropical, seasonally dry, and sculpted by high rainfall volume tropical storm events.

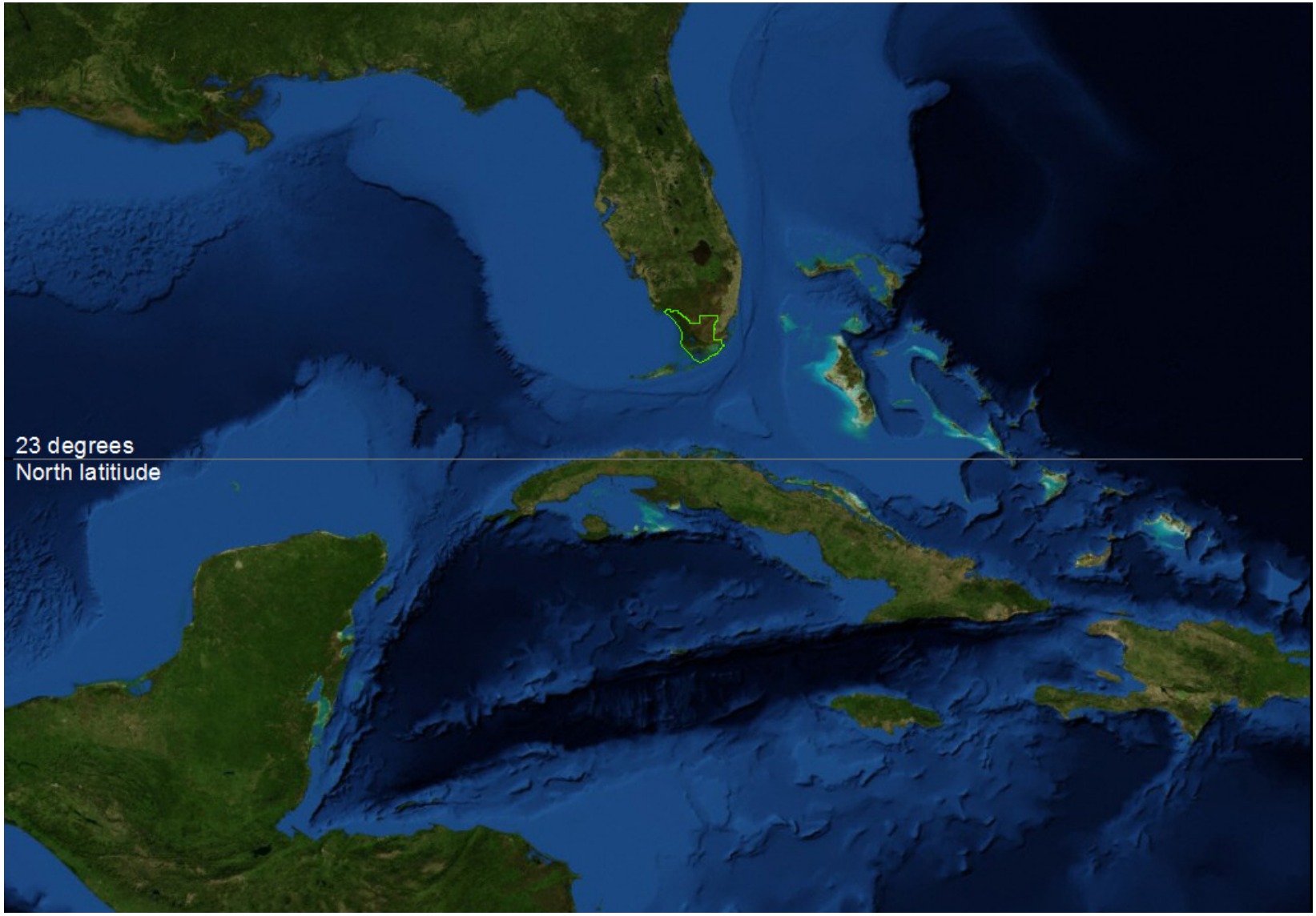


Figure 2.3. Everglades National Park (green outline) located in a broad geographic context. The southern Florida peninsula sits just above the Tropic of Cancer (23˚ N latitude) at the intersection of the tropical Caribbean and temperate North American continent.

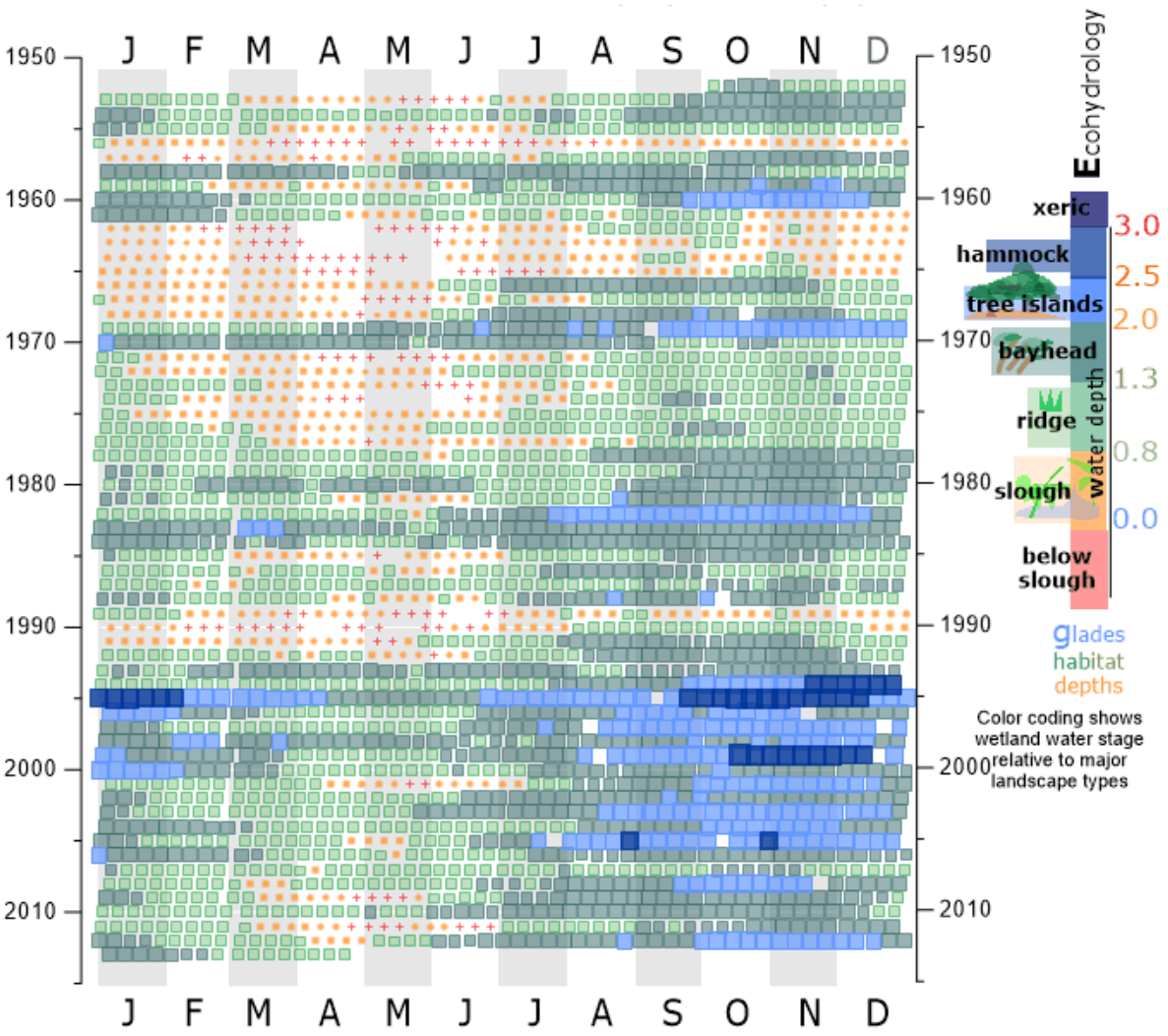


Figure 2.4. Seasonal hydrology patterns for the last sixty years, interpreted from a monitoring gage located in the center of Shark River Slough. This graphic shows water stage patterns during each year and the type of vegetation flooded at different water stage levels. Solution holes ("below slough") pools are flooded first and xeric areas (often pine rocklands) are flooded last. Flooding condition is summarized weekly and the degree of flooding is correlated to the thickness of the line. The color of the line corresponds with the thickness and indicates which habitat types are inundated. The legend (labeled Ecohydrology) shows the relationship between the color and a specific habitat type. This graphic is reprinted with permission of Bob Sobczak (NPS).

2.2.3. Links to Ecology

Everglades National Park is biologically unique for several distinct reasons. The size of the wetland ecosystem is quite unique in the world. Between four and six percent of the earth's land surface are home to wetland habitats (Mitsch and Gosslink 2000), and very few locations on earth are home to over ten thousand square kilometers of contiguous wetlands. Southern Florida is closer to the Yucatan Peninsula than it is to Atlanta, GA, and it contains a blend of the biological characteristics of both places. The peninsular geography, sub-tropical environment, and biogeographic link to the Caribbean shape the unique character of EVER. Habitats in the wetter portions of the park

accumulate organic (i.e., carbon rich) soils (often called peat or muck soils) which interact with water flow patterns to produce a striking patterned landscape of tree islands, ridges, and sloughs (Photo 1). The result is a landscape where even the "upland" hardwood hammocks can be flooded during the wettest conditions (Figure 2.4). Heavy rains from hurricanes, tropical storms, or El Niño conditions in the winter can flood the Everglades. A seasonal accumulation of "normal" rainy-season conditions can also cover the park in water, and this tends to occur in September-October. Droughts occur almost every spring: beginning in March, and are relieved by June. Offshore breezes become more consistent as day lengths increase in June causing this seasonal pattern.

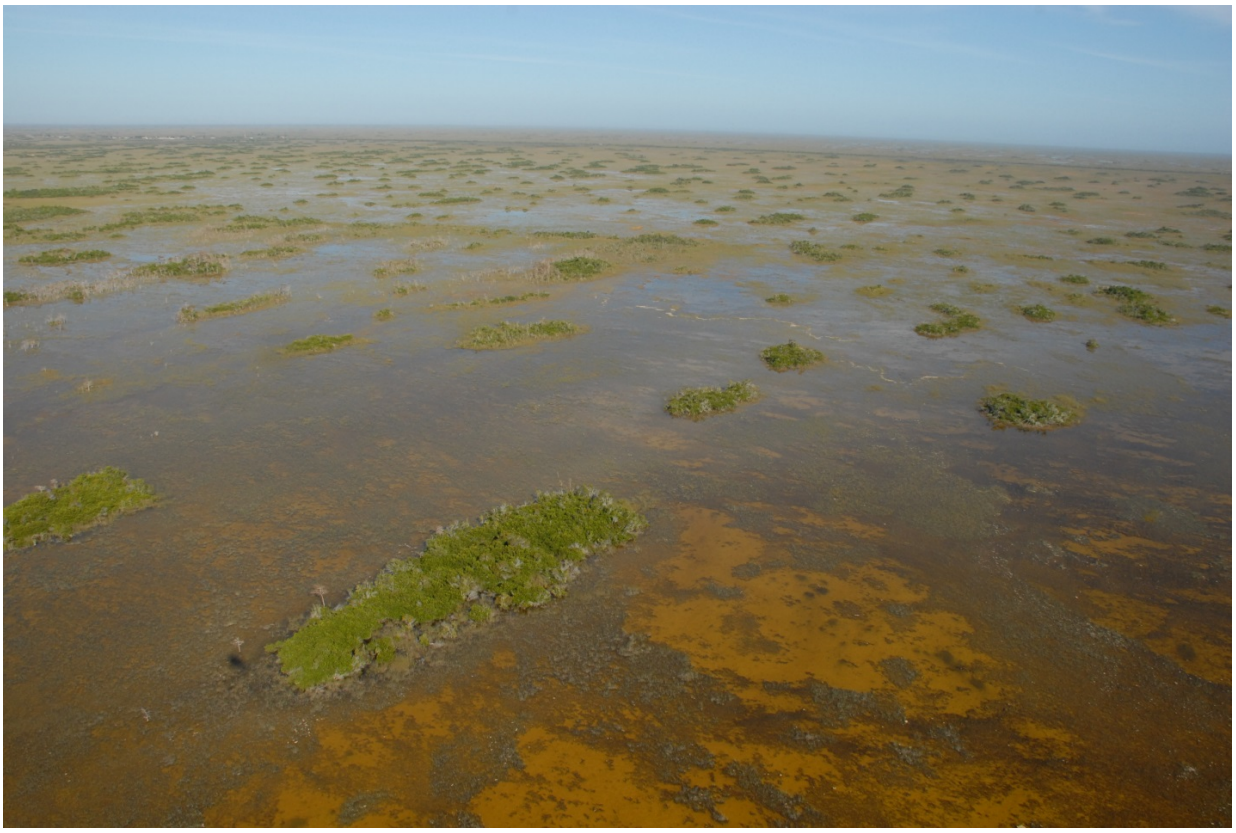


Photo 1. Ridge, slough, and tree island patterned landscape during flooded conditions. Photo taken by Joaquin Alonso of SFCN.

High volume rainfall events that occur during the wet season are essential for the creation and maintenance of the ridge, slough, and tree island patterned landscape that defines the Shark Slough region of the park. Up to a third of annual rainfall totals can occur in association with a single tropical storm event. These high volume rainfall events are also important for keeping salinity moderate in the hundreds of square miles of coastal marsh and creek habitats in the park. Restoring these storm-driven pulses of freshwater flow into the Everglades is a key component of the Decompartmentalization Physical Model, a $10.5 million field-scale design test that should identify the key ecological processes triggered by pulse-flow events, and help more accurately predict the rate of recovery of this landscape.

Seasonal rainfall patterns combine with flat topography to produce a large marshland. This marshland and the warm tropical oceans that surround southern Florida prevent hard freezes from occurring, and create the conditions where tropical plant species can colonize the otherwise temperate North American continent. Complementary temperature patterns between the Everglades and the surrounding Caribbean region have resulted in a clear biogeographic link between these areas (Olmstead 1983). Vines, trees, and epiphytes present in the region have more tropical genera than temperate genera (Muss et al. 2003). The blending of temperate and tropical plant species ranges is one of the causal factors that accounts for uniqueness of plant species in the park. Over half of the plant species observed in Everglades National Park occur in fewer than five other U.S. National Parks or Preserves (Figure 2.5). Tropical hardwood trees co-occur with temperate tree species in upland forests; temperate pines (*Pinus elliotii* var *densa*) predominate in fire-frequent areas; cypress forests and swamp forests (composed of mostly temperate hardwood tree species) are present in seasonally flooded lowlands. Many species of orchids and bromeliads that grow as epiphytes are tropical species that are threatened, endangered, or commercially exploited. These epiphytes grow in the cypress, hardwood hammock, coastal buttonwood/mangrove, and bayhead swamp forests.

A broader inspection of the species present in the park reveals some interesting insights about the unique characteristics of the different species groups that are present. The National Park Service Inventory and Monitoring (I&M) program has produced species lists for the 297 National Park Service lands that they routinely monitor. These lists are integrated in a common dataset that can be accessed by the public. Extracting these lists and processing them into a dataset that counts the number of NPS units that contain a given species provides an opportunity to compare uniqueness among taxonomic groups within a park unit. A result of this analysis is presented in Figure 2.5, which demonstrates that many of the 363 bird and 36 mammal species present in Everglades National Park are commonly observed in other NPS units, while the 52 reptiles, 1,121 plants, 238 fish, and 21 amphibian species are not so commonly observed in other park units. While individual species of any of these species groups may be rare, this information provides one piece of evidence to support the perspective that the species assemblages of reptiles, plants, fish, and amphibians are important for focusing conservation and protection efforts.

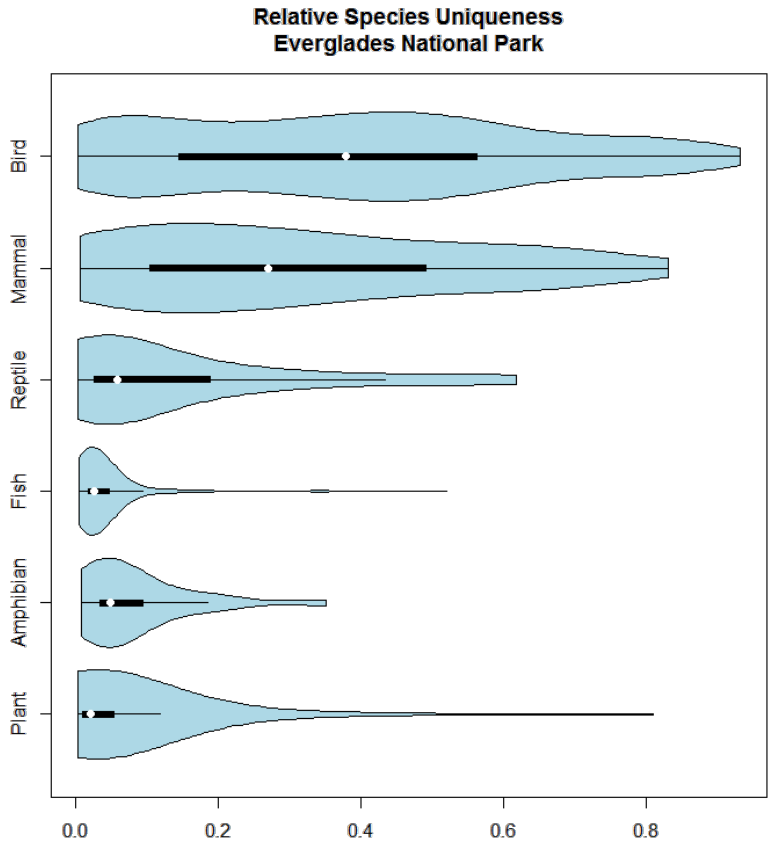


Figure 2.5. A violin plot depicts the relative frequency of occurrence of all bird, mammal, reptile, fish, amphibian, or plant species found in Everglades National Park on other NPS administered lands. Birds and mammals are often found in many other National Park Service units, while reptiles, fish, amphibians, and plants are usually found in only a few other NPS units.

A second piece of evidence that helps enhance our awareness is the number of species within the park that are listed for special protection by either the state of Florida or the U.S. Federal Government (Table 2.2). One hundred and fifty-one plant species have special status (13% of plants in the park) – and are listed as either threatened in the state (42), endangered in the state (104), commercially exploited (4), or federally endangered (1 – Small's milkpea – *Galactia smallii*). Twenty six bird species are afforded special protection (or 7% of birds in the park), in one of five categories: species of special concern (16), federally endangered (2), state threatened (3), or federally threatened (5 – one of these, the sandhill crane – *Grus canadensis* – is listed due to similarity of appearance to the varieties of sandhill cranes that are listed as endangered). Fourteen reptile species have special protection (27% of reptiles in the park) as federally endangered (3), federally threatened (4 + 1 due to similarity of appearance), state threatened (5), or species of special concern (1). Six mammal species are protected (17% of mammals in the park), five are federally endangered, one is a species of special concern, and one listed threatened by the state of Florida. Two fish species found in the park are listed as species of special concern: the mangrove rivulus (*Rivulus marmoratus*) and the federally endangered smalltoothed sawfish (*Pristis pectinata*). No amphibians are listed, although there are global concerns about declining amphibian biomass and biodiversity patterns, since these

organisms are particularly sensitive to aquatic contaminants, fungal infections, and climate change. Two butterflies are proposed for listing as federal endangered: Florida leafwing and Bartram's scrub hairstreak. The Miami blue butterfly is considered to be extirpated, but was formerly native to EVER. A variety of other butterfly species are considered to be declining or otherwise imperiled, though they are not officially listed. No official species list exists for a potentially large number of species groups including insects, arthropods, mollusks, and several other organismal groups that many undergraduate zoology students may recognize. There are no federally listed species among these less frequently recognized groups of organisms. The lack of awareness of these organisms is one important reason why no listings or designations of rarity exist for them. A recent "Bioblitz" inventory of species in nearby Biscayne National Park (BISC) identified 532 new species to the official park list across all taxonomic groups, 93% of which were marine invertebrates, insects, non-vascular plants, and fungus/lichens. Given the proximity of BISC to EVER, marine invertebrates, insects and non-vascular plants are likely to be similarly undersurveyed in EVER, as they were prior to the BISC bioblitz.

Everglades National Park is globally renowned for its physical and biological characteristics. A diverse biological community thrives in EVER, within an expansive patterned peatland in a sub-tropical climate. The position of the park at the tip of an 80-mile wide, seasonally flooded peninsula that is surrounded by a warm Caribbean sea has resulted in the formation of a diverse and unique hoard of biological treasures. The massive coastal mangrove forest is complemented by an expansive wetland ecosystem. Densely populated rookeries of wading birds in Florida Bay are able to reproduce on isolated islands that are protected from predation, but still close enough to the mainland to support daily foraging flights in the marshes. The upland sites in the park contain pine rocklands and tropical hardwood hammocks, and both habitats feature a high diversity of plants. Beginning at the coastline, the estuarine system of creeks, lakes, and bays serve as the nursery for marine animals and invertebrates that forage as adults in the expansive seagrass beds of Florida Bay and the world's third largest coral reef system that sits along the Atlantic coast. Individually, the terrestrial marshes, coastal forests, estuaries, and the Bay are each worthy of preservation. It is the good fortune of Floridians that these magnificent systems occur together here, and together these landscape formations produce an ecosystem that commands the respect and admiration of the world.

Table 2.2. Count of species with special State or Federal protection status in Everglades National Park.

Species Group	Federal Endangered	Federal Threatened	Federal Threatened (Similarity of Appearance)	Species of Special Concern	State Threatened	State Endangered	Commercially Exploited	Total
Plants	1	–	–	–	42	104	4	151
Birds	5	1	1	16	3	–	–	26
Reptiles	3	4	1	1	5	–	–	14
Mammals	5	–	–	–	1	–	–	6
Fish	1	–	–	1	–	–	–	2
Amphibians	–	–	–	–	–	–	–	0
Total	**15**	**5**	**2**	**18**	**51**	**104**	**4**	**199**

2.3. Geology, soils, and water

Understanding the geologic context of the region enhances the understanding of the status and trends of many natural resources found in EVER. At the earth's surface, geology strongly influences soils, plants, and the formation of habitats. Investigations of geologic stratigraphy (or layering of geologic formations) below the surface aids our understanding of historical patterns of plant and animal abundance, whole-system level properties of the regional watershed, and pre-historical cultures. Furthermore, these investigations can provide an understanding of the historical ranges and rates of change in climate conditions (see Figure 2.6 - from Thornberry-Ehrlich 2008).

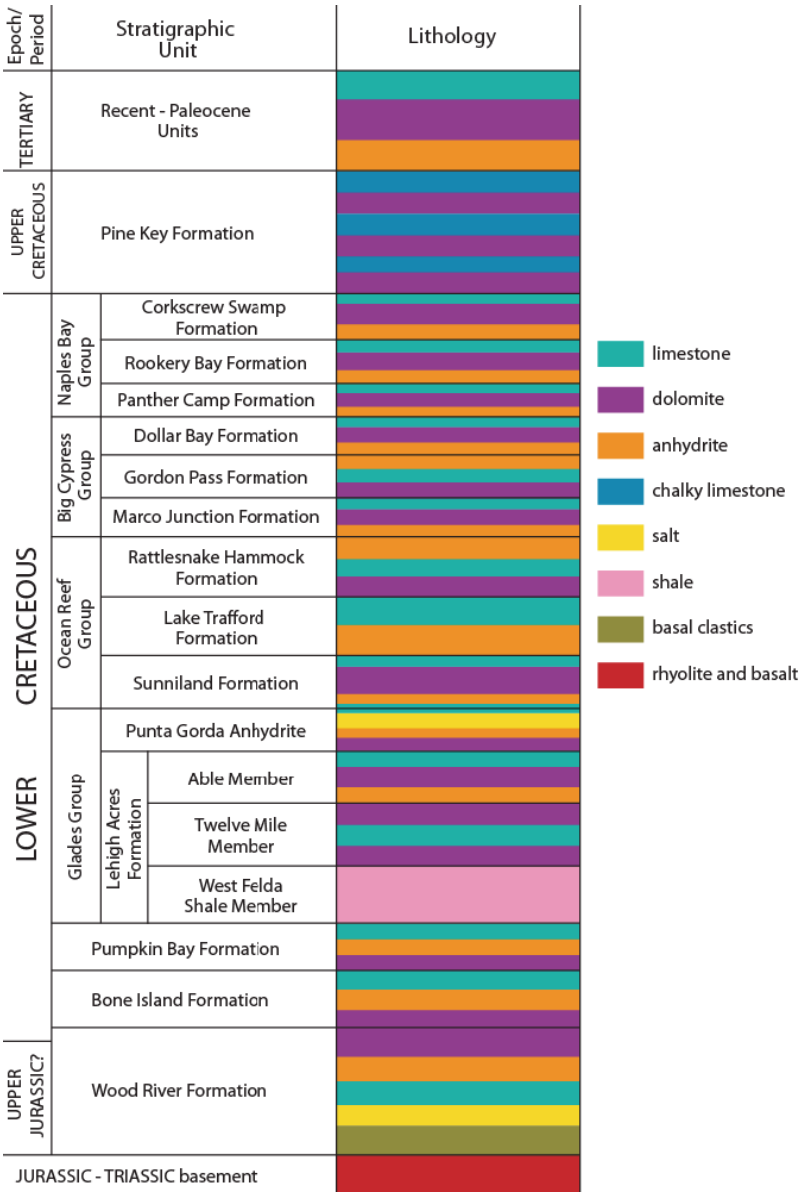


Figure 2.6. Geologic time scale; adapted from the U.S. Geological Survey. Red lines indicate major unconformities between eras. Included are major events in the history of life on Earth and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years before present (Ma. or mega-annum, reprinted from Thornberry-Ehrlich, 2008).

2.3.1. Surface Geology

The freshwater wetlands of Everglades National Park rest on Miami limestone – a depositional accumulation of calcium carbonate – that was mostly created during the Pliocene/Pleistocene (10,000–5,300,000 years before present; Figure 2.7, Thornberry-Ehrlich 2008). The calcium dominated chemical profile of Miami limestone binds phosphorus to strongly affect biological processes in the region. Holocene sediments are the other major surface geology type in the terrestrial portions of the Everglades. These sediments are mostly beach sand, shells, and calcitic muds that are mixed by tidal processes and storm surges. Coastal marshes, creeks, and mangrove forests are the dominant habitat that occurs on the Holocene sediments (1–10,000 years before present – the youngest possible geologic surface). A small portion of the park's land surface – in the area along the boundary with Big Cypress National Preserve – occurs on the Tamiami formation. Sand laced calcitic muds are the predominant constituent of the Tamiami formation, which is derived from the Pliocene (1.8–5.3 million years before present).

The surface geology of the park's marine areas - Florida Bay and the Ten Thousand Islands - are essentially marine-derived sediments that are well mixed and worked by tides. Florida Bay is a shallow lagoon formed by over 50 interconnected basins with both supra- and sub-tidal banks. All three of these geological surfaces are calcium rich and dynamic. The coastal creeks and marshes experience significant deposition and erosion of sediment due to tidal activity and storm surges that causes these areas to exhibit perceptible change over the course of a human lifetime. Normal daily and seasonal variability in sea level accounts for some of the coastal dynamics. Dramatic impacts to the coast result from hurricane-induced storm surges that tend to pile marine sediments and debris in some areas, while rapidly eroding other locations. Storm surges can exceed twenty feet and impact areas that are miles inland from the coast. Significant storm surge effects have been documented inside of the park in association with Hurricanes Donna (Craighead 1961) and Wilma (Smith et al. 2009). Both of these storms delivered a significant storm surge (5 ft. storm surge for Wilma, 2 ft. for Donna) for several miles into the marshes along the southwest coast (Figure 2.8), loaded marine sediments into the mangroves along the coastline of Florida Bay (in amounts usually observed to occur over a century or more of normal conditions), and introduced saline waters several miles into the interior marshes of Cape Sable and the surrounding areas.

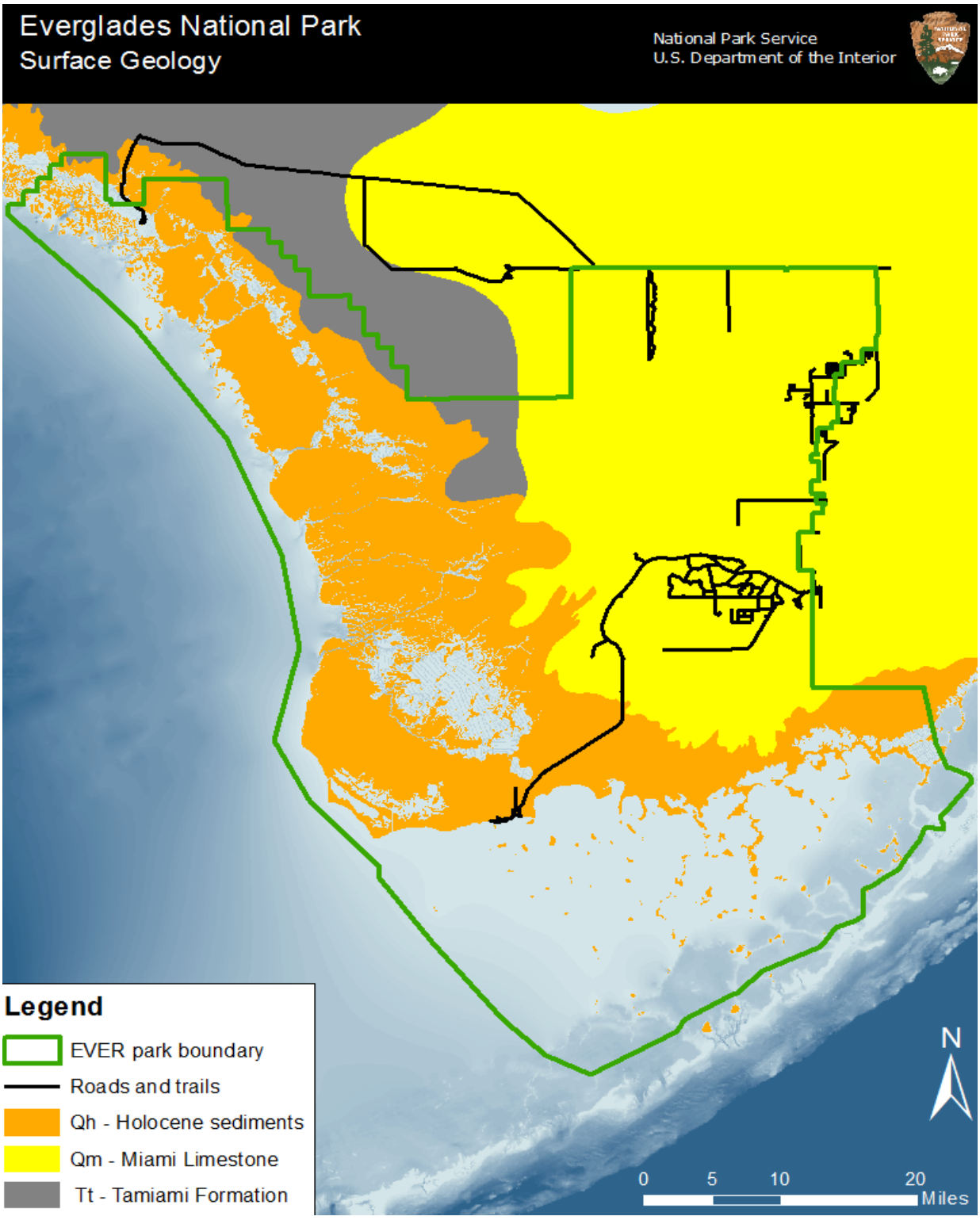


Figure 2.7. Surface geology of Everglades National Park.

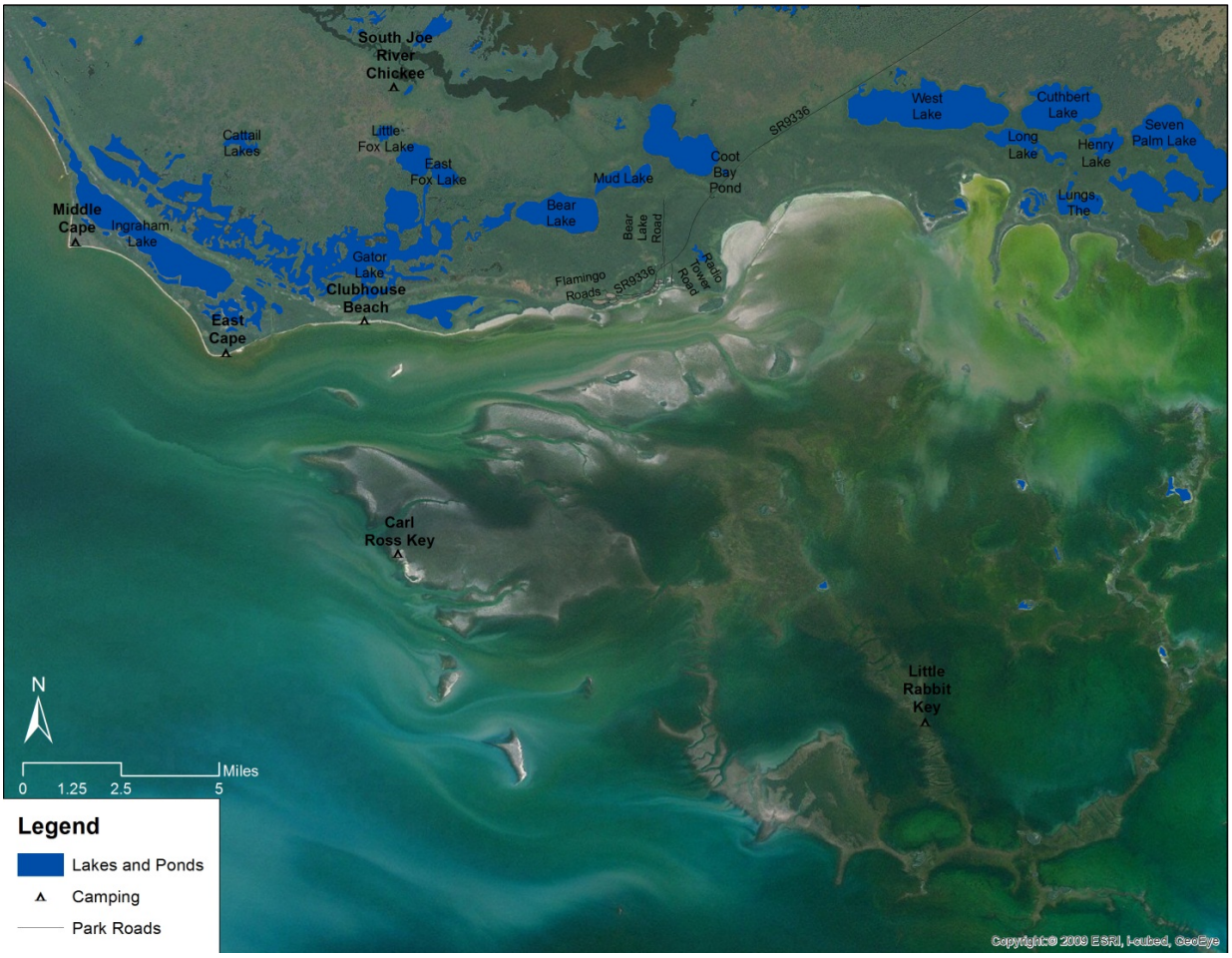


Figure 2.8. Coastal Lakes, mudflats, and campsites of the Cape Sable and western Florida Bay region of Everglades National Park.

Short-term daily and seasonal variation in sea level due to tides and storm surges are typical of coastal environments. Longer-term increases in sea level of 2.2 mm/year have also been observed over the last seven decades (Walton 2007, Pearlstine et al. 2009). The long-term effects of these dynamics in Everglades National Park have resulted in an expansion of mangrove forests along the southwestern portion of the park. Both sea-level rise and canals dug prior to park establishment are linked to increased sedimentation of Lake Ingraham, and the expansion of mud flats along the western edge of Florida Bay. All three of the surface geology types found in Everglades National Park can be dynamic, but the surface geology of the coastal and marine areas of Everglades National Park are the most dynamic – essentially in a state of continual change.

2.3.2. Sub-surface geology and groundwater

Below the surface, the geological profile of Everglades National Park is quite stable, and dominated by calcium-based deposits that are occasionally interlaced with sand layers. This type of geologic profile is often named “karst,” a globally common geologic type that is often associated with the development of highly porous aquifers, underground caves, and sinkholes. A Geologic Resource

Evaluation Report developed by the National Park Service in 2008 highlights these geological aspects of the Everglades:

> *"The Everglades area is one of the lowest, youngest, and most geologically stable platforms of North America. This overall stability belies incredibly dynamic geologic processes at work on the landscape of south Florida. Beneath the surface at Everglades National Park, there are thousands of meters of roughly horizontal geologic units rich in carbonate minerals. These minerals dissolve in acidic solution. Rainwater and groundwater rich in decaying organic materials have dissolved interconnected void networks in the subsurface of south Florida. This dissolution ultimately results in a karst landscape characterized by solution holes, sinkholes, disappearing streams, springs, and incredible water storage capacity"* (Thornberry-Ehrlich 2008).

Historically, the sub-surface geology supported a massive system of fresh groundwater that extended thousands of feet off the coast. Freshwater springs emerged from the bottom of the ocean in Biscayne Bay, and hundreds of square miles of seagrass beds in Florida Bay functioned as estuaries – large waterbodies that are detectably less salty than the open ocean.

Developing a more specific understanding of the aquifer system of southern Florida has proven complex. These challenges are reflected in the historical record of southern Florida detailed comprehensively by the United States Geologic Survey (USGS).

The aquifers that occur in and around Everglades National Park are described as "unconfined". Near the surface, the Biscayne aquifer interacts with surface water, the canal system, and rainfall. The sedimentary rocks that hold this water are "…riddled with well-developed solution cavities and conduit networks rendering it highly permeable" (Thornberry-Ehrlich 2008). This feature of the limestone affects the behavior of the "salt-water wedge" (Figure 2.9) near the coastline that has been observed to change depth and distance from the coastline on a seasonal basis.

Essentially as drought intensity in southern Florida increases, saltwater approaches the surface near the coast and becomes detectable in deeper groundwater several miles inland. A significant amount of information about the dynamics of coastal groundwater systems has been summarized at large spatial scales across the Atlantic Coast of the U.S. (see Barlow 2003) and in this context, the coastal system of southern Florida is among the most susceptible to saltwater intrusion due to a combination of: the large number of cracks and fissures in the limestone rocks (Cunningham et al. 2006), large quantities of groundwater extraction (Barlow 2003), and the regional hydrologic infrastructure (Lodge 1994). Regional flood control infrastructure is the most important cause of saltwater intrusion in southern Florida.

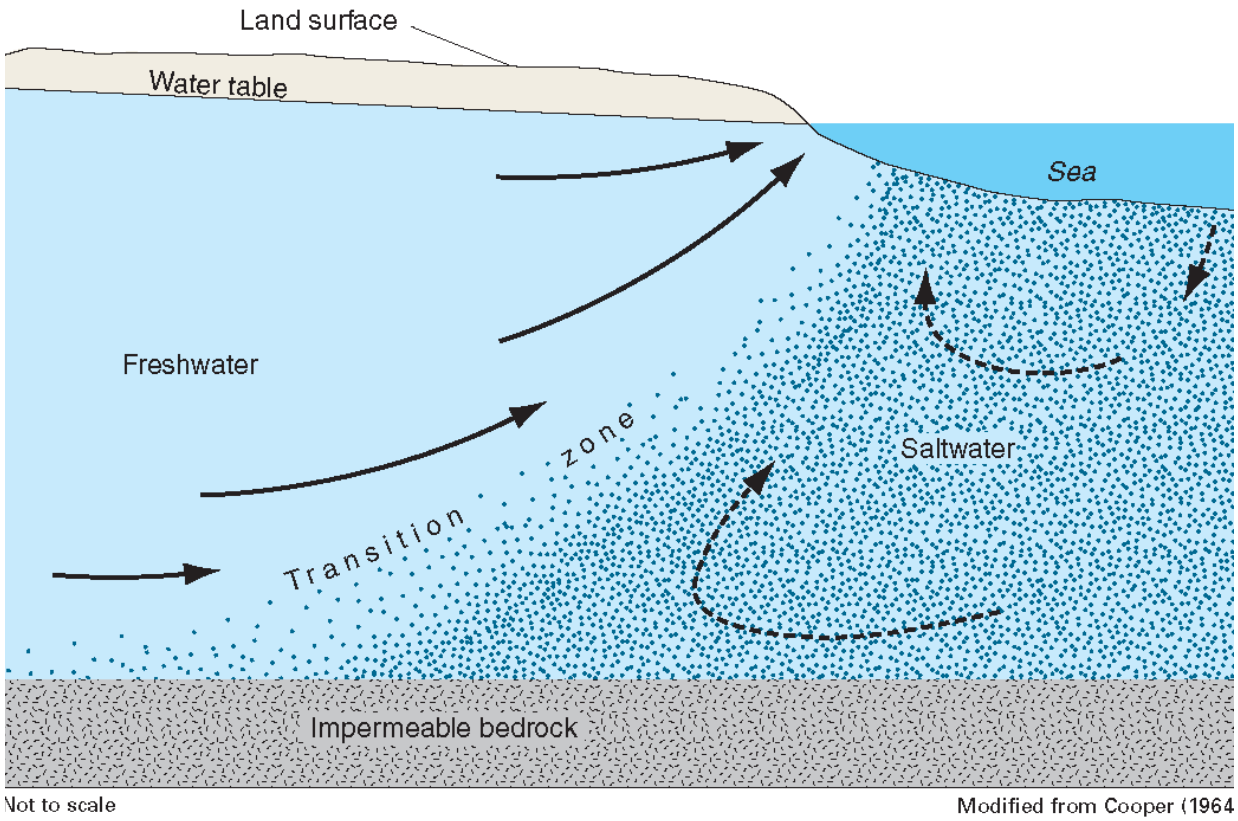


Figure 2.9. Ground-water flow patterns and the freshwater-saltwater transition zone in an idealized coastal aquifer. A circulation of saltwater from the sea to the transition zone and then back to the sea is induced by mixing of freshwater and saltwater in the transition zone (reprinted from Barlow 2003).

At a fine scale, the directional movement of water through the groundwater system is well known. There has been a general expansion of saltwater intrusion into the Biscayne aquifer over the past century (Sonenshein 1997, Barlow 2003, Figure 2.10). Direct observation of this process requires a significant number of wells to be drilled, and consistent monitoring of the salinity in these wells across a range of depths. These types of observations have not been feasible throughout much of Everglades National Park. Since the basic mechanisms of reduced freshwater, sea-level rise, and increased demand of fresh groundwater operate throughout southern Florida, it seems likely that increased saltwater intrusion into the surficial aquifer is occurring in the park. The potential for increased saltwater intrusion is most notable near the coastline or where human populations are consuming significant quantities of groundwater.

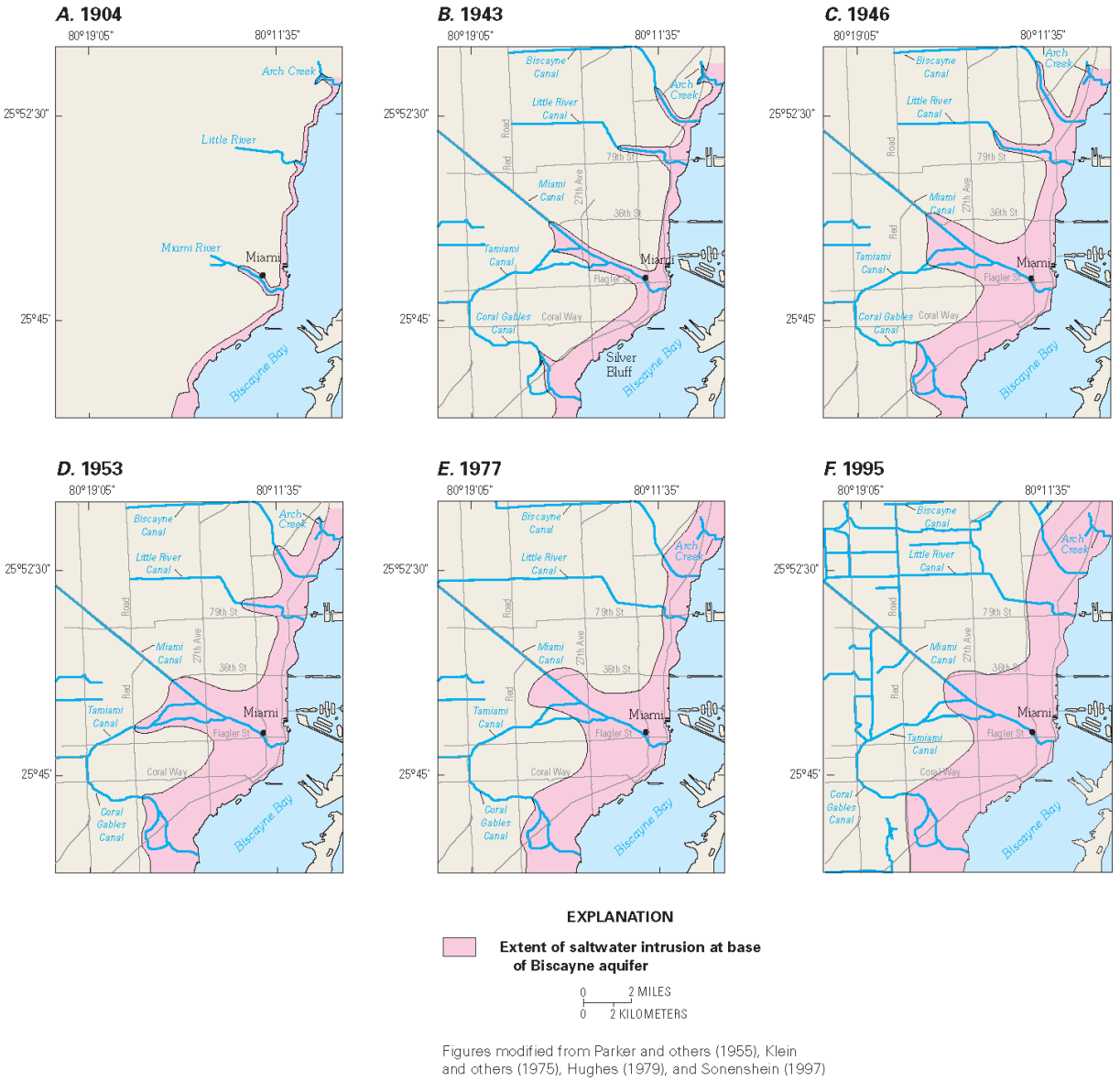


Figure 2.10. Saltwater intrusion in the Biscayne aquifer in Miami-Dade County near the Miami Canal, (A) 1904, (B) 1943, (C) 1946, (D) 1953, (E) 1977, and (F) 1995. Reprinted from Barlow (2003).

2.3.3. Soils

The dominant soil types found in Everglades National Park are identified by three primary physical characteristics – geologic parent material, local patterns of variation in elevation, and vegetation. "Soils occur on the landscape in an orderly pattern that is related to the geology, the landforms and the vegetation" (Soil survey of Dade County 1996). These three aspects of soils are closely linked due to the broad/flat topography of the region, the historical role of marine processes in defining geologic types, and the strong effect of hydrology (often defined by topography) on vegetation. The linkages between these processes result in only a few types of soils: mucks (organic dominated black/brown soils), marls (calcium carbonate muds), rocklands (calcium carbonate rocks that are above the water table), and sands. Human actions in some areas have been extensive enough that

there are several human associated types – the gravel dominated areas of Chekika are rockland and marl areas that have been plowed, crushed, or otherwise 'scarified'; and the intensive human use environments that are dominated by pavement and fill (usually crushed rocks). All five of these soils types form on top of some type of limestone.

The drivers of soil development (hydrology, vegetation, geologic parent material, and human activity) vary spatially. This results in broad spatial patterns of soils (a very coarse geographic summary of soils is presented in Figure 2.11). For this reason, the general soil map presented is complemented by a series of smaller scale soil maps when a complete investigation of soil properties is conducted (see Soil Surveys of Dade, Monroe, and Broward counties: Pendleton et al. 1976, Hurt et al. 1995, and Noble et al. 1996). The only portion of the park that has these finer scale maps is the East Everglades Addition Lands. These maps are essential for developing a practical understanding of soil conditions and developing options for influencing soil properties or defining appropriate land uses. Very detailed investigations of local soil properties within the park do exist, and the broad scale pattern of soil conditions depicted in Figure 2.11 is based mostly on an expectation of soil conditions - given large-scale patterns of vegetation, hydrology, geology, and human activities, combined with the knowledge of soil development processes.

Muck (or peat) soils occur in natural drainages, where water is aboveground for at least eight months per year. These soils are composed of plant material and only occur in places where the rate of plant growth outpaces the rate of decay of dead plant material. The low oxygen environment that occurs under standing water slows the decay process enough to allow muck soils to accumulate. Muck soils enforce the separation between the surface and ground water systems, and all four of the muck soil types identified by the Natural Resource Conservation Service (NRCS) are characterized as "poorly drained". The major muck types occur either in the main historical flowpath of the "river of grass" or along the coast. The coastal muck type (named Terra Ceia) is the deepest organic soil, averaging 80 in of depth and is often inundated with saltwater. Historical evidence indicates that muck (or peat) soils occurred in areas where marl dominates today, and that these soils were burned up during fires that became more frequent as the Everglades was systematically drained from the 1880's through the 1960's.

Marl soils are found in areas that are hydrated 2–8 months per year. Three types of marls are identified in the region, and these are differentiated by their average depth (between 15 and 44 in of marl), color (gray/brown or dark brown), and undersurface type (soft or hard limestone). The marl soil types observed in southern Florida are poorly drained, and are often described as "calcium laced muds". Marl soils can form as a result of the chemical precipitation of calcium from the water column, or as a result of weathering of limestones produced by biological processes (e.g., shell formation of mollusks or coral reef formation). Calcium crystals precipitate directly from the water column on hot summer days in the shallow marshes of the Everglades when the water column is stripped of carbon dioxide by submerged aquatic plants (Dierberg et al. 2002, Grace 2003, Pietro et al. 2006).

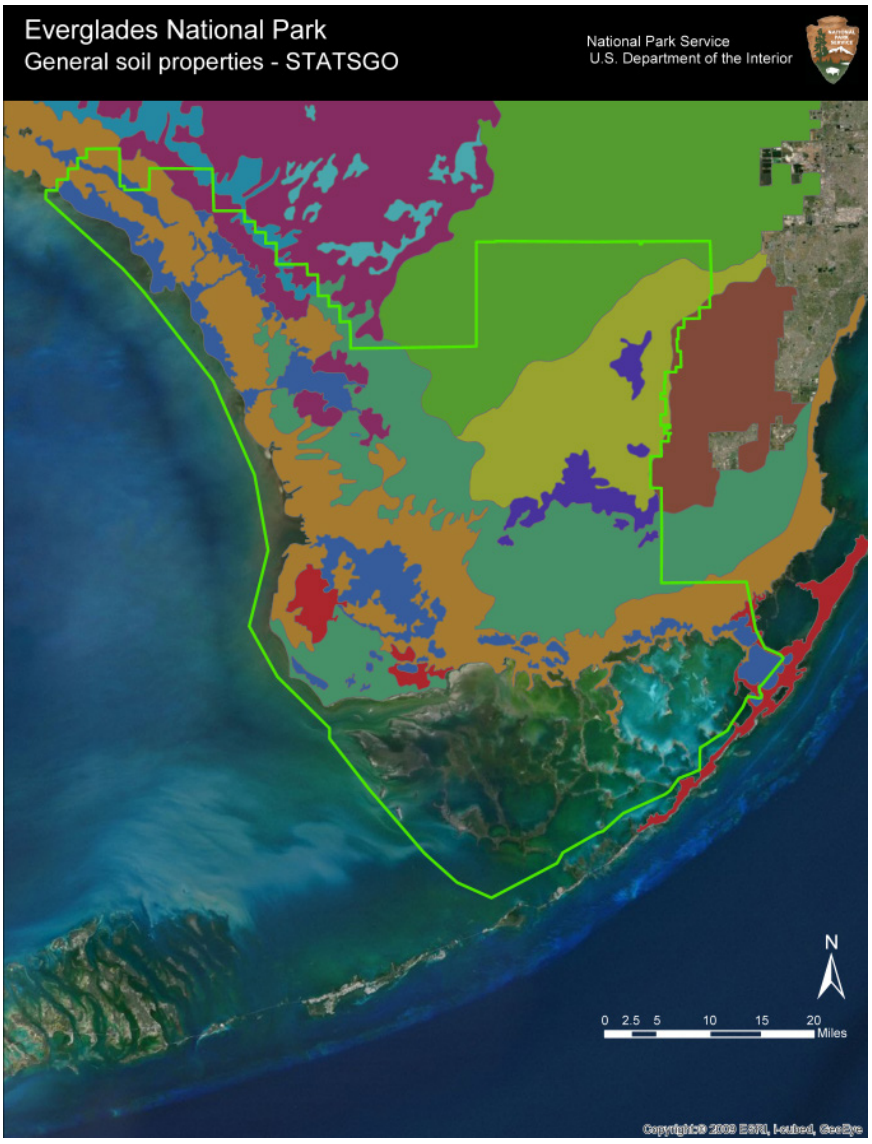


Figure 2.11. A coarse scale summary of soil types in the region surrounding Everglades National Park. Multiple soil types occur within each discreet area depicted at this spatial scale.

Rock outcrops form in areas that experience minimal hydration. In these areas, the limestone hardens into a white, rocky surface. Human activities tend to be concentrated in these "upland" areas that are generally above the water surface. When the rock soil is crushed, it becomes a rock/gravel mix (characteristic of the Chekika soil type), or is applied to an area as fill material (named Udorthents). Pavement is the other soil "type" that is common in southern Florida, and present in the roads, concession areas, and parking lots where visitors are often found.

2.4. Legal Boundaries, Ecological Units, and Watersheds

2.4.1. Legal Boundaries

Everglades National Park contains land in Miami-Dade, Monroe, and Collier Counties within the State of Florida (Figure 2.12). Miccosukee Tribal Lands occur within the park, along Tamiami Trail (US 41) (adjacent to the northern boundary of the park), and perpetually leased lands extend just north of US 41 - stretching up to I-75 in Broward County. The western boundary of Everglades National Park begins almost a mile off the coastline, from the northwestern corner in the Ten Thousand Islands area, continuing parallel to the coastline to Cape Sable. At the tip of the Peninsula, the boundary continues southeast toward the middle Florida Keys, but stops nearly two miles before connecting to Long Key near the center of the Florida Keys archipelago. At this point, the boundary turns and stretches to the northeast, remaining mostly 0.5–2 miles off the Keys, with the exception of the inclusion of two small parcels of land on Key Largo. The boundary turns northward just west of the intersection of US 1 and SR 405 (Card Sound Road) in northern Key Largo, and parallels US 1 through the coastal marshes and lakes that occur between Key Largo and the southern tip of the Florida Peninsula. A bit over three miles after connecting with the mainland, the boundary veers west for about eight miles through the coastal marshes until it abruptly turns northward around five miles south of the L-31W canal. The boundary proceeds northward for over 32 miles, generally following the canal infrastructure in Miami-Dade County until reaching Tamiami Trail. The boundary then turns westward and follows the Tamiami Trail across the river of grass for nearly 20 miles until reaching Big Cypress National Preserve. Everglades National Park and Big Cypress National Preserve share a boundary that begins near the intersection of US 41 and Loop Road, stretching westward through an area of cypress strands, coastal marshes, and rivers known as the stair steps region until reaching the Gulf Coast at Everglades City in the Ten Thousand Island region.

Shifts in the eastern boundary and the addition of lands acquired by NPS after 1989 bring the current park area to ~1.5 million acres (~2,400 square miles). Given the active restoration process and development pressures in Miami-Dade County, one can expect minor changes along the eastern boundary to continue for the foreseeable future.

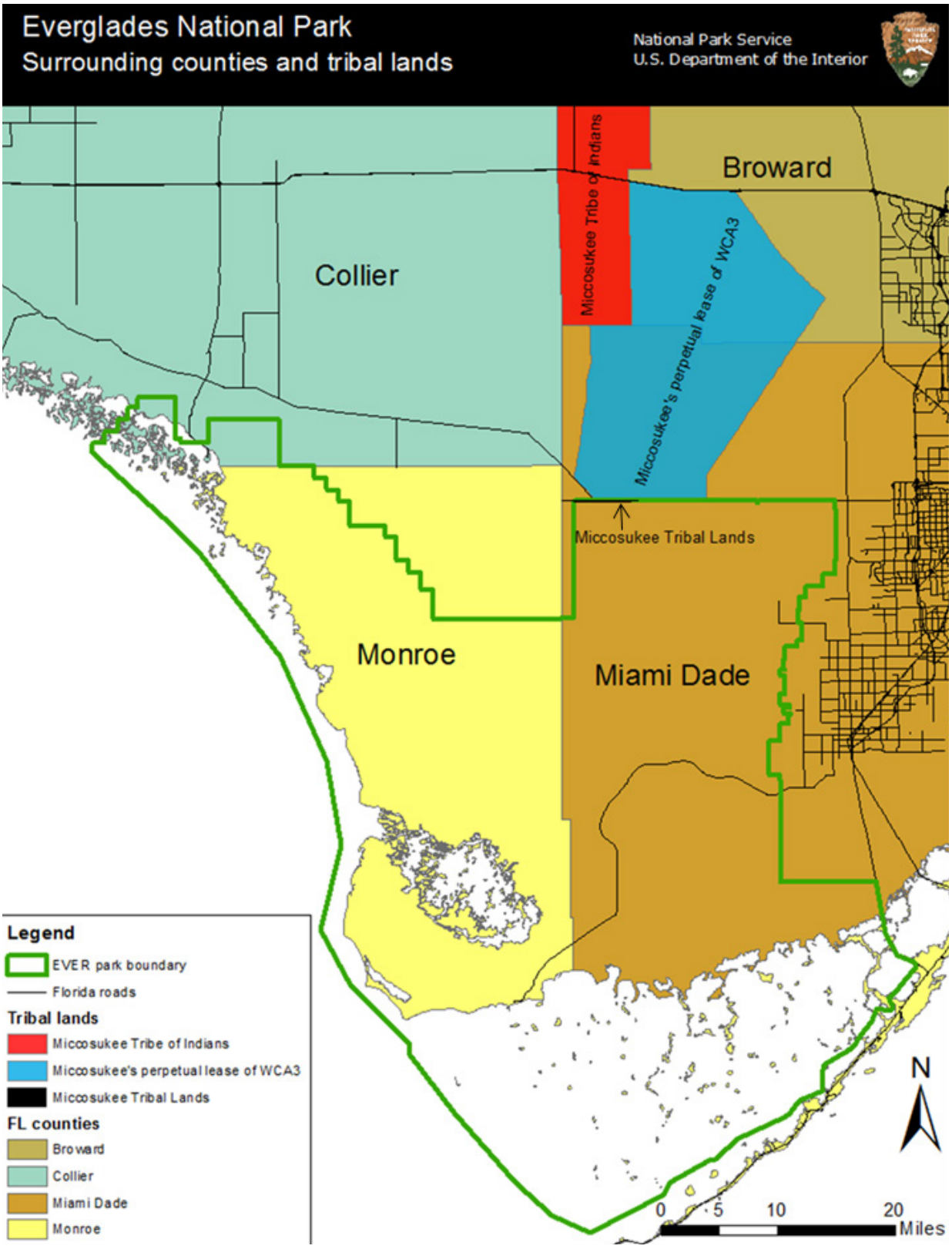


Figure 2.12. Location of EVER relative to political boundaries, including counties, tribal lands, and large roads found in the area.

The Everglades boundary encircles a vast area of freshwater wetlands, coastal marshes, mangrove forests, and seagrass beds. The emphasis on wilderness values expressed in the founding legislation for the park is evident in the existence of the largest designated wilderness area east of the Mississippi River (Figure 2.13). Nearly 87% (or 2,084 square miles) of Everglades National Park is designated as wilderness – either terrestrial or marine, with another 5% identified as potential wilderness (Table 2.3). Non-wilderness areas are essentially limited to two types of areas. The first type includes the hardscape roads and buildings that support visitor use or administration of the park, and boat-transit areas near the Florida Keys. The second type includes the East Everglades Addition Lands – an area that was added to the park in 1989 - and which was previously occupied by a significant number of people who built roads, small housing developments, and agricultural fields with accessory canals. Most of the Eastern Everglades Addition Lands have been identified as wilderness eligible, and are managed in a way that does not diminish the wilderness character and values. Official designation is still under consideration (Draft Everglades National Park General Management Plan 2013). The East Everglades is also the area where continued alteration of water management infrastructure to support large-scale hydrologic restoration is expected to continue to occur. Generally, wilderness is the preferred designation for National Park Service lands, but areas that are managed for human use, or that require extensive management, are typically designated as Wilderness only after the management actions are completed.

Table 2.3. Wilderness Area designations in Everglades National Park.

Everglades National Park Areas	Percent of Park	Area (mi^2)
East Everglades Addition Lands	7%	168.9
Non-wilderness	1%	22.2
Potential Wilderness Addition	5%	119.0
Submerged Marine Non-wilderness	0.2%	5.2
Submerged Marine Wilderness	37%	882.1
Wilderness	50%	1,203.0

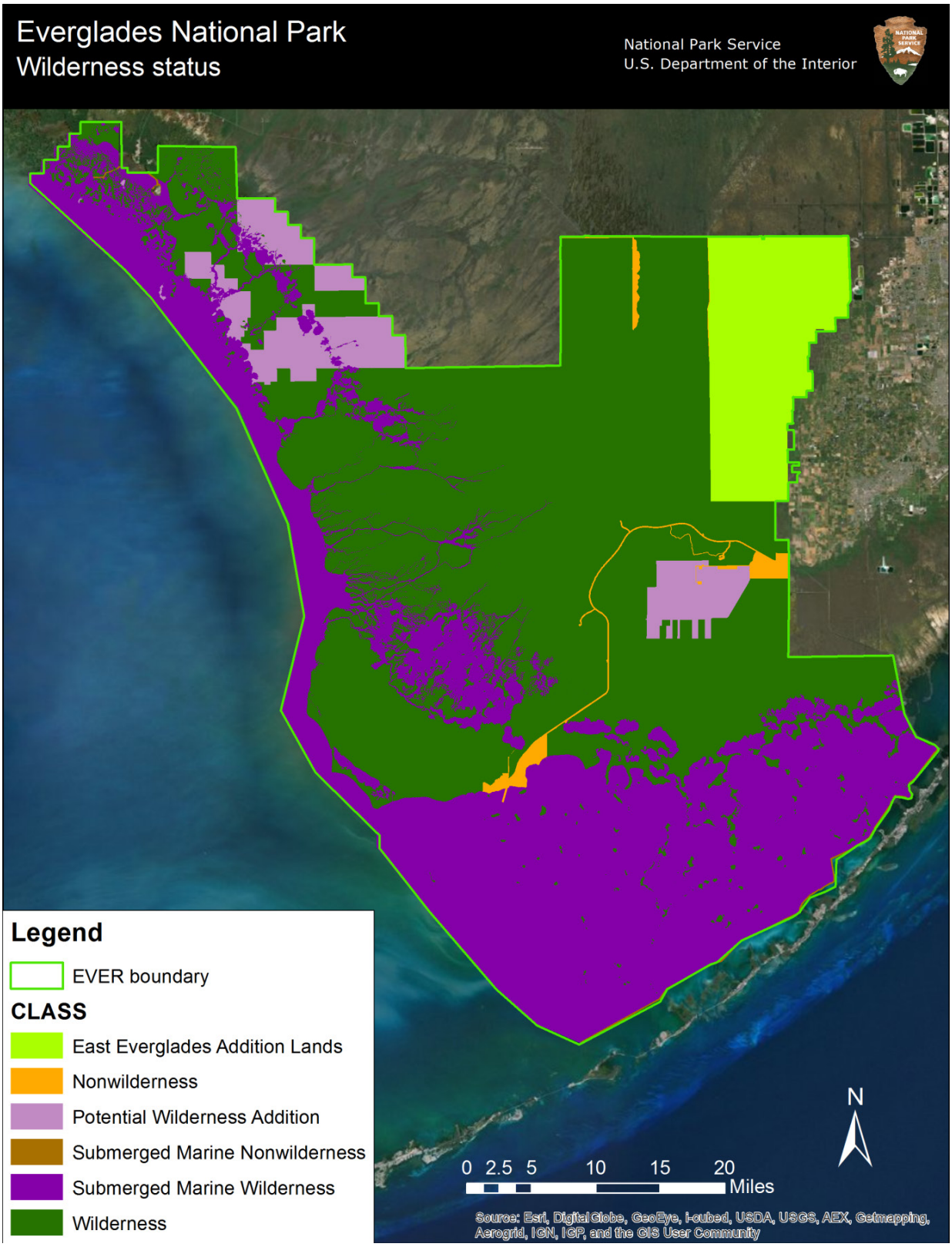


Figure 2.13. Wilderness status of all areas within Everglades National Park.

2.4.2. Ecological Units and Watersheds

Nested within the wilderness are clearly recognizable landscape types that serve as the primary basis for organizing our discussion on the status and trends of natural resources. These large landscapes are often described as "physiographic units", since they are organized based on a combination of physical properties that are assembled geographically. The physiography of the region was first delineated by Harshberger (1914) who identified the subtle topography and soil structures of the Florida Peninsula. The boundaries he designated became the outlines for development of the regional hydrologic infrastructure. Physiography is a practical approach to organizing our understanding of the park. The version presented here (Figure 2.14) was developed with information obtained from Schomer and Drew (1982), Davis (1943), White, (1970), Puri and Vernon (1964), and Herbert et al. (2011).

The seventeen distinct ecological regions in Everglades National Park can be separated into three general groupings: 1. Freshwater marshes and uplands; 2. Coastal marshes, mangrove forests, and rivers; 3. Estuaries and marine zones. The status of these landscape types is strongly affected by their physical arrangement and the degree of influence that the Central and Southern Florida Project (C&SF, also referred to as the regional water supply and flood control system) exerts on the watershed. A brief description of each of these areas helps us recognize the unique aspects of each region, and begin to quantify the ecological conditions of the park.

<u>Region 1 - Ten Thousand Islands</u>

The northwestern corner of Everglades National Park is defined by the Ten Thousand Islands ecological region. This region covers ~10.5% of the park (162,000 acres) and receives overland water flows across more than twenty-eight miles of shared boundaries with the cypress strands and coastal marshes of Big Cypress National Preserve and the Fakahatchee Strand Preserve State Park. These flows filter through freshwater marshes and cypress strands which can intergrade into mangrove dominated wetlands and coastal mangrove forests. More than thirty discrete creeks develop just upstream of the mangrove fringe. These creeks are linked through a series of coastal lakes that parallel the coastline for almost twenty miles. The system of creeks and lakes are part of the Wilderness Waterway that connects the Turner River canoe trail in Big Cypress National Preserve to Florida Bay, nearly 56 miles away. The creeks and lakes consolidate into five drainages that are linked by tidal flows to the Gulf of Mexico: delivering freshwater to the Gulf during seasonally wet conditions, and receiving salt water from the Gulf in response to tidal fluctuations during dry conditions. Tropical storms can deliver marine sediments and significant storm surges to this region. Storm events are important for sculpting the contours of the coastline and extending the coastal mangrove system inland. Storm surges deposit salt in surficial groundwater and carry mangrove propagules inland. Pre-European human-created sites can be found throughout this area. Most are shell mounds, which are classified as "coastal uplands" that have a distinct species composition of tropical trees. Everglades City and Chokoloskee are the major locations of human activity today, and are minor features on the landscape. Primary agents of change (or stressors) in this region are frost events; storm events; altered fire regime; exotic plants and animals; sea-level rise; regional hydrologic infrastructure.

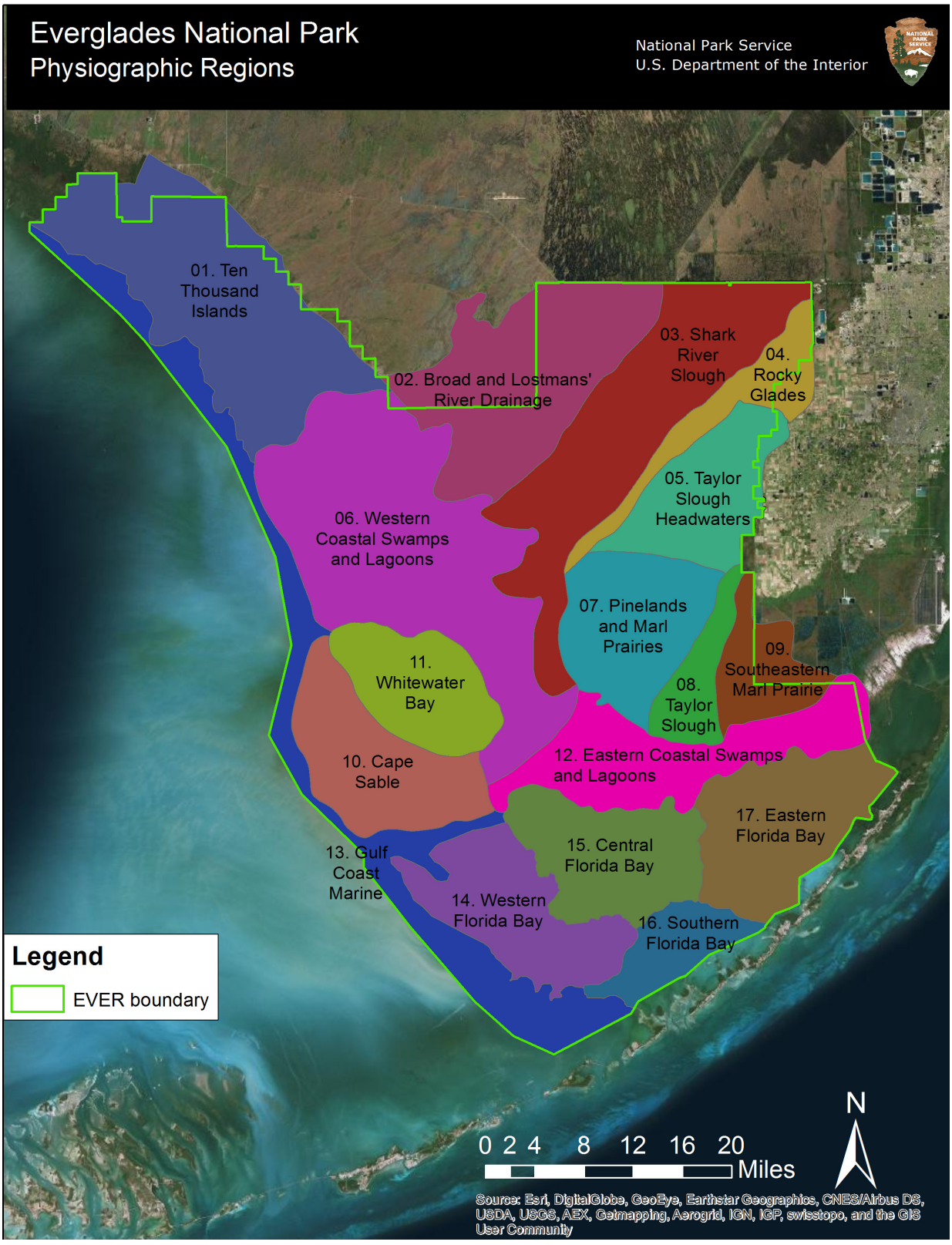


Figure 2.14. Seventeen physiographic regions of Everglades National Park. Twelve terrestrial and five estuarine/marine regions occur in EVER.

Region 2 - Broad and Lostman's River Drainage

The Broad and Lostman's River Drainage region define the remainder of the shared boundary between Everglades National Park and Big Cypress National Preserve. Two-thirds of this ecological region occurs in Everglades National Park (92,000 acres) and one-third occurs in Big Cypress National Preserve (45,000 acres). The area covers 6% of the park and is predominantly wetlands - with the characteristic ridge-slough-tree island patterned landscape - that is a unique and defining attribute of the Everglades Ecosystem, along with marl prairies and extensive cypress communities (Photos 2 and 3). These wetlands occur on top of Miami limestone – the main geologic surface. The major drainage features in this region include Lostman's river, Broad river, Dixons Slough, and East Slough. Only portions of Broad river occur inside the boundary of Everglades National Park, and the other drainages are in Big Cypress National Preserve, but flow into the Ten Thousand Islands and Coastal Swamps and Lagoons regions of the park before they reach the Gulf of Mexico. Primary agents of change (or stressors) in this unit include regional water management infrastructure (releases through the S-343 A&B gates and S-12 structures); altered fire regime; sea-level rise; exotic plants and animals; road traffic along Tamiami Trail.



Photo 2. Sawgrass marsh in the Broad and Lostman's river region.



Photo 3. Marl Prairie in the Broad and Lostman's river region.

Region 3 - Shark River Slough

The Shark Slough defines over 150,000 acres of the park (10%). This area is a massive overland drainage for the region that is affected by the accumulation of water management and land development decisions that can occur as far away as the Kissimmee River Basin (over 200 miles north). Miami limestone is the dominant geologic substrate of this area, and the ridge-slough-tree island patterned landscape occurs across the entire region (Photo 4). Human influences are prevalent on the tree islands throughout Shark Slough. Many of these islands exhibit a teardrop shape with the pointed end oriented in the direction of the slow-flowing waters of the marsh. Northeastern Shark Slough was added to the park in 1989 after it had been drained, farmed, and platted for development in some areas. The northern boundary of the Shark Slough region is defined by a large road – the Tamiami Trail (US 41) that has an accessory canal and levee (L-29) and several culverts which form a tenuous hydrological connection between the park and over a thousand square miles of wetlands that occur north of the park (also known as Water Conservation Area 3). The combination of historical land uses and altered hydrology have created an area with significant management challenges that are addressed through actions at multiple spatial scales, ranging from changes to the operations of regional scale water management infrastructure, to modifications of the Tamiami Trail, to local management of invasive plants and animals. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (releases through the S-12 D gate, S-334, S-355 A&B gates and S-12 structures); altered fire regime; climate change (particularly sea-level rise); historical land uses; exotic plants and animals; reduced spatial extent of habitats in landscape surrounding the park; commercial and private airboat usage; road traffic along Tamiami Trail.

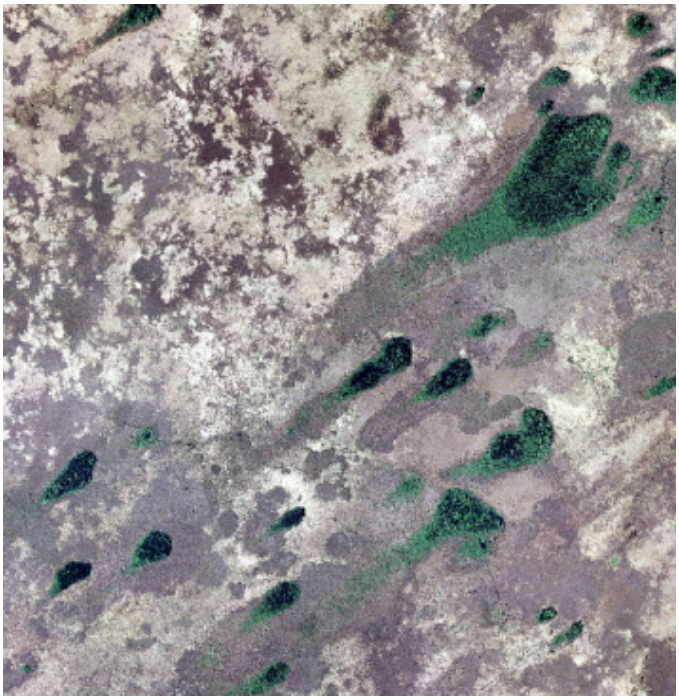


Photo 4. Ridge, slough, and tree island patterned landscape in Shark River Slough.

Region 4 - Rocky Glades

Just east of Shark River Slough is the Rocky Glades ecological area. Marl soils and short hydroperiod marshes are interspersed with tree islands in the Rocky Glades landscape. Slightly more than 2% of the park (34,800 acres) is covered by this ecological region. The Rocky Glades function as an accessory drainage feature to Shark River Slough, since there is no obvious elevation barrier separating the two ecological regions. The habitats in the Rocky Glades can be disturbed with gravel soil types that result from intensive human activities. Melaleuca (*Melaleuca quinquenervia* (Cav.) S.F. Blake) and Australian pine (*Casuarina equisetifolia* L.) are the most important exotic plant species management challenges. The most common substrate in this region is exposed limestone with or without thin marl soils. Exposed limestone can be riddled with "solution holes" (localized areas of lowered elevation where the limestone has dissolved) that can contain water into the dry season. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (releases through the S-12 D gate, S-334, S-355 A&B gates and S-12 structures); reduced spatial extent of habitats in landscape surrounding the park; altered fire regime; sea-level rise; historical land uses; exotic plants and animals.

Region 5 - Taylor Slough Headwaters

Short hydroperiod prairies (1–4 months of inundation per year), disturbed uplands along the eastern boundary of the park, and a few pinelands are the predominant plant communities occurring in this ecological area. The Taylor Slough Headwaters region covers almost 4.5% of the park (70,300 acres) along the eastern boundary. The predominant soil type is marl (calcium carbonate muds) occurring on a surface of Miami limestone. Much of the Redlands agricultural area was naturally part of the Taylor Slough Headwaters region prior to development. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (the releases through all structures on Tamiami Trail and a series of construction projects that reduce the loss of water along the eastern boundary of the park have significant effects on the area); reduced spatial extent of habitats in landscape surrounding the park; altered fire regime; exotic plants and animals.

Region 6 - Western Coastal Swamps and Lagoons

Mangrove forests, coastal marshes, over a dozen square miles of coastal lakes, and hundreds of linear miles of creeks occur within this ecological area. The Western Coastal Swamps and Lagoons ecological region covers 15% of Everglades National Park (228,000 acres), and receives inflows across roughly 34 miles of shared boundaries with Big Cypress National Preserve (1.7 miles), the Broad/Lostman's River Drainage, and Shark River Slough. About half of the creeks deliver water directly to the Gulf of Mexico, while the other half empty into Whitewater Bay. Holocene (or recently derived marine sediments) are the dominant geological type of this region, overlaid with peat soils in high biomass mangrove forests or simply marine muds in areas with less plant biomass. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (the releases through all structures on Tamiami Trail have significant effects on this area); altered fire regime; climate change (particularly sea-level rise); historical land uses; tropical storm surges; exotic plants and animals.

Region 7 – Pinelands and Southwestern Marl Prairies

Pine rocklands, Short hydroperiod prairies, Cypress forests (both domes and prairies), and abandoned agricultural areas occur in this ecological area which covers nearly 5% of the park (~82,100 acres). Rocky limestone and solution holes occur throughout the pine-dominated uplands, while marl soils occur in seasonally wet marshes. The pine rocklands are unique to southern Florida and the Bahamas. This habitat type was once widespread in the region, but has been reduced to less than 5% of their former extent. The patches that remain are severely fragmented due to urbanization, leaving Long Pine Key in the park as the largest remaining stand where many endemic species occur, and the only remaining location in southern Florida where the system of uplands, wetlands, and ecotonal communities occur together. Previously farmed areas have either crushed rock soils (along with a dense infestation of Brazilian pepper), or have been scraped to a continuous limestone surface that now supports native marsh vegetation and marl soil formation. Miami limestone underlies all of the soils in this area. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (the releases through all structures on Tamiami Trail and a series of construction projects that reduce the loss of water along the eastern boundary of the park have significant effects on the area); altered fire regime; historical land uses; exotic plants and animals; roads; climate change, reduced spatial extent of habitats in landscape surrounding the park.

Region 8 - Taylor Slough

A long hydroperiod slough defines this major drainage feature of the park. A small area of remnant slough-ridge-tree island patterned landscape persists in Taylor Slough. This pattern is diminished and narrow at the upstream end, but then broadens south of Anhinga Trail, towards the coast. The Taylor Slough ecological area covers almost 2% of the park (30,100 acres). Marl and peat soils occur over Miami limestone and primary agents of change (or stressors) in this unit include: regional water management infrastructure along the eastern boundary of the park (specifically canals, seepage structures, and water treatment detention ponds); altered fire regime; historical land uses; climate change (particularly sea-level rise); exotic plants and animals.

Region 9 - Southeastern Marl Prairies

The southeastern marl prairie ecological area occurs just east of Taylor Slough, covering 1.7% of the park (or 26,750 acres). Marl soils and short-medium hydroperiod marshes (short 1–4, medium 4–11 months inundation per year) are the predominant vegetation types in this region, with a few pinelands and a few cypress domes. Another 40,000 acres of this ecological region extends outside the boundary of the park and includes significant portions of the Southern Glades Wildlife Management Area – owned by the State of Florida. Primary agents of change (or stressors) in this unit include: regional water management infrastructure (a series of construction projects that reduce the loss of water along the eastern boundary of the park, and rehydration projects that deliver water to the southeastern marl prairie through the C-111 canal have significant effects on the area); altered fire regime; historical land uses; exotic plants and animals.

Region 10 - Cape Sable

The southwestern tip of the park's land surface is the Cape Sable ecological area. Coastal marshes, coastal grasslands, mangrove/buttonwood forests, a series of coastal lakes, and a narrow band of

coastline are the main features of this ecological area that covers 5.4% of the park (83,600 acres; Photo 5). Over ten square miles of Coastal Lakes are now brackish due to lack of freshwater delivery to the region. Many of the park's worst Lygodium infestations (*Lygodium microphyllum* (Cav.) R. Br. or *Lygodium japonicum* (Thunb.) Sw.) occur in the coastal wetlands of Cape Sable. Primary agents of change (or stressors) in this area include regional water management infrastructure (the releases through all structures on Tamiami Trail); historical land uses and drainage structures; exotic plants and animals; altered fire regime; tropical storm surges; climate change (particularly sea-level rise).



Photo 5. Sandy beach along Cape Sable is suitable for turtle nesting.

Region 11 - Whitewater Bay

The Whitewater Bay ecological area is a brackish water body that is connected with the Gulf of Mexico on its northwestern corner. A fringe of mangrove forests occurring on top of recently created marine sediments borders the area. Over 4% of the park's surface is occupied by this ecological area (64,200 acres). The bay receives water from dozens of creeks that originate in the Western Coastal Swamps and Lagoons and Shark Slough regions. Freshwater flows out of Whitewater Bay into both the Gulf of Mexico to the west and Florida Bay to the southeast. Much of the lake bottom of Whitewater Bay is at or below sea level. Primary agents of change (or stressors) in this area include regional water management infrastructure (the releases through all structures on Tamiami Trail); historical land uses; exotic plants and animals; tropical storm surges; climate change (particularly sea-level rise).

Region 12 - Eastern Coastal Swamps and Lagoons

The coastal area along the southern and eastern edge of the Florida Peninsula contains over eight square miles of coastal lakes, coastal marshes, a coastal hardwood forest along the "buttonwood embankment", and mangrove forests. Twelve distinct embayments occur in this region, and these receive water through more than a dozen coastal creeks, most of which occur in the eastern third of

the region. This long, thin ecological area covers 6% (92,600 acres) of the park's surface, stretching over thirty miles from east to west. Some of the most severely compromised ecological conditions in the park occur here. The coastal lakes in the western part of this region become hypersaline during extended droughts. Primary agents of change (or stressors) in this area include: exotic plants and animals; tropical storm surges; climate change (particularly sea-level rise); regional water management infrastructure (the location of releases through structures on Tamiami Trail and the total volume of releases into the park are the most important aspect of water management for this ecological region).

Region 13 - Gulf Coast Marine

The narrow band of marine areas that define the western boundary of the park stretch over 80 miles from the northwestern corner to the southern tip of the park and cover over 8% (or 124,000 ac) of the park's surface. These four zones are shallow (mostly < 3 ft. deep) marine areas that extend 1–3 miles from the coast. Seagrass beds are the dominant benthic habitat. Primary agents of change (or stressors) in these areas include tropical storm surges; climate change (particularly sea-level rise).

Region 14 - Western Florida Bay

Seven marine basins flanked by mudflats and crowned with a few emergent islands (known locally as keys) occur in this ecological area that covers 5.4% of the park (82,700 acres). Seagrass communities are the dominant benthic habitat, and tend to be sparse on the mudflats and dense/continuous within the basins. Emergent keys are always fringed with mangrove or buttonwood trees, and occasionally contain stands of subtropical hardwood forests. Mudbanks are often exposed during low tide, and depths rarely exceed 3 ft. in basins. Primary agents of change (or stressors) in these areas include recreational impacts (e.g., fishing, propeller scars, groundings); tropical storm surges; frost events; exotic plants and animals; climate change (particularly sea-level rise).

Region 15 - Central Florida Bay

This ecological area is downstream of one of the most challenged ecological zones in the park, and stands to benefit greatly from changes to the regional water management infrastructure. Nearly 81,000 acres of estuaries, seagrass beds, and mud banks that are occasionally tipped with subtropical islands occur in the Central Florida Bay ecological area that covers 5.3% of the park. The influence of marine processes is diminished while the influence of estuarine processes is elevated in this region compared to areas in western Florida Bay. Primary agents of change (or stressors) in these areas include: regional scale water management infrastructure by reducing freshwater flows and altering timing that induces hypersaline conditions, recreational impacts (e.g., fishing, propeller scars, groundings); exotic plants and animals; tropical storm surges; climate change (particularly sea-level rise).

Region 16 - Southern Florida Bay

Four marine basins separated by mudflats with five emergent keys occur in this 35,000-acre ecological zone that covers 2.3% of the park. Dense seagrass is the predominant benthic type with a few acres of unconsolidated sediment and a few dozen acres of turbid plumes. While the park boundary does not touch the Florida Keys archipelago in this region, the two southernmost marine basins connect to the Atlantic Ocean through four major channels that bisect the archipelago either

north of Islamorada or among the Matecumbe Keys. The degree of influence of the Atlantic Ocean differentiates this region from the rest of Florida Bay. Primary agents of change (or stressors) in these areas include recreational impacts (e.g., fishing, propeller scars, or boat groundings); tropical storm surges; frost events; climate change (particularly sea-level rise); exotic plants and animals; residual effects from the construction of Flagler railway which reduced connectivity with the Atlantic Ocean.

Region 17 - Eastern Florida Bay

Two estuarine basins with thin mudbanks, over a hundred acres of forested islands, and three sounds (a long broad passage of the ocean that parallels the coast and connects two waterbodies) occur within this 93,000-acre ecological area that covers 5.4% of the park. Eastern Florida Bay is affected by surface and groundwater flows from Taylor Slough that travel through the coastal creeks of the Eastern Coastal Swamps and Lagoons region, as well as the Southeastern Marl Prairies region. Eastern Florida Bay is more isolated from marine processes than all areas south and west due to the intersection of the Florida Keys and the mainland that occurs in the northeastern corner. The three sounds (Blackwater, Little Buttonwood, and one unnamed 1,000-acre sound) are surrounded by land, with only small connections that function as outlets and which are nestled between the Florida Keys archipelago and the southern edge of the peninsula. The sounds exhibit ecological functions that are clearly distinct from the other basins in Florida Bay that are more tightly integrated with either the Atlantic Ocean or the Gulf of Mexico. The Atlantic Intracoastal Waterway (a boat passage channel maintained by the Army Corps of Engineers that enables nearly continuous boat passage from Boston, MA to Key West, FL) passes through this ecological area. Highway US 1 defines the northeastern boundary, and is the primary source of direct impacts from humans. Primary agents of change (or stressors) in these areas include: regional scale water management infrastructure that reduces freshwater flows, alters timing, and induces hypersaline conditions; recreational impacts (e.g., fishing, propeller scars, groundings); nutrient impairments resulting in algal blooms; tropical storm surges; exotic plants and animals; climate change (particularly sea-level rise); residual effects of construction of Flagler railway which reduced connectivity with the Atlantic Ocean.

2.5. Agents of Change

The agents of change (or stressors) in the Everglades ecosystem can affect the entire park. Any one of these agents by itself can force a patch of the Everglades landscape into a completely different condition in a few short years. Together these agents of change can interact to produce immediate degrading impacts or the stressors can be skillfully modulated to set a patch of land onto a developmental pathway that restores and sustains desired ecological characteristics. The distinguishing factor between these possible future conditions is how we collectively understand and manage linkages between: historical land uses; regional water infrastructure and management; fire management; exotic species infestations; reduced spatial extent of habitats in the landscape surrounding the park; recreational uses; fishing activities in Florida Bay; environmental contaminants; climate change; and land-uses in the areas upstream of the park (as far north as the Kissimmee River, Figure 2.15). The choice to identify change agents this way is intended to ensure consistency with conceptual models and documents associated with restoration of the Greater Everglades ecosystem.

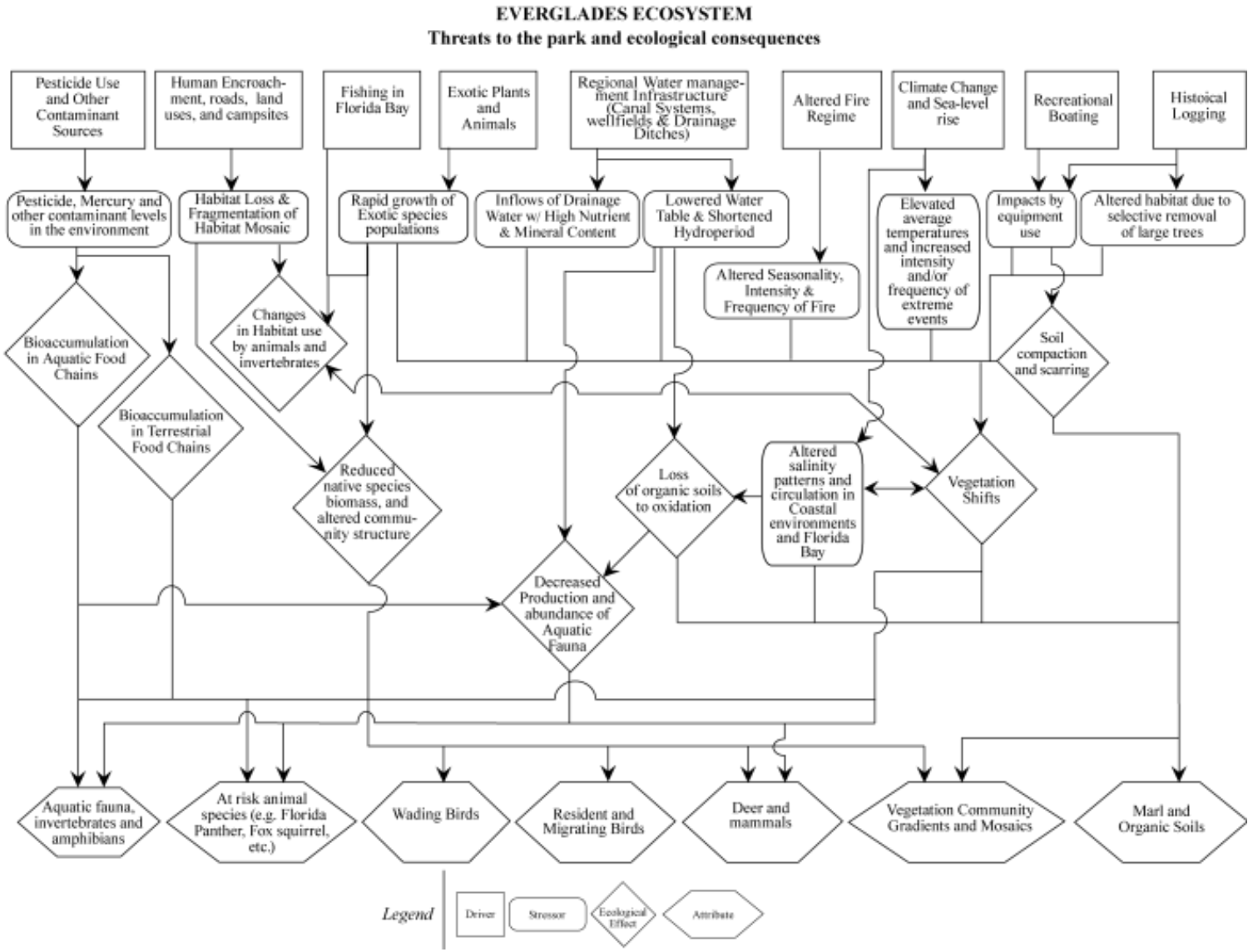


Figure 2.15. A conceptual model links drivers (a.k.a. threats) to natural resources through the stressors and ecological effects that occur in Everglades National Park. Attributes are collectively identified as the food web.

2.5.1. Threats to the park

The main threats to Everglades National Park (in alphabetical order) are:

- Altered fire conditions
- Climate change and sea-level rise
- Exotic species infestations
- Historical land use
- Historical or current roads
- Nutrient pollution
- Pesticides and environmental contaminants
- Recreation and fishing in Florida Bay
- Reduced spatial extent of habitats in the landscape surrounding the park
- Regional water management infrastructure
- Storm surge

The presence of any of these ecological threats (a.k.a. drivers) at a location does not automatically mean that the area is ecologically disturbed. However, these activities have each been directly associated with ecological impacts in at least one location (Table 2.4), and therefore, it seems reasonable to identify the locations where any of these factors are operating. Each of these threats has one or more aspects, which directly cause a certain type of environmental impact, and it is these aspects which can be managed to reduce or eliminate impacts. Chapters 4 and 5 deliver more information about how these threats are linked to individual natural resources, specific regions of the park, and describe risks that can result from multiple/interacting threats.

Table 2.4. Threats to the park by ecological region. X means the stressor is present.

Ecological Region	Altered Fire Conditions	Climate Change and Sea-Level Rise	Exotic Species Infestations	Historical Land Use	Nutrient Pollution	Pesticides and Environmental Contaminants	Recreation and Fishing	Reduced Spatial Extent of Habitats Surrounding the Park	Regional Water Management Infrastructure	Historical or Current Roads	Storm Surges
1[a]	X	X	X	X	X	–	X	–	X	–	–
2[a]	X	X	X	X	X	–	–	–	X	–	–
3[a]	X	X	X	X	X	–	–	X	X	X	–
4[a]	X	X	X	X	X	–	–	X	X	X	–
5[a]	X	–	X	X	X	–	–	X	X	–	–
6[a]	X	X	X	–	X	–	X	–	X	X	X
7[a]	X	–	X	X	–	–	–	X	–	X	–
8[a]	X	X	X	–	X	X	–	–	X	–	–
9[a]	X	X	X	X	X	X	–	–	X	X	–
10[a]	X	X	X	X	X	–	X	–	X	X	–
11[b]	–	X	X	X	X	–	X	–	X	X	X
12[a]	–	X	X	X	X	X	X	–	X	–	X
13[c]	–	X	–	–	–	–	X	–	–	–	X
14[d]	–	X	X	–	–	–	X	–	–	–	–
15[d]	–	X	X	–	X	–	X	–	X	X	X
16[d]	–	X	X	X	–	–	X	–	–	X	–
17[d]	–	X	X	X	X	X	X	–	X	X	X

[a] Terrestrial

[b] Lake

[c] Gulf coast

[d] Florida Bay

Altered fire conditions

Fires have shaped the ecosystems of southern Florida for thousands of years. Lightning strikes occur much more frequently in peninsular Florida than in most of the world. In 2011, most of the Florida peninsula experienced more than 30 flashes of lightning per km^2 (Figure 2.16). Lightning strikes are seasonally concentrated in May, June, July (Figure 2.17), and August. NASA's spaceborne Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS) observed more than six flashes per km^2 over Florida during these four months (Figure 2.16). Not all of these flashes touch the ground, but the total number of flashes per km^2 is correlated with the number of flashes touching the ground. This pattern of lightning activity corresponds to the rainy season.

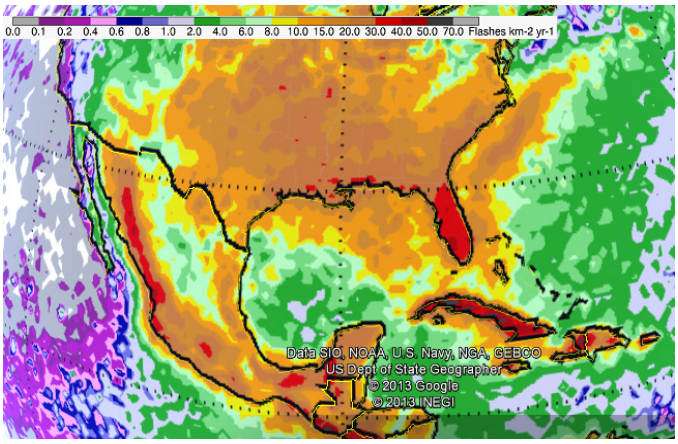


Figure 2.16. Map depicts the number of lightning flashes per km^2 per year in 2011. These flashes were observed directly by the spaceborne Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS).

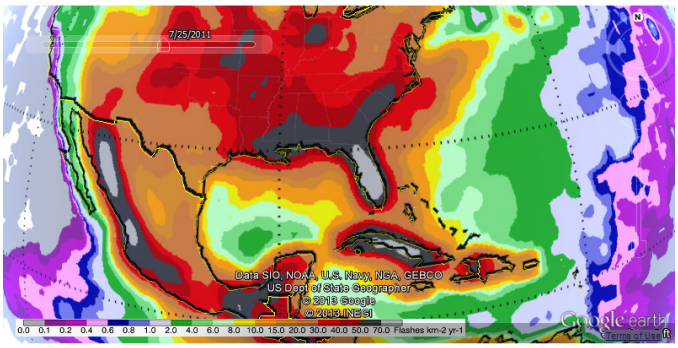


Figure 2.17. Map depicts the number of lightning flashes per km^2 in the month of July 2011. The light gray area covering the Peninsula of Florida demonstrates six flashes per km^2 during the month (equal to an annualized rate of more than 70 flashes per km^2).

The seasonal pattern of lightning strike frequency is relevant to the discussion of fire conditions, because lightning and humans are the principal causes for the occurrence of fire. Linking lighting strikes to the peninsular weather patterns suggests that lightning-initiated fires have been a persistent feature of the Florida peninsula for many centuries. Seasonal concentrations of lightning strikes during the spring and summer suggest that historically, growing season fires were the most common

type of fire occurring in the region. The effects of Native American burning likely had some influence as well, though the consequences or the extent of these fires across the region is not as well documented or understood. Fire is known to strongly affect the species composition of forests, shrubs, grasses, and herbaceous plants (i.e., the plant "community") of patches of land (USGS 2000). Pinelands are more fire-tolerant than hardwoods; therefore, more fire can maintain pinelands or cause them to expand whereas an absence can allow hardwoods to expand. Cypress domes are usually tolerant to fire or protected from fire by standing water - except under drought conditions. Fire restricts mangroves from shifting inland into freshwater marshes. Current research is focused on determining the magnitude of the effect fire season has on wildlife, forests, and understory vegetation communities. Fire intensity, species-specific growth patterns and physical features, fire seasonality, time since the last fire, the presence of exotic species, and local hydrology are recognized to play an important role in predicting the consequence of a fire on a local ecological community (Platt 1999, USDA 2008, and many others). Current fire management in Everglades National Park is focused on moderating fire severity by burning when moist conditions prevail. The climate and hydrology of southern Florida can exhibit moderate differences in seasonal temperatures and water levels. As a result, moisture conditions and safety considerations are the primary factors considered when applying prescribed fires.

The damaging effects of hot, high intensity canopy fires and peat soil consuming fires are well known. Intense fires can develop during drought and are usually caused by arson or careless use of equipment. These types of fires are actively suppressed whenever possible. The importance of low-medium intensity fires that consume understory vegetation for maintaining healthy pinelands and prairies is also well understood. The effects of some of the more subtle attributes of fire behavior and fire management strategies (like ignition patterns, target flame lengths, effects on plant communities occupying the boundaries between habitats) remain areas of active research.

The consequences of altered fire regimes are well understood. When fire is systematically suppressed, pinelands and prairies accumulate shrubs and hardwood trees. These associations are not stable, however, and chronic fire suppression leads to an outbreak of very high-intensity, ecologically devastating fires that consume most of the plants (even large trees) and can sterilize soils, killing seedbanks. The appropriate frequency and intensity of fire is habitat-specific, so specific objectives for fire management are defined in the context of subsequent discussions of habitats. Pinelands and prairies in general should experience fire more frequently than cypress strands or hardwood hammocks.

Climate Change

Changes to global climate are occurring and documented. The South Florida Natural Resources Center recently published a literature synthesis (Pearlstine et al. 2009) compiling the evidence of climate change in southern Florida. Assessments of the potential vulnerabilities of the southern Florida ecosystem and the region's capacity for adaptation to climate change were primary features of this report. The main concerns about the effect of climate change on the natural resources of EVER include: sea-level rise in the coastal marshes; increased frequency of extreme storm events; reduced winter rainfall that causes more intense drought and increased fire risk; altered timing of

biologically important events (phenology); and vegetation shifts that accumulate from the interaction of these multiple causes.

Increased intensity and frequency of extreme weather events is expected as atmospheric CO_2 levels increase. For EVER, this may mean more intense and enduring droughts that stress plants and animals directly. Extreme droughts means increased severe fire risk, and given increased background stress-levels in the ecosystem, there may be a need to enhance activities focused on prescribed fires near the wildland/urban interface as a way to prevent wildfires caused by arson. Increased climate extremes may also mean larger hurricanes that deliver more water to the regional system in 24 hr. – 2-week long storm events. When rare or threatened plant and animal species populations experience these more intense swings of environmental conditions, their existence may become more tenuous.

Nearly all categories of organisms – amphibians, butterflies, birds, plants, fish – have been shown to shift timing of biologically important spring events (i.e., phenological events - like reproduction, migration, bud break, etc.) in response to changing temperature patterns. These shifts are organism-specific, and as a result, loss of synchrony between plant populations and the migrating organisms that they host can occur. Loss of synchrony between migrating butterflies and host plants has been observed in some areas of the world. While butterfly migrations are not prominent features of the southern Florida ecosystem, bird migration is very important, and changing weather patterns may have a pronounced effect on the timing of bird migrations as well as the quality of the habitat that birds find when they are transiting southern Florida.

Sea level has increased .73 ft. in 100 years (or 224 mm – Figure 2.18) and is expected to continue rising at least this quickly. In the context of the EVER landscape with such a low elevation gradient, sea level rise has potential to greatly change the distribution of habitats across the landscape: sea water intrusion allows estuarine environments and mangrove habitats to push inland into formerly freshwater environments; seawater intrusion into the aquifer may further exacerbate these changes; deepening embayments and expanding the shallow Florida bay which may result in changes in water circulation patterns; coastal hammock areas may become more vulnerable to storm surges. Sea-level rise concerns have already affected park infrastructure decisions, and these concerns appear likely to escalate during the rest of this century.

The challenge of managing natural resources in the context of climate change is considerable. The development and application of simulation models is essential for managing in this context (sensu Williams et al. 2007). Learning through direct experience is unlikely to be an effective management strategy, since we expect environmental conditions that are outside the range of previous experience to occur more frequently in a changing climate. It is conceptually possible for the location of habitats to shift in space, but be healthy. Nurturing the transitions that are likely to occur as sea-level rises is best accomplished by enhancing the health of habitats at their existing locations. Some ecological functions will be very difficult to sustain – particularly those functions that are associated with large coastal forests, since long-lived trees require centuries to achieve their maximum size.

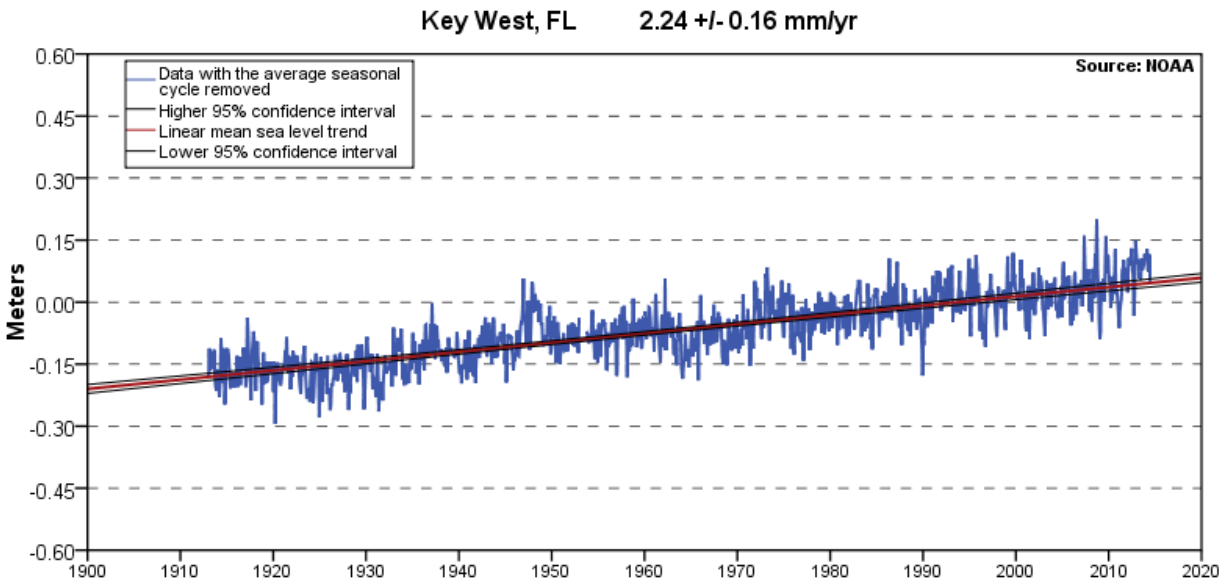


Figure 2.18. A continuous record of sea-level rise in southern Florida has been collected by NOAA since 1913 and is available online.

Exotic species infestations

Exotic species that are reproducing and spreading across the environments of southern Florida represent a significant threat to the ecological integrity of EVER. Exotics (or non-natives) are species that have been introduced to a region by humans (either deliberately or accidentally) across a natural barrier to dispersal. This definition is rooted in the recognition that for much of earth's history, species have been confined to specific regions of the planet because they simply were not able to cross certain barriers (like oceans, mountain ranges, etc.) in large numbers. As humans began to travel greater distances on a more frequent basis, they have been moving all types of living things around the planet, and there have been consequences to these actions. When humans share new varieties of crops across regions, the result has often been positive for people, but when humans bring weeds, diseases, or nuisance species into a new region, the consequences can be quite negative to people as well as native ecological communities (see section 4.6.6 for a more detailed discussion).

In the Western Hemisphere, the 15th and 16th centuries are a key time-period for differentiating non-native plants from natives. The big increase in the frequency of travel across the Atlantic Ocean between Europe and the Americas that began at this time resulted in a large number of introductions of non-native plants and animals into continents where they had not previously existed. For southern Florida in particular, the 1880's mark the beginning of a rapid increase in the number of people residing in Florida. The expanding human population introduced many new species, and some of these species began to reproduce, establish expanding populations, and transform the habitats that were historically dominant in the region. This process occurred so often that the term "invasive" became associated with the species that rapidly proliferate after introduction across a historically insurmountable boundary. Many of the plants and animals that are managed as invasive exotics in southern Florida today arrived after 1900.

Exotic organisms of all types are a concern to agriculture, suburban, and urban residents of southern Florida. Exotic fungi and microbes are more commonly recognized as disease outbreaks. The consequences of exotics and management approach to these three groupings of nonnative species are different enough that we separate the discussion of plants, animals, and diseases in this report.

Exotic Plants

Exotic (or nonnative) plant species were recognized as threats in reports to the Superintendent of Everglades National Park by Craighead as early as 1961, and many reports, peer-reviewed scientific literature, and books have been devoted to the issue of exotic species in the last five decades (Simberloff et al. 2012, Doren et al. 2009). Japanese climbing fern (two species - *Lygodium microphyllum* (Cav.) R. Br. or *Lygodium japonicum* (Thunb.) Sw.), the Brazilian pepper tree (*Schinus terebinthifolius* Raddi), Melaleuca (*Melaleuca quinquenervia* (Cav.) S.F. Blake), Australian pine (*Casuarina equisetifolia* L.), Seaside mahoe (*Thespesia populnea* (L.) Sol. ex Corrêa), and Lather Leaf (*Colubrina asiatica* (L.) Brongn.) are currently the priority invasive exotic species that are being actively controlled in the park. The best available evidence yields an estimate of 246 non-native plant species are present in Everglades National Park, and 17 are listed as noxious weeds by the Florida Department of Consumer Services (FDACS Rule 5B-57.007, accessed 6/7/2013). Noxious weeds are defined by the state of Florida as:

> *"Any living stage, including, but not limited to, seeds and reproductive parts, of a parasitic or other plants of a kind, or subdivision of a kind, which may be a serious agricultural threat in Florida, or have a negative impact on the plant species protected under Section 581.185, F.S., or if the plant is a naturalized plant that disrupts naturally occurring native plant communities."*

The consequences of invasions can be stark, and invasions can be more severe in areas where other forms of ecological disturbance occur. Multiple exotic invasive species can interact to produce "invasional meltdown" of local food webs (Simberloff and Von Holle 1999). One of the objectives of the NRCA is to document the extent of invasive species in the park, and identify areas in EVER that are likely to be more vulnerable to invasional meltdowns than other areas. This relative comparison is important for establishing priorities for management action. The extent of invasion of different areas will be identified in Chapter 4.

Exotic animals

The ecological destruction caused by exotic animals is well documented and extensive. Destruction of agricultural systems are perhaps the best documented cases (Simberloff and Rejmanek 2011). The Florida Fish and Wildlife Conservation Commission recognizes the threat that nonnative animal species present to humans and native organisms, and maintains several publically accessible lists of key animal species that are either prohibited from entry into Florida or allowed conditionally through a permitting process. These lists identify 68 conditionally prohibited species and 721 prohibited species. Burmese pythons (*Python molurus*) and several other large constrictors have been identified as injurious species by the US government under the Lacey Act (2012). The North African python (*Python sebae*), Argentine tegu (*Tupinambis merianae*), feral hogs (*Sus scrofa*), and European

Starling (*Sturnus vulgaris*) are known management challenges in the park. Lionfish (*Pterois volitans* and *P. miles*) are an emerging threat to marine areas in the park (and in the region), as are at least 16 other species of nonnative freshwater fish species.

Exotic animals can displace native animal species by eating them, competing with natives for food, destroying native habitat, or spreading disease to native organisms. The introduction of top predators such as the Burmese python (*Python molurus*) or the lionfish (*Pterois volitans* and *P. miles*) can have cascading effects throughout the ecosystem, as prey communities shift in density and distribution as a result of novel, intense predation pressure (Salo et al. 2007). Exotic animals can also affect habitats through effects on vegetation or soils. When a native species is affected, this can alter how habitats are used, and this can affect vegetation and/or affect how vegetation responds to other events (like fires, floods, or hurricanes). Altered habitat use by animals can initiate a feedback loop that creates more impacts to native populations over time.

Prevention of new introductions and suppression of existing established populations is the principle approach for managing exotic fish and wildlife in EVER. Exotic animals are combined into three distinct groupings for purposes of reporting and management: Exotic herpetofauna (reptiles and amphibians), exotic marine species, and exotic freshwater fish. Unlike the current situation with exotic plant control, few to no proven technologies are available to control or eliminate exotic fish and wildlife once they are established. As a result, slowing the rate of introduction of new species into the park and constraining the rate of spread of the species that are present are the main management focus for this group of organisms. The management actions that are the most effective for reducing the introduction of exotic animals remain outside NPS control, i.e., legislation and policies that regulate the importation, trade, custody, and care of herpetofauna in the United States and the state of Florida.

Exotic insects, invertebrates, fungi, and microbes (also recognized as diseases)
Exotic insects, invertebrates, fungi, and microbes are known to produce significant impacts to regional ecological systems. The Southern Region of the U.S. Forest Service does a considerable amount of work tracking forest disease spread, and identifying risks zones for disease impacts that is potentially relevant to Everglades National Park. The Forest Service identifies 35 insect species that are known forest pests and 17 diseases. Ecological consequences of the spread of Laurel Wilt (a fungus spread by the non-native ambrosia beetle), lobate lac scale, croton scale, and ficus spiraling whitefly, have been detected in the park.

Fire ants, love bugs, and snails were identified as exotic species that were present in Big Cypress National Preserve when it was established (Duever et al. 1986), and these same organisms were probably present in EVER. Laurel wilt (a fungal pathogen - *Raffaelea lauricola* that is spread by a non-native insect – the redbay ambrosia beetle - *Xyleborus glabratus*) has been identified as present in EVER and throughout southern Florida in recent years. The swamp bay (*Persea palustrus*) is a common native tree in the swamp forests of EVER, and is a culturally significant species to the Seminole and Miccosukee tribes. The Laurel wilt appears to be killing most of the swamp bay as the ambrosia beetle moves southward into the park. Two species of butterflies (the palamedes swallowtail (*Pterourus (Papilio) palamedes*) and spicebush swallowtail (*Pterourus (Papilio) troilus*)

use the swamp bay to complete their life cycle. Therefore, the occurrence of laurel wilt is a significant concern to the park and is likely to become a focal issue in the coming years.

Historical Land Use

Evidence of land use by Pre-European cultures is found throughout the park. Shell mounds along the Gulf Coast and piling of materials on the large tree islands in the interior of the park are evidence of the thousands of people who inhabited southern Florida for centuries prior to European colonization. Since the 1880's the human population in southern Florida has grown from several thousand to over seven million (Figure 2.19). Southern Florida was typically surveyed before a significant number of people immigrated into an area. Figure 2.20 (reprinted with permission from McVoy et al. 2011) shows the year which townships across southern Florida were surveyed, and this map provides a sense of when these areas began to be colonized in larger numbers by people of European descent.

Several townships were surveyed as early as the 1840's, and then a group were surveyed in the 1850's. Only one township was surveyed in 1860, followed by a decade-long pause of surveying, until 1870 when several coastal areas were surveyed. Exploratory surveys into the interior continued in the 1870's. Interior surveys became more frequent in the 1880's. A lull in survey followed, with few sites evaluated in the 1890's, until 1907 when surveys again became more frequent. Between 1912 and 1918, the interior areas of Broward County, Miami-Dade County, and the southern rim of Lake Okeechobee were surveyed and by this time, settlement of the region began to increase significantly.

Road building is a prominent form of land use that generally creates long-lasting, clearly perceptible impacts on soils and plant communities. There are roads and other infrastructure in EVER that can have local effects on water flows including Main Park Road, Old Ingraham Highway, Shark River Tram Road, fill pads in Eastern Everglades Addition Lands, Pine Island, and Flamingo. These locations exist because of historical (or current) land uses. The Old Ingraham Highway for example, was established prior to the 1940's and was used to transit the areas now in the park. Several historical sites in Chokoloskee, Flamingo, and along the lower west coast were once in use by pioneers but have not been used for decades.

Because Florida was so wet, these surveys often triggered the beginning of canal development. The C-43 (or Caloosahatchee river canal) that connected western Lake Okeechobee to the Gulf coast began in the 1880's and was completed by 1900. The major drainage canals were established by 1920 (Figure 2.21). These canals reduced the amount of water in the regional system and allowed homebuilding, the development of towns, railways, and conversion of wild lands to pasture and crops.



Figure 2.19. Map of southern Florida with urban areas indicated. Two rings indicate regions that are 50 and 100 miles from the park boundary, and an estimate of the number of people residing in these two areas is embedded as a table.

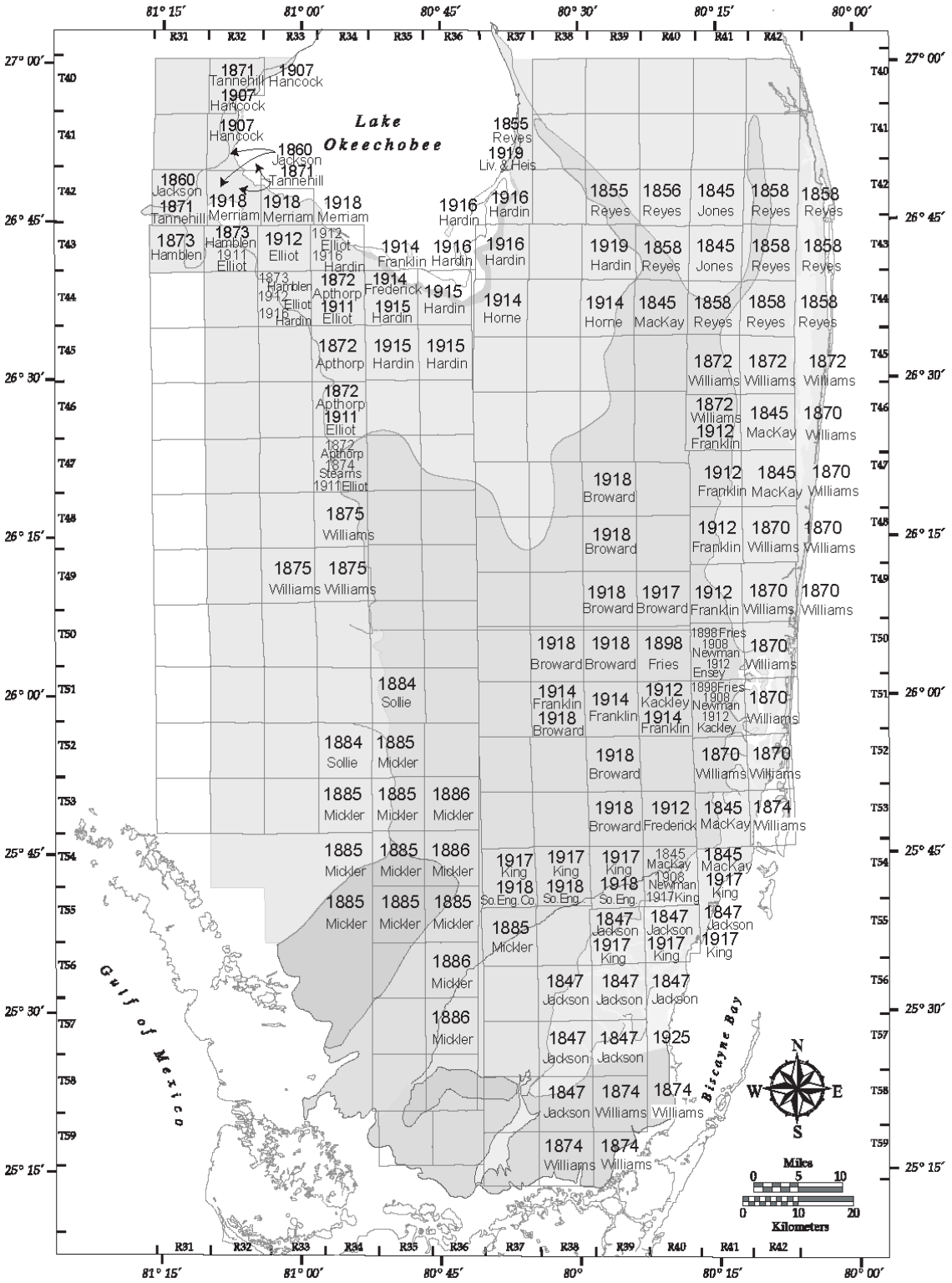


Figure 2.20. Townships examined in McVoy et al. 2011. Label numbers indicate the year of survey. Reprinted with permission of Chris McVoy.

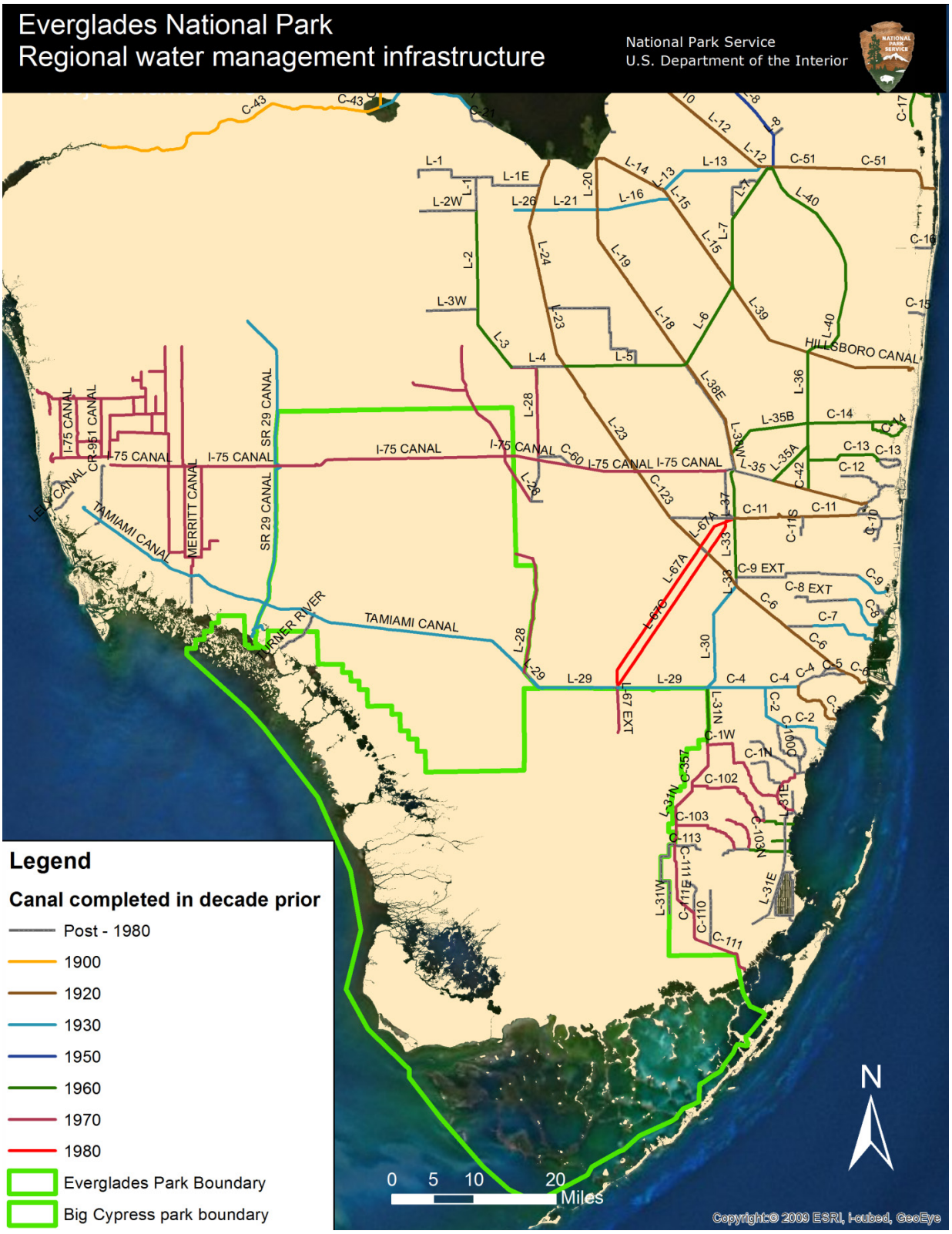


Figure 2.21. Regional Water Management Infrastructure of southern Florida. Canals established in the decade prior to the date listed. The park boundary is drawn below the canal system.

Nutrient pollution (Water Quality)

The challenge of nutrient pollution is almost entirely associated with industrial-scale agriculture. This type of farming emerged after World War II, and has been associated with the use of large quantities of fertilizers and pesticides (Pait et al. 1992). Deliveries of unfiltered agricultural runoff into marshes of Water Conservation Area 2 in the 1980's triggered a shift in plant species composition from a typical everglades sawgrass marsh to a 100 square mile patch of cattail (*Typha* spp.). This conversion event triggered a lawsuit between the state of Florida and the U.S. Federal government. The resolution of the lawsuit involved two decades of development, testing, operation of the Stormwater Treatment Areas (STAs), and a settlement between the U.S. Environmental Protection Agency and Florida Department of Environmental Protection. The development of numeric nutrient criteria for Florida's waters is the result of this extended process of conflict resolution. Florida's numeric criteria were accepted by the EPA in 2013. The transfer of nutrient-laden waters into EVER is a continuing concern, particularly where water management infrastructure transfers water into the park. These concerns can now be addressed in cooperation with state agencies with the knowledge that state laws are in harmony with the federal legal framework (i.e., the Clean Water Act).

Pesticides and environmental contaminants

There are hundreds of environmental chemical contaminants present in EVER. The ultimate sources of most contaminants are the 4.95 million humans living within 50 miles of the park boundary. Activities that are connected to contaminant introduction are: extensive boat usage in Florida Bay and along the Gulf Coast; historical land uses in areas that were added to the park after they had been farmed or developed (and subsequently acquired by the Federal Government); ongoing agricultural practices in areas adjacent to the park; agricultural runoff discharges that eventually enter the park; widespread septic tank usage by people who live in/around the park; contamination associated with particulates that are deposited through atmospheric processes (Saharan dust cloud events are one example of an atmospheric deposition process); exotic plant management actions. Mercury is the only other major contaminant that does not fit neatly into a human-source perspective, but evidence suggests that local sources of mercury include coal-burning power plants, cement kilns, and incinerators (see Table 3.3 in FDEP 2012).

Around two hundred potential contaminants including pesticides, pharmaceuticals, and trace metals, were found at low and very low concentrations in water, sediment, and fish tissue samples collected from DOI lands from 2006 to 2009 (Castro et al., 2013; Gardinali et al., in progress: Chemical Assessment and Risk Evaluation (CARE) of EVER, BISC [Biscayne National Park], and BICY). Organophosphorus pesticides have been screened in the C-111 canal (southeastern marl prairie region) by Key et al. (2003); 42 agricultural compounds were screened in canals between 2002 and 2004 (Harman-Fetcho 2005); Endosulfan (a pesticide used on vegetable crops) has been extensively observed (Potter et al. 2014) and will no longer be used in the region beginning in 2014; mercury (and its derivatives) has been extensively monitored in the region (Rand and Gardinali 2005, Rumbold et al. 2008, Axelrad et al. 2010). Approximately 70 pesticides and their degradation products were sampled in the region by the South Florida Water Management District (SFWMD) between 1992–2001 (Pfeuffer and Rand 2004).

Environmental contaminants pose a risk to humans through the food web. Trace quantities of these contaminants can produce cognitive and developmental defects in mammals (Mullins et al. 2013), fish (Potter et al. 2014), and arthropods (Harman-Fetcho et al. 2005, Carriger et al. 2006, Palma et al. 2009). Pesticide application rates in southern Florida are higher than most other parts of the U.S. (Pait et al. 1992), so risks to humans and aquatic organisms from exposure may also be higher.

Recreational activities and fishing in Florida Bay

Recreational boating in Florida Bay, along the Gulf coast, and in the wilderness waterway are popular activities among park visitors. Many of these boaters also legally fish, collect shrimp, bait, crab, or oysters, and are subject to the rules for collection of these organisms that have been established by the park superintendent. Taking or collecting marine or freshwater life beyond the types listed above is prohibited (Public Law 95-625, section 7.45). Neither lobsters nor mammals can be legally harvested in EVER. Nonnative species roundups occur periodically, and removal of nonnatives by resource managers is an ongoing management process. There are three commercial entities that have permits to use airboats in the park, and private individuals who were operating airboats in the Eastern Everglades Addition Lands prior to 1989 are permitted to continue airboating as outlined in the Everglades Expansion Act of 1989. Potential impacts from recreational boating are most commonly associated with the impact of propellers or hulls on vegetation, soils, sandbars or bottom-communities like seagrass beds, sponges, or coral reefs. Collisions of boats with manatees and other wildlife also occur.

Hiking, canoeing/kayaking, biking, and camping are also popular recreational activities that generally have far fewer impacts than boating or fishing. Visitors and staff that drive vehicles through the park risk accidental collisions with animals crossing the roadways. Maintenance of roadways and campgrounds require significant management activities, which may cause limited impacts to park natural resources.

Reduced spatial extent of habitats in the landscape surrounding the park

Human populations have consistently grown in areas surrounding Everglades National Park over the past century. Converting habitats and landscapes into agricultural, suburban, and urban areas involves modification of vegetation, soils, and the natural contours of hydrologic basins that are embedded within watersheds. The human population in the five counties surrounding the park has changed dramatically in the last century from less than 30,000 in 1910 to 4,678,251 people in 2010 (U.S. Census Bureau 2010). This rapidly expanding human population has converted millions of acres of natural habitat to agricultural, suburban, or urban use. During the last few decades, there has been a significant effort to protect lands, resulting in an expansive set of protected areas in the region (Figure 2.2). The result is a very complex land use pattern across the southern Florida landscape.

As converted lands accumulate, the remaining natural areas can become isolated “islands of preservation”. A major concern with isolating populations is the increased tendency for local extirpation (or complete loss) of populations of organisms when short-term fluctuations in population numbers are not buffered by the ability to emigrate into nearby populations and immigrate back into previously occupied areas after challenging conditions become more favorable. The theory of island biogeography has been developed since the 1970’s. After conducting many large-scale experiments,

the development of rigorous mathematical models, and long term monitoring of island formations across a broad set of climate conditions, it is clear that the size and connectivity of populations are directly related to their capacity to survive fluctuations in environmental conditions over century-long timescales. Large populations, or populations that are well connected (i.e., individuals can easily travel between areas where populations are centered), are more stable over time, and less likely to be locally extirpated. Even if nothing else changes, the process of isolating a population can render it more vulnerable to decline and extinction when experiencing the natural variability of climate conditions. When this tendency for decline is coupled with a deterioration of the habitat associated with other agents of ecological change, the risks of decline and extirpation increase. Concerns over habitat isolation are a serious concern for Long Pine Key, one of the most speciose habitats in EVER, and the largest intact pine rockland in southern Florida.

Regional water management infrastructure

The South Florida Water Management District (SFWMD) collectively operates the levees, canals, gates, weirs, and pump stations that have been installed throughout southern Florida as a regional water supply and flood-control system. The effects of the water management system on the ecological systems of southern Florida are well documented, and regional-scale changes to the infrastructure system are being contemplated by a consortium of state agencies, federal agencies, sovereign tribal nations, and non-governmental stakeholder groups as a part of the Comprehensive Everglades Restoration Plan (CERP). Canals have been constructed for both drainage purposes and as support structures for levees or roads. Drainage canals tend to be generally oriented N-S, following the flow-pattern of the landscape, while levee-associated canals tend to be oriented perpendicular to the flow-pattern across the landscape and are associated with either water control or transportation.

Everglades National Park encompasses the most downstream portion of the regional watershed, and therefore is extensively influenced by the regional water management system. The net effect of water management infrastructure has been a reduction in the total volume of freshwater present in the region (compared to historical natural conditions – Lodge 1994, Bowen 2003). Drainage canals tend to lower the water table of the area surrounding the canal, and increase groundwater salinity near the coast (Figure 2.10). Water table effects can vary based on the season, with dry season effects being the most severe - when water tables can be lowered several feet for miles into the surrounding marsh. The water management infrastructure surrounding Everglades National Park can shift the hydrologic conditions in a particular direction – making an area generally wetter or dryer than the historical condition, or it can cause areas to exhibit increased extremes in both directions. One of the challenges for natural resource managers is to differentiate hydrologic shifts that are within the historical range of variability from those shifts that are outside of the same range. The “Slough Performance Measure” (LoGalbo et al. 2012) is among the best methods for evaluating change in the return frequency of hydrologic conditions that is caused by the regional water management infrastructure.

The design of the regional system has profoundly affected Everglades National Park. Canals that directly affect the park are the SR-29, L-67 A&C seepage management canals, the L-29 that is

associated with the Tamiami Trail, the L-28 – north of Tamiami Trail, the L-31 N running N-S along the eastern border, the L-31 W, and the C-111/C-111 E canals - located near the southeastern corner of land portion of the park. The L-67 A&C and L-29 canals have levee-like effects, while the SR-29, L-28, L-31N&W and C-111 canals are drainage canals (Figure 2.21). Recent modifications to the L-31 and C-111 canals have been made in order to reduce the drainage-related effects associated with these canals.

2.6. Resource Stewardship

Resource stewardship is the ethic that defines the approach to resource management in the National Park Service.

> *"The national parks of the United States stand as a singular achievement of the nation. From the establishment of Yellowstone as the first national park in 1872, the National Park System has grown to include 397 national parks, historical sites, urban recreation areas, national monuments, wild and scenic rivers, and national trails, with more than 279 million visits each year. The character and importance of this precious heritage lies at the heart of the American experience, and stewardship of the national parks is an enduring responsibility shared by all Americans"* (NPSABSC 2012).

The Everglades National Park was founded in the recognition of the biological attributes of the Everglades as a global treasure (Truman 1947). Visitors to the park repeatedly identify the core values of wilderness, solitude, and native plants/animals as important aspects of the park that should be protected (Littlejohn 2002, Papadogiannaki 2008). Resource managers are focused on cataloging the attributes of the natural resource systems and identifying "chains of causation" (or linkages) between the major resource categories. Diagnosing and modulating these linkages is the current state-of-the-art of resource management (e.g., restoring seasonal timing, spatial location, and total volume of water deliveries to northeastern Shark Slough supports the development of wetland vegetation and enhances the regional aquatic food web).

Assembling a set of resource stewardship strategies is a robust approach for fulfilling the mission of the National Park Service,

> *"...to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations"* (16 U.S.C. l, 2, 3, and 4).

The decision to promote resource stewardship as the defining management ethic for the National Park Service is deliberate. As a part of the centennial celebration of the National Park Service, the National Park System Advisory Board appointed a committee to revisit the concept of resource stewardship and investigate what effective resource stewardship means today. Some of the findings of this committee are stark:

> *"Environmental changes confronting the National Park System are widespread, complex, accelerating, and volatile. These include biodiversity loss, climate change, habitat fragmentation, land use change, groundwater removal, invasive species, overdevelopment,*

and air, noise, and light pollution. All of these changes impact park resources, from soil microbes to mountain lions and from historic objects to historic landscapes. Parks once isolated in a rural or wildland context are now surrounded by human development. Increasing pressures on public lands—from recreational use to energy development—amplify the importance of protected public lands and waters, creating challenges far more complex than in the Leopold era [circa 1963]"

and some are inspiring:

"Understanding of system complexity and interrelatedness has advanced along with recognition that this understanding is incomplete. The need for science—to understand how park ecosystems function, monitor impacts of change (even from afar), inform decision makers and their decisions, and enrich public appreciation of park values—has never been greater. In addition, the National Park System is an extraordinary national asset for advancing science and scholarship—from new discoveries of valuable genetic resources to monitoring benchmarks for environmental change and increasing knowledge of the impact of thousands of years of human history on the American landscape." (NPSABSC 2012 – Revisiting Leopold: Resource Stewardship in the National Parks).

Telling the story of the status and trends of natural resource systems in Everglades National Park requires all contributors to this narrative to reconcile their understanding of the park with information derived from several distinct perspectives: the visceral experience that is repeated each year by thousands of first time visitors; the growing awareness of new and repeat visitors as they encounter native organisms, interpretive information, park rangers, and other visitors throughout the park; and the career professionals who use cutting edge science to formulate effective policies and management programs. All of these perspectives are vital and must continue for resource stewardship to be successful.

The practice of effective stewardship of natural resources in Everglades National Park consists of three essential elements:

1. Documenting the experiences, values, and backgrounds of visitors to EVER.
2. Monitoring the status and trends of the natural resources that are present in the park.
3. Interpreting the science-based understanding of how natural resource systems function to park visitors and all other interested people (as resource management efforts).

Recent activities that support documenting the experience of visitors and a description of the current management plans are the focus of the rest of this section of the report. The subsequent chapters catalog the extent of current monitoring efforts in the park.

2.6.1. Visitors to the park – numbers, seasonal pattern, activities, values, and economics

An annual estimate of the number of people visiting EVER has been recorded since establishment in 1948. The number of visitors reached 1 million per year for the first time in 1965, and has varied

around this number ever since (Figure 2.22). Monthly visitation numbers have been estimated with consistent methods since 1979. The seasonal pattern of visitation has been consistent across this 33 year period – winter/spring (January – April) are high visitation periods, June – September are low visitation periods, and May/October/November/December are transitional (Figure 2.23). These data are obtained from the part of the National Park Service's IRMA (Integrated Resource Management Application) that is focused on visitors.

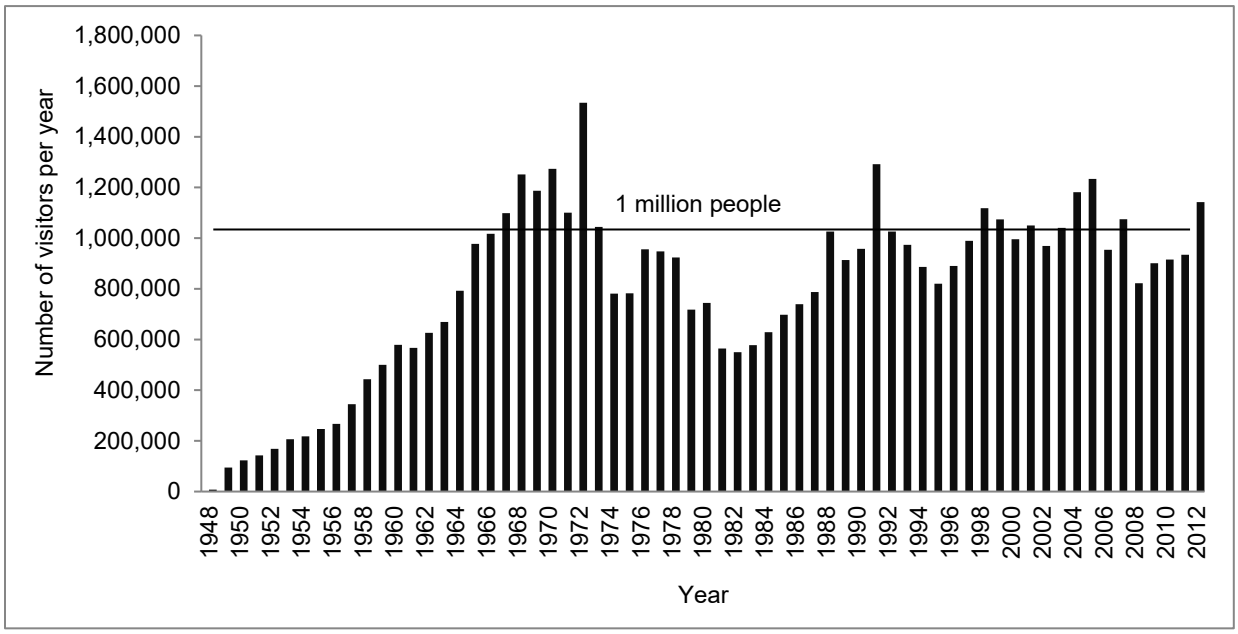


Figure 2.22. Estimated number of visitors to Everglades National Park each year from 1948–2012.

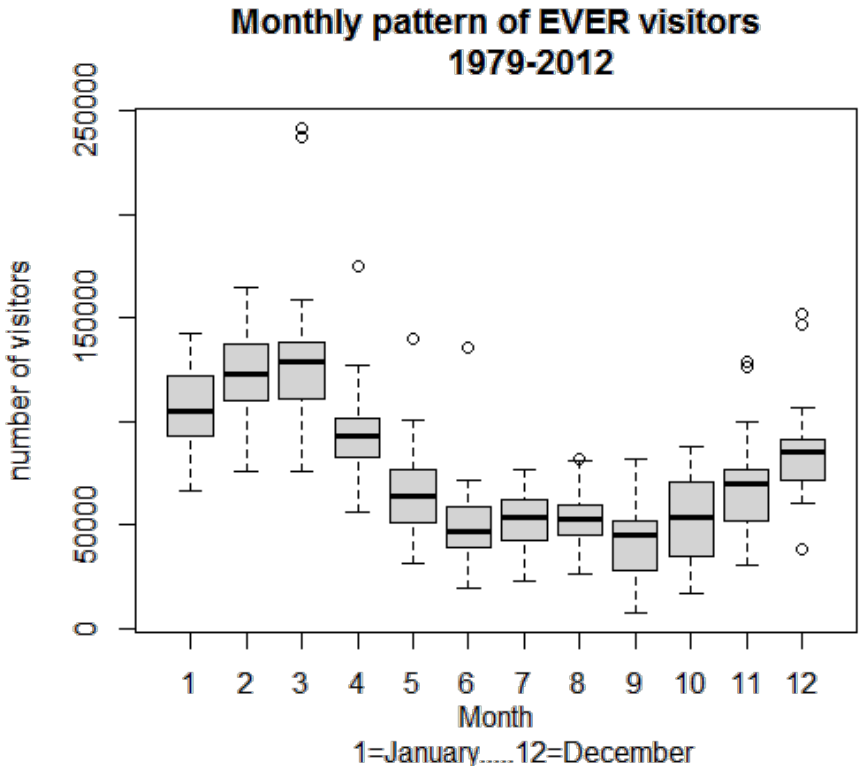


Figure 2.23. Visitor counts summarized monthly – 1979–2012.

The monthly visitation counts for EVER are collected in a way that allows reporting of the numbers of visitors that engage in eight possible types of overnight stays: campers, backcountry campers, concession camping, RV campers, tent campers, concession lodging, and non- recreation visitors (Table 2.5). The overnight stay information shows the same seasonal visitation pattern that the aggregate data shows. RV camping was the most popular form of overnight stay in 2012, with tent campers and backcountry campers the next most popular groups (Table 2.5).

Table 2.5. Monthly summary of Visitor Use in EVER by Month and Year.

2012	Recreation Visitors	Non-Recreation Visitors	Concession Lodging	Tent Campers	RV Campers	Concession Camping	Backcountry Campers	Misc. Campers	Total Overnight Stays
January	128,689	238	0	2,142	3,345	0	1,652	97	7,236
February	133,777	256	0	1,864	3,813	0	1,393	73	7,143
March	132,603	0	0	1,743	1,728	0	1,463	186	5,120
April	99,501	266	0	442	372	0	527	4	1,345
May	73,188	150	0	230	119	0	492	0	841
June	55,627	144	0	21	17	0	28	0	66
July	65,022	276	0	29	9	0	48	0	86
August	73,081	74	0	9	23	0	33	42	107
September	49,588	150	0	12	29	0	71	0	112
October	84,150	267	0	91	217	0	375	1	684
November	100,040	274	0	773	994	0	1,223	15	3,005
December	146,640	178	0	1,562	1,755	0	1,151	53	4,521
2012 Totals	**1,141,906**	**2,273**	**0**	**8,918**	**12,421**	**0**	**8,456**	**471**	**30,266**

Visitor counts are supported by surveys of visitor satisfaction that are conducted every few years. Visitor surveys conducted throughout NPS are available online, and four of these have been conducted in EVER (Dolsen and Machlis 1989, Littlejohn 1996, Littlejohn 2002, Papadogiannaki 2008). The surveys use a stratified random statistical design, which means that users of the results can infer that the surveyed population is representative of the population that visited the park in the same month that the survey was conducted, but the survey results cannot be interpreted to be representative of visitors throughout the entire year. All four surveys were distributed to visitors during the spring (as early as February 26 until as late as April 1).

The most recent survey (2008) measures visitor's perspectives both during this traditional period, and during a second sample period between April 29 – May 5. The number of questionnaires distributed in the surveys range from 500–1,100, and a 60–80% response rate has been realized over time. The questions posed in each survey change a small amount between surveys, but there is enough consistency to identify subjects where perceptions are changing versus those areas of visitor perception that are stable over the past two and a half decades.

International visitors have consistently been between 15–24% of the surveyed population, and Germany has been the most common country of origin of international visitors in all four surveys. Florida residents have consistently ranged from 28–45% of the surveyed population. The remaining 30–50% of visitors surveyed are U.S. citizens from states other than Florida. Visitors often come in groups of two or more and large majorities of visitors stay less than one day (71% in 1989), and most often spend five hours or less in the park. Visitors who were not Florida residents chose southern Florida as a destination for several reasons. Roughly one quarter of non-Florida residents came to see EVER as their primary purpose.

The most recent survey (2008) indicates that visitors to EVER were most likely to be viewing nature/bird watching (75%), walking/hiking (71–74%) or taking visual records (photography/painting/drawing- 57%). Popular guided activities include the tram tour (43%), boat tour (41%), or airboat tours (37%). Visitors have consistently ranked the overall facilities, services, and recreational opportunities in EVER as "good" or "very good" (83% in 2008, 90% in 2002, 88% in 1996), while less than 1% of visitors ranked their overall experience as very poor in any of the four surveys. Visitors consistently rank some aspect of park services as important or very important to their experience (14 categories over 50%, 7 categories over 75%, 3 categories over 90% of respondents). Very few visitors felt disturbed by noises of any sort; over 93% of visitors would like to learn more about the park during their next visit, and either printed materials (58–64%) or self-guided tours (52–54%) are the preferred methods for receiving additional information.

When visitors were asked about the importance of protecting eleven of the park attributes there were significant majorities of visitors who ranked protection of nine categories as either "very important" or "extremely important" (Figure 2.24).

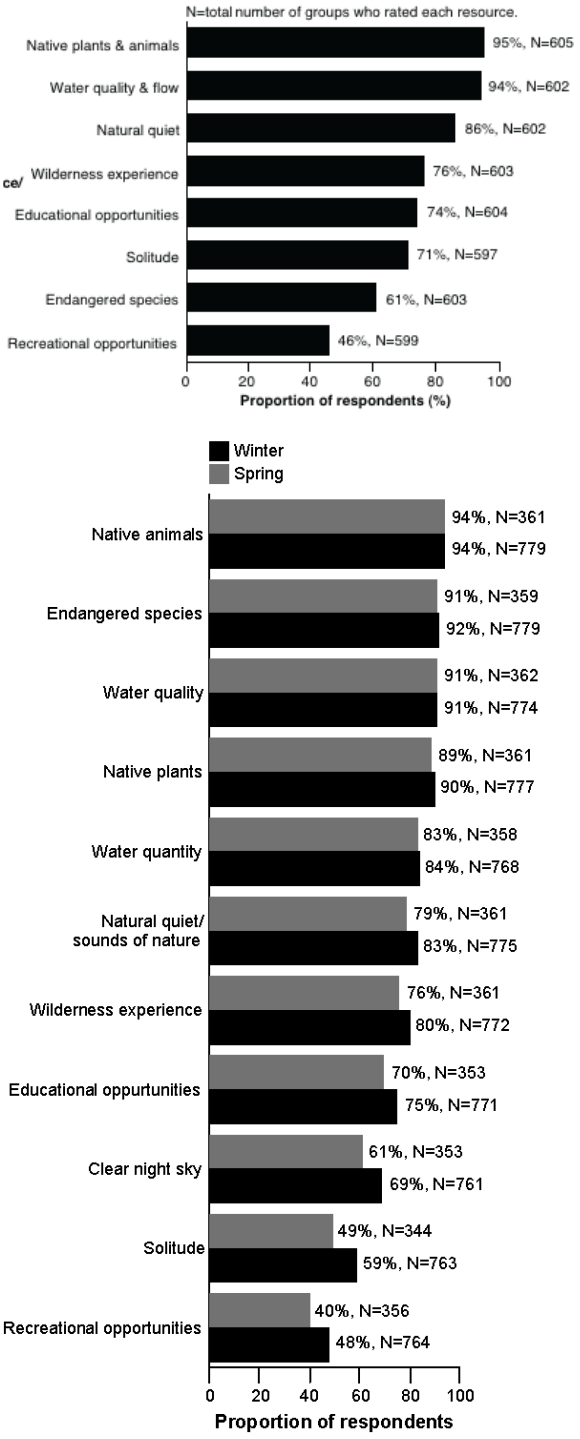


Figure 2.24. Proportion of visitors surveyed in 2002 (top panel) and 2008 (lower panel) that rank each aspect of their park visit as “very” or “extremely” important.

The economic impact of EVER visitors (as indicated by their self-reported spending levels) is a subject that has been increasingly scrutinized over time. Comparable questions on group and individual spending were presented in the 2002 and 2008 surveys. Visitors spent $245 per person in

2002 and $360 per person in 2008. Most of this spending was associated with lodging and visiting restaurants in both 2002 and 2008 (Figure 2.25).

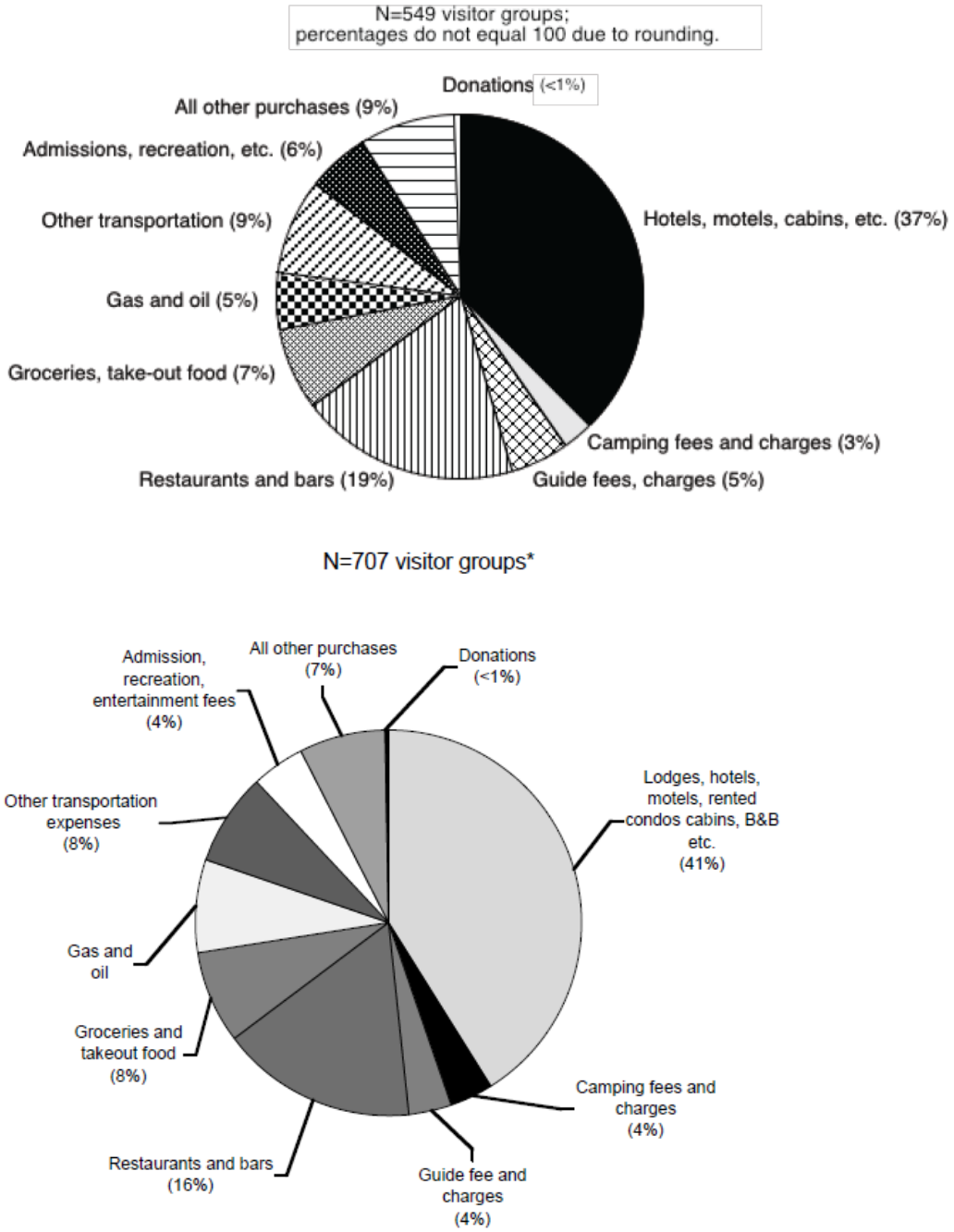


Figure 2.25. Visitor group spending in 2002 (top) and 2008 (bottom). Note the similarity in spending proportions among categories in both surveys. Protecting recreational opportunities ranked below all other categories in both surveys.

2.6.2. Resource stewardship: Links between Management Programs, Planning, and Ecological Restoration projects

Within the boundaries of EVER the fire management program, exotic plant and animal suppression teams, and a project management team are all part of the natural resource management program. Recent work has delivered a draft General Management Plan (NPS 2013a) that includes an evaluation of options for the redevelopment of the gulf coast visitor site. A "Seagrass Habitat Restoration Management Plan" (NPS 2013b) delivers a comparison of options for restoring seagrass beds after they have been damaged by boat propellers/groundings. These documents contain exhaustive descriptions of the ecological condition of the park and a comparison of the options for management actions based on the costs and benefits of how the actions would affect key natural resources.

One portion of the Draft General Management Plan (2013) deals with the process of designating a significant portion of the East Everglades Addition Lands (the northeastern corner of the park) as a wilderness area. The process of designating the Eastern Everglades as wilderness is affected by the current condition of this portion of the park (see Figure 2.13), which was extensively modified by people who practiced agriculture and established residential areas prior to the addition of the area to EVER in 1989. Restoration efforts have implemented extensive modifications of the lands adjacent to the EVER boundary during the last decade. A 1-mile bridge was constructed near the eastern edge of the park boundary on Tamiami Trail, and modifications have been made to the L-29 canal. These two efforts interact to enhance water deliveries to northeastern Shark Slough (Figure 2.26). Land purchases and design modifications of the canal system on the southern and eastern portion of the East Everglades have been implemented to reduce water losses from EVER that can occur through the exceptionally transmissive groundwater system. Figure 2.27 depicts these modifications to lands (areas are named the "frog pond" lands and detention area) and the additional structures that have been installed.

The modifications around the Eastern Everglades Additional Lands are part of the CERP - a high-profile restoration effort that is focused on hydrologic restoration of the southern Florida region. The CERP will affect an area much larger than Everglades National Park. The CERP (in its current form) has been ongoing for a decade and a half, and is rooted in land use activities that date back to the 1880's and prior (see McVoy 2011). The CERP is led by the U.S. Army Corps of Engineers and the South Florida Water Management District in consultation with ten other state or federal agencies and two sovereign tribal nations. The most recent (and extensive) plan for restoration that is likely to produce measurable effects in large areas of EVER is the Central Everglades Planning Project (CEPP). This project should result in improved water deliveries to EVER by increasing volumes of water, improving seasonal timing of delivery, and restoring the ability to deliver water to northeastern Shark Slough where flows historically sculpted the ridge and slough landscape of the park.

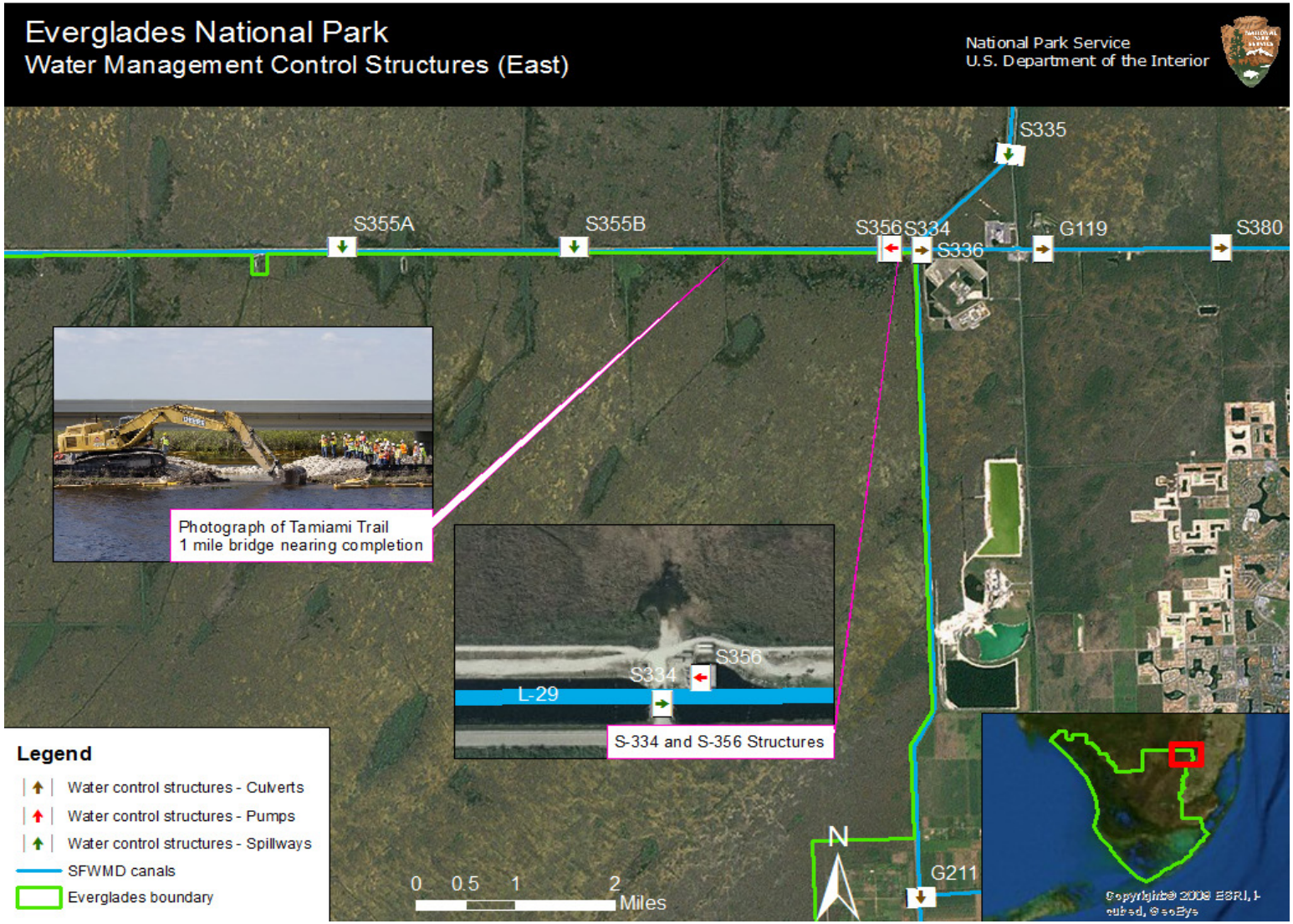


Figure 2.26. The map shows the location of water control structures along the northeastern boundary of Everglades National Park. The map includes a photograph of the Tamiami Trail 1 mile bridge nearing completion and a zoomed in extent of the S-356 pump and S-334 spillway to show how those structures function together.

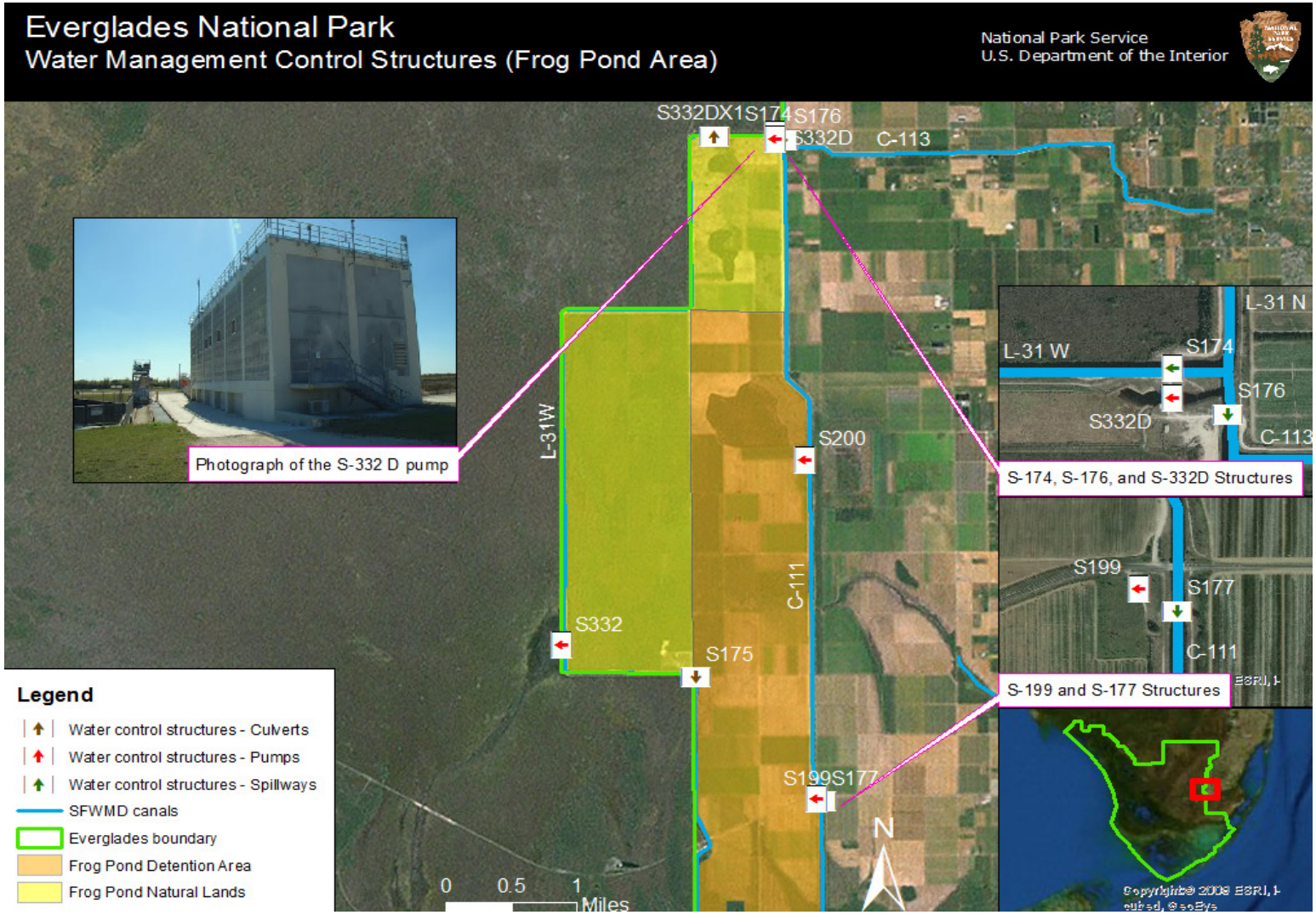


Figure 2.27. The map shows the water control structures found near the Frog Pond Lands, along the eastern boundary of Everglades National Park. A photograph of the S-332 D is included. This pump introduces water in the S332D detention area in the Frog Pond Natural Lands as seen in the zoomed in extent showing this pump and the S-174 and S-176 spillways. The other zoomed in extent shows the S-177 spillway and S-199 pump, which brings water into the Aerojet Canal.

At smaller spatial scales, natural resource managers have implemented several significant projects to enhance the condition of natural resources in EVER. Each of these projects addresses a known threat (or agent of change) identified in section 2.5.1, including:

- A ten square mile In-Lieu-Fee Wetland Restoration Mitigation project (often referred to as the "Hole-in-the-Doughnut" mitigation Area) where lands that were once converted to agriculture and subsequently overrun with exotic plants are being restored to wetland functions (see section 4.6.1.1 for additional detail). Mitigation funds have been applied to this area in support of habitat restoration since 1992.

- Rehydration of the C-111 basin (rehydrates large portions of the Southeastern Marl Prairie and Eastern Coastal Swamps and Lagoons regions) through canal modification and changes in operations of the regional water management infrastructure.

- Canal plugs were installed in the East Cape and buttonwood canals near Flamingo. These canals, which were dug in the early 1900's in a failed attempt to drain the marsh for agriculture and cattle grazing, had subsequently been dammed, but the dams had failed – allowing saltwater to move into the region in response to tides. Over time, this saltwater intrusion process reduced habitat quality for the endangered American crocodile (*Crocodylus acutus*).

- Land acquisition along the eastern boundary and evaluation of potential land swaps to support the protection of natural resources and address the 320-acre right-of-way owned by Florida Power and Light within the Eastern Everglades Addition Lands.

- Prescribed fire management activities are designed to address the threat of altered fire regimes in the context of maintaining endangered species within the reduced spatial extent of pine rocklands. Prescribed fire in wild lands and wildland/urban interfaces are essential for reducing the risk that high intensity, arson-caused fires occur in EVER.

- Exotic animal and plant suppression teams (python/argentine tegu/exotic animal and exotic plant management programs) address the threats of ecological degradation from exotics. Exotic plants and animals emerged from areas with altered land use surrounding the park.

- Florida bay poll and troll zone, and associated Seagrass Habitat Restoration Program (sometimes identified by the acronym: SHRMP) are designed to address the impact of visitors on Florida Bay and our other marine areas.

- Re-design of the Flamingo visitor use area after the destruction caused by Hurricane Wilma in 2005 is a direct consequence of adapting to expected changes in climate. Sea-level rise is the defining concern for the Flamingo area.

Fire management, vegetation management, planning, and NEPA-compliant construction activities are all essential components of effective resource management. Visitors to EVER demonstrate a desire to learn more about resource management in the park, and fact sheets or self-guided tours are the most

commonly requested format for receiving additional information. Comprehensive evaluations of the park's natural resources are written every two years for the United Nations' World Heritage Committee, and periodically for the Natural Resource Condition Assessment program. Taking the next step of consolidating these reports into fact sheets or using them to develop self-guided tours in the park may be a leading strategy for accomplishing resource stewardship goals.

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Chapter 3: Study Scoping and Design

3.1. Project Management

The Natural Resource Condition Assessment for EVER is administered by a NPS project manager who coordinates the NRCA process throughout the southeast region (Figure 3.1) from NPS regional headquarters in Atlanta, GA. NRCAs throughout the southeast region were initially focused on smaller parks and were conducted mainly through cooperative agreements with universities or otherwise contracted out. However, Big Cypress National Preserve and Everglades National Park are the two largest parks (by area) in the southeast region. Both parks deal with extremely complex issues including the Comprehensive Everglades Restoration Plan (CERP) which involves hundreds of millions of dollars and multiple agencies, non-profits, universities, tribes, and other partners. Instead of bringing in a cooperator or contractor, the NRCA project manager coordinated with the NPS South Florida / Caribbean Network (SFCN) Inventory and Monitoring Program Manager in 2009 to hire a NRCA ecologist to produce summary reports for these two NPS units over the course of several years and based the position at the SFCN office in Palmetto Bay, FL. By embedding the NRCA ecologist with the staff of SFCN, the ecologist was able to take advantage of the understanding and relationships already developed with the parks and partners and meet as frequently as needed with park staff and local partners.

3.2. Preliminary Scoping

Around twenty staff members of EVER and SFCN met to develop a shared awareness and set of expectations for the NRCA on March 28, 2012. The focus of the EVER NRCA report is to support park planning by delivering concise summaries of resource status and trends to a broad, non-technical audience.

Given the advanced nature of the discussion around many of the large-scale management issues in EVER, initial discussions about the NRCA were focused around ensuring consistency and harmony with existing report processes. A substantial number of status and trends reports are produced by EVER park staff, the Department of Interior's South Florida Ecosystem Restoration Task Force, the CERP System Status Report, the World Heritage Convention reporting process of the United Nations Educational, Scientific and Cultural Organization (UNESCO - which has designated the Everglades as a World Heritage site), the SFCN inventory and monitoring program, and the NPS' Florida and Caribbean Exotic Plant Management Team. The presence of so much information and reporting is a consequence of the scale of management actions being undertaken in southern Florida. The overarching goal of the EVER NRCA is to continue to develop these status and trend reporting procedures, and integrate new information from SFCN and EVER staff into a publicly accessible document that is written in the voice of the National Park Service. A secondary goal is to streamline reporting so authors can meet the needs of the multiple reports by writing the summaries in a format that can be easily rearranged to meet the needs of other reports. The question of how to break up the large Everglades ecosystem for reporting was another major focus, and the group chose to assess EVER using a combination of spatial subsets of the park, combined with a list of focal resources (major indicators) that have various histories of monitoring intensity/continuity over the six and a half decades since park establishment.

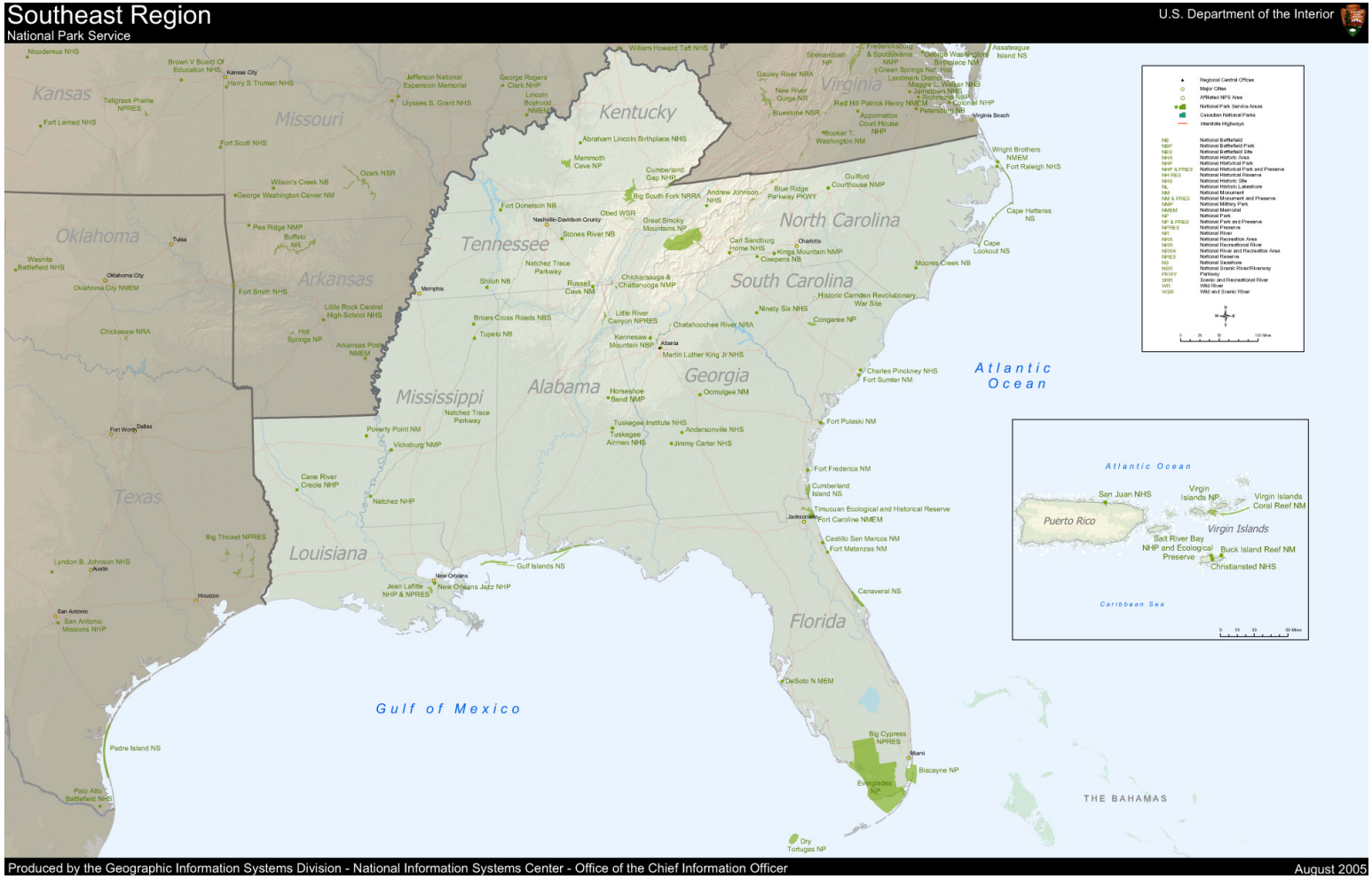


Figure 3.1. An outline of the states where National Park Service lands are administered through the Southeast Region headquarters in Atlanta, Ga. Note that the largest NPS units in the Southeast Region are Big Cypress National Preserve and Everglades National Park in southern Florida, followed by the Great Smokey Mountains in eastern Tennessee.

A hierarchical analysis of resource conditions was preferred for reporting (i.e., analysis of indicators such as fish, hydrology, and vegetation, in a spatial context within physiographic sub-regions, then combining these indicators to allow analysis of the overall status within each physiographic sub-region and across the park as a whole). This approach supports effective assessment by identifying where resource managers can most effectively resolve challenges. Hierarchy theory is focused on identifying horizontal coupling (i.e., co-varying components) among resources and vertical structures (i.e., larger spatial and temporal contexts) that may control a resource condition. Conducting hierarchical assessments should lead to a greater degree of agreement among scientists that are focused on individual resources, and support strategic efforts to enhance or conserve resource conditions (like NPS Resource Stewardship Strategies). Spatially-explicit reporting supports hierarchical analysis by providing the existing context of resource conditions. EVER is so large that some areas of the park may be experiencing profound and rapid ecological decline while others are much more stable. Identifying the spatial context for many different resources is useful for linking physical causes to ecological challenges (many of which are associated with water flows, nutrient loading, sea-level rise, and historical land uses). There was broad agreement among the participants in the NRCA meeting that spatial analysis is an essential part of effective resource condition reporting in EVER.

In addition there was broad agreement that EVER would support the NRCA reporting process provided it could be made to integrate well with ongoing reporting for the United Nation's (UN's) World Heritage program, the Comprehensive Everglades Restoration Project, and other regional reporting. EVER staff would write sections that would work for the multiple reports and then be reformatted and adapted as needed by the NRCA ecologist. EVER staff would also provide review for sections written by the NRCA ecologist.

Subsequent to the March 28th meeting, the NRCA ecologist, SFCN supervisors, and SFNRC (South Florida Natural Resource Center) deputy director, science coordinator, and natural resource manager met on April 12, 2014 to discuss some of the specific management goals that EVER would like to see addressed in the NRCA. Connecting the NRCA to a Resource Stewardship Strategy for EVER was highlighted as a high priority. Identifying a "desired state of conservation" (i.e., the condition of the resource in a healthy natural system) for natural resources that do not have these was a priority. Delivering results for each topic in concise 4–10 page summaries that start with the bottom line and implications for management was identified as the ideal result of this report. The deputy director of SFNRC (Carol Mitchell), the NRCA ecologist (Jed Redwine), and the SFCN quantitative ecologist (Andrea Atkinson) continued to refine the list of indicator topics for the NRCA report over a series of weeks through telephone conferences and emails. Primary authors, editors, and expert contacts were assigned for each section, and a mutual understanding of the potential fluidity of these assignments was reached. Much of this scoping discussion with supervisors served to help us develop a shared perspective of the task of writing the NRCA, and to help SFNRC supervisors identify where they could harmonize their staff's work efforts to take advantage of the additional analysis and writing support that the NRCA ecologist could provide. The outline document, writing schedule, and contact lists were updated periodically over the next two years of writing the NRCA. These scoping documents proved to be useful for keeping track of shifts in the availability and progress of the many

components of the NRCA, and for communicating changes in status to supervisors, project managers, and interested cooperators.

A comparison of the scoping process of the EVER NRCA to other recent NRCAs (like SEKI – among the first "large park" NRCAs to be written) indicated that EVER was uniquely prepared for the NRCA. Many of the topics and framework elements were already established in the minds (and work schedules) of EVER staff. The NRCA ecologist interpreted the other NRCA frameworks to EVER staff, while EVER staff identified the connections to existing reports and data sources. The scoping process for the NRCA helped establish a set of "common" reporting goals: including a concise summary of the "desired state of conservation" for the resource, the use of maps to pinpoint the locations of individual resources, time series plots, and standardized status/trend icons that are consistent with national NPS guidelines, national NRCA guidelines, and Section 508 of the Rehabilitation Act.

3.2.1. Watershed-based Reporting Areas

This NRCA used watershed-based units to summarize resource conditions because watersheds are:

1. Natural boundaries
2. A major driver of the ecosystems in the park and alterations in hydrology and water quality are the source of many of the changes
3. A sound basis for on-the-ground management and planning
4. Generally hierarchically nested, supporting comparisons across spatial scales

The smallest local unit of the nationally recognized, standardized hydrologic classification system of Hydrologic Unit Codes (or HUC's - Seaber et al. 1987) is larger than the boundaries of EVER in southern Florida, so instead we adopted a set of physiographic regions that were previously designated by regional scientists based on the combination of elevation, soils, hydrology, and vegetation communities observed in discreet areas (Figure 2.14, Davis 1943, Puri and Vernon 1964, White 1970, Schomer and Drew 1982). A second, coarser scale of summary was crafted to identify the major discrete watersheds within EVER (Figure 3.2). The flat topography, seasonal rainfall patterns, large interannual difference in rainfall volumes, and transmissive groundwater system that occur in southern Florida preclude the development of hydrologic units that are uniformly nested across spatial scales. Each watershed contains a large overland drainage crossing several physiographic regions. The key feature of a terrestrial watershed is that when water is inserted as overland flow, it generally meets the ocean within the same watershed. Estuarine and marine watershed units are designated due to discrete differences in circulation patterns that affect a suite of chemical characteristics (salinity levels, phosphorus concentrations, dissolved organic carbon, turbidity and chlorophyll a content). Water movement through the groundwater system is less straightforward.

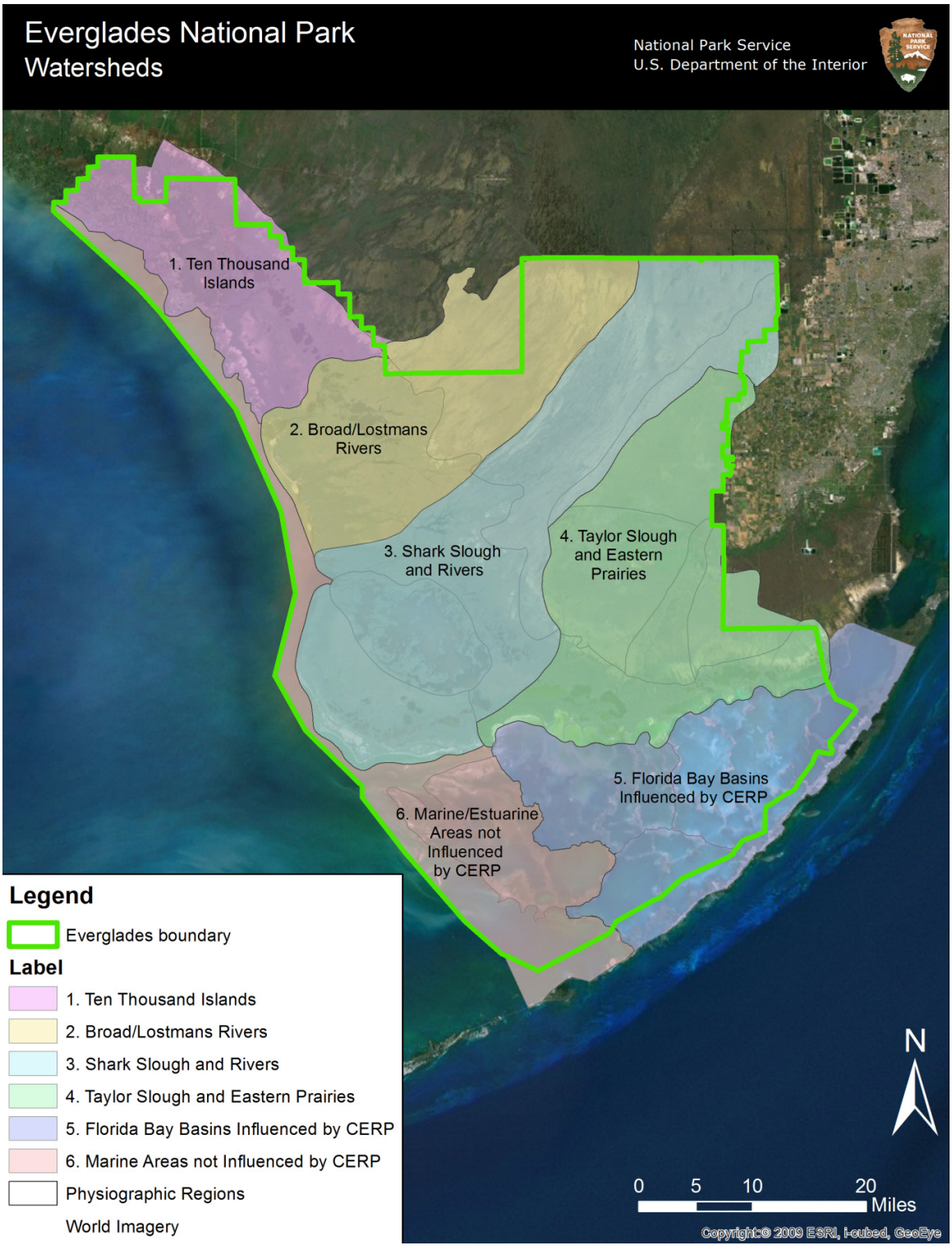


Figure 3.2. Flowpaths in EVER overlaid on regions with distinct physical geography and biological attributes.

3.3. Study Design

3.3.1. Indicator Framework, Focal Study Resources and Indicators

Ecological systems are composed of interacting abiotic and biotic factors. The ecosystem concept brings the biological and physical worlds together into a holistic framework within which ecological systems can be described, evaluated, and managed (Tansley 1935, Major 1969, Rowe 1992, Cleland et al. 1997). There are limitless ways that ecosystem frameworks can be organized (e.g., spatially, functionally, or by complexity) from the global scale down to microbial scale. A framework organizes the components of ecosystems into a hierarchical set of elements or processes, and places them into a limited number of discrete units that are spatially explicit, repeatable, and/or distinguishable from one another by differences in various structural or functional characteristics (Cleland et al. 1997). We selected the Heinz ecological condition assessment framework (Heinz 2002, EPA 2002) because the hierarchical organization of system attributes could be synthesized into larger ecological units (see Figure 3.3) which collectively covered the entire park.

Both the watershed scale of summary and the Heinz framework are hierarchical. Combined, the two provide options for composite scoring of condition results either within Heinz ecological attribute or within a watershed unit as is graphically depicted in Figure 3.3. The hierarchical organization of related ecological attributes of the framework allows us to view relative conditions within a functional relationship context. While the framework cannot represent the complex ecological interdependencies of all the ecosystem attributes, it can facilitate analysis and reporting of focal resources into generalized condition classes. For example, focal resources such as water and air quality belong to the chemical and physical ecological attribute category in the Heinz Framework. Combining these focal resources into a generalized condition assessment report makes sense when equivalent trend or regulatory condition data are available. On the other hand, status, trend, and regulatory condition analyses should not be combined spatially or graphically to represent a more generalized condition unless the focal resource attributes are reasonably related and the data equally robust across space and time. This caveat is discussed in more detail in Section 3.4.

<table>
<tr><td rowspan="2">Heinz Categories</td><td colspan="6">Watersheds</td><td rowspan="9">Composite integrity score by Heinz Category</td></tr>
<tr><td>Ten Thousand Islands</td><td>Broad River</td><td>Shark River</td><td>Taylor Slough and Eastern Prairies</td><td>Florida Bay – CERP influenced</td><td>Florida Bay and Marine areas not influenced by CERP</td></tr>
<tr><td>System Dimension</td><td colspan="6" rowspan="7">Heinz Category integrity score by watershed</td></tr>
<tr><td>Chemical/Physical</td></tr>
<tr><td>Biological - Plants</td></tr>
<tr><td>Biological - Animals</td></tr>
<tr><td>Biodiversity</td></tr>
<tr><td>Agents of change (stressors)</td></tr>
<tr><td>Human Experience</td></tr>
<tr><td colspan="8">Composite integrity score by watershed</td></tr>
</table>

Figure 3.3. Indicator Framework. Both the Heinz and Watersheds frameworks enable hierarchical nesting of related attributes, which creates two options for composite scoring.

Focal Study Resources

Identifying the focal resources to be evaluated began with the creation of a table that cross-walked the focal resources that have been traditionally included in other NRCAs, the World Heritage Report, the Vital Signs for the South Florida/Caribbean Network, the System-wide Ecological Indicators for Everglades Restoration (Brandt et al. 2012) written by the South Florida Ecosystem Restoration Task Force, and the CERP System Status Report. The final list of indicators is summarized in Table 3.1 and described subsequently. There is a wealth of monitoring information around EVER, due to at least three different legal reasons: Federal environmental laws (e.g., Endangered Species Act, Clean Air Act, Clean Water Act); to support the Comprehensive Everglades Restoration Plan; to support implementation of National Park Service policies. Still other resources are monitored by private individuals or non-governmental groups simply because many people value the Everglades, seek to nurture the ecosystem, and hope to enhance humanity's understanding of this biological treasure. The continued monitoring of resources by NGOs (non-governmental organizations) is consistent with the history of the park that was established around areas owned by the National Audubon Society (Flamingo) and the Florida Federation of Women's Clubs (Royal Palm Hammock).

The process of developing the list of focal resources and designing metrics that provide meaningful evaluation for these resources provided the context to recognize some of the challenges with resource monitoring. Step one was developing the long list of resources of interest. Step two was consolidating this list into categories (the Heinz framework is used for this). A major challenge to meaningful reporting emerges when one attempts to use tabular summaries to aggregate information developed for step one into the framework established in step two. Creating summaries of status and trend using the Heinz framework is often a meaningful and concise way to communicate about the factors affecting the health of a large natural resource system. Sometimes, rarely in our experience, creating straightforward tabular summaries of metric information using the Heinz framework is meaningful. More often creating these summaries does not lead to a straightforward/intuitively understood result.

Air and water quality summaries provide a good example of this challenge. Sensitivities to nitrogen deposition are quite different across habitats based on a set of complex chemical processes that influence the supply and demand of essential limiting nutrients. Seagrass beds in western Florida Bay seem likely to be the plant community in EVER that is most sensitive to nitrogen deposition since phosphorus rich waters of the Gulf of Mexico relieve the P limitation that predominates in terrestrial wetlands and the seagrass beds of eastern Florida Bay. The terrestrial marshes are less affected by nitrogen deposition, simply because there is already more nitrogen in the system than the organisms can use to grow as a result of the lack of available phosphorus. Therefore, if one wished to sum the air and water quality metrics that interact to affect the health of EVER, it is necessary to create a set of "index metrics" that are unique to the different regions in the park.

One challenge with using index metrics is that the evaluation of air/water quality takes a bit longer to explain. A more straightforward approach of summarizing nitrogen deposition across the park would not produce a biologically meaningful result. The challenge to telling the more subtle, complex, and meaningful story is that it makes the process of aggregating information across categories more

difficult. The Heinz framework was developed in order to stimulate a nation-wide reporting process on the status and trends of natural resources. The NRCA is intended to support this type of nation-wide reporting process. After a bit of contemplation about how to construct an NRCA framework that serves both local managers and national-global institutions, it is the opinion of the author that metrics focused solely on individual constituents cannot be rolled up into global summaries in a single step. Instead, an index-development process is required to convert metrics into meaningful summaries. A strength of the index-development approach is that it supports simple summary statements (e.g., 30% of the vegetated communities in the US are compromised by excessive deposition of nutrients) for each category. A challenge of the index-development approach is that the recommended actions for ameliorating the impacts of resource challenges become long lists of needed activities, which can seem to be unrelated, and confusing for non-experts to understand, prioritize, and implement.

The tension between simplicity, meaning, and the ability to connect assessments with coherent management actions influences much of the design of this NRCA. The first priority of this document is to express the perspectives of local scientists and land managers accurately and clearly. The second priority is to streamline the reporting of resources and stressors as much as possible. The third priority is to produce information that can easily be aggregated at a national/global scale. Priority one was achieved throughout the document. Priority two was achieved more than half of the time. Priority three was achieved whenever possible.

Table 3.1. Analytic Framework. The Heinz (2002) framework modified for use in this NRCA. The Heinz attributes are used for grouping resources into a concise framework.

Heinz (2002) Ecological Attributes	**Focal Resources**	**Condition Metrics**
System Dimension	Landscape Context	Conserved lands across the regional watershed, roads, regional water management, water quality risks
Chemical/Physical	Air Quality	Visibility, number of days ground-level ozone exceeds background concentrations, sulfur and nitrogen wet deposition
	Surface Water Hydrology	Magnitude and direction of sheetflow, average annual volume into NE Shark Slough, water temporal pattern and spatial distribution of surface water depth
	Salinity Patterns in Florida Bay	Proportion of year in desired salinity range; difference between mean and desired salinity; occurrence of extreme high salinity events
	Total Phosphorus	Inflow P concentration, interior marsh P concentration in Shark and Taylor Slough
	Nutrients in Freshwater Wetlands and Periphyton	Tissue P concentration, biomass, and community composition

Table 3.1 (continued). Analytic Framework. The Heinz (2002) framework modified for use in this NRCA. The Heinz attributes are used for grouping resources into a concise framework.

Heinz (2002) Ecological Attributes	Focal Resources	Condition Metrics
Chemical/Physical (continued)	Nutrients & Florida Bay Algal Blooms	Chlorophyll A concentration
	Soils	Status for each major soil type (peat, marl, rock, and coastal peat soils)
	Mercury and Other Contaminants	Concentration of mercury in tissues of bluegill, redear, spotted, warmouth, and largemouth bass reported annually; concentrations of mercury across wildlife groups are measured periodically
Biological - Plants	Vegetation Communities Extent & Distribution	Extent, distribution, shape, orientation of vegetation community types
	Seagrass Communities	Seagrass abundance, species diversity, and benthic community structure
	Ridge, Slough, and Tree Island (RSTI) Landscape	Tree island neighborhood area, exotic plant presence, soil dehydration risk, and soil fire risk
	Wetland Ecotones and Community Structure	Wet prairie-forest ecotone change
	Mangrove-Marsh Ecotone	Changes in location of ecotone, plant species composition, and physical structure
Biological – Animals and invertebrates	Marine Exploited Invertebrates	Lobster spatial/temporal distribution, abundance/density, size structure
	Marine Fish Communities	Fish community composition, abundance, diversity
	Estuarine Sport Fish and Invertebrates	Catch per unit effort for snook, red drum, spotted seatrout, gray snapper, and density of pink shrimp
	Freshwater Fish and Aquatic Invertebrates	Abundance (density and relative abundance) of all fish, bluefin killifish, flagfish, mosquito fish, and everglades crayfish
	American Alligator	Abundance, nesting effort, nest density, and nesting success
	Amphibians	distribution, community composition
	Wading Birds	Total number of nesting pairs, month of wood stork nest initiation, proportion of nests in ENP headwaters, mean interval between exceptional ibis nesting years, ratio of wood stork and white ibis nests
	Threatened or Endangered Marine Invertebrates	Total population size and critical habitat areas of rare, threatened, endangered, or exploited marine invertebrates
	Sea Turtles	Nest counts and distribution, egg counts/nest, hatching success
	American Crocodile	Abundance, nesting, hatchling/juvenile growth and survival
	Florida Panther	Annual estimates of abundance, distribution, recruitment, and mortality

Table 3.1 (continued). Analytic Framework. The Heinz (2002) framework modified for use in this NRCA. The Heinz attributes are used for grouping resources into a concise framework.

Heinz (2002) Ecological Attributes	Focal Resources	Condition Metrics
Biological - Comprehensive	Biodiversity	Proportion of species at risk, proportion non-native species, number of non-native species in Florida but not in EVER; for regions: proportion non-native and meltdown risk
Agents of Change (Stressors that are not captured elsewhere)	Altered Fire Regime	Long term fire return time, fire intensity, time since last burn (last 20 years), fire in restoration areas
	Climate Change	Sea-level, rate of sea-level rise, seasonal rainfall patterns
	Terrestrial Invasive Exotic Plants	Total occupied area for top four exotic invasive species, number of exotic plant species in park
	Invasive Marine Species	Lionfish density, biomass of prey species, spatial distribution of lionfish
	Exotic Fish in Freshwater Marshes	Rate of new species introductions, and relative abundance of exotic species
	Exotic Herpetofauna	Rate of new herpetofauna introductions, containment of Burmese pythons, response to invasive species in adjacent areas, response to recently introduced organisms
Human Experience	Night Skies	Luminance and star count
	Soundscapes	Median decibel impact (L_{50}) and proportion of time human-sourced sounds are audible

3.3.2. System Dimension

Landscape context

Both historical land uses within the current boundaries of EVER and changes in land use outside the park have a major impact on current conditions. Agricultural canals, road grids from nascent development, and former agricultural fields have been integrated into EVER since its inception. Industrial agriculture is pervasive in the lands immediately east of the park. Major changes in land use in the region have occurred since the park was established following World War II. Landscape context is directly relevant to the management of individual patches within the park. Surrounding land uses are important for identifying chemical and biological contamination, and regional scale land uses affect the landscape-scale water pattern that much of the biota in EVER interact with to survive and thrive. Conversion of some habitat types outside the park (e.g., pine rocklands and hardwood hammocks), has sharply reduced and fragmented habitat for rare endemic species.

3.3.3. Chemical and Physical Attributes

Air Quality

Everglades National Park is a Class 1 airshed with the highest level of statutory protection in the United States. Air quality monitoring in EVER is used to determine compliance with the Clean Air

Act for the 10 state region of the Southeastern United States. Haze, sulfur dioxide, mercury deposition, and airborne pesticides are the most commonly observed pollutants in EVER.

Surface Water Hydrology

The magnitude and direction of sheetflow are among the most important natural resource challenges in EVER. Spatial pattern, seasonal timing, and total volumes of water flow have been altered by regional scale water management infrastructure. The effects to the Everglades ecosystem have been profoundly negative, and the challenges that result are affecting nearly all categories of living and non-living natural resources in the park.

Estuarine salinity patterns

Changes to surface water flows have caused increases in the frequency and intensity of hypersaline events in Florida Bay. These events kill large numbers of organisms and dominate the physical structure and ecological functions of the areas where they occur. Elevated salinity levels occur across areas where overland flows have been altered or restricted.

Water Chemistry

Many of the classically measured water chemistry constituents are stable and consistent in EVER. Calcium dominated geology combine with the broad, flat topography to deliver stable and consistent patterns of water chemistry. Dissolved organic carbon dynamics can be altered by the influence of canal water that is sourced from agricultural or urban runoff.

Total Phosphorus

Phosphorus loading from the water column is perhaps the greatest threat to ecological stability and resilience in EVER. Polluting effects of total phosphorus from untreated agricultural runoff was the subject of "the seminal case that spawned all of the collateral litigation on the Everglades" (environmental case # 88-1886-CIV-Hoeveler). This lawsuit, subsequent legal actions by the State of Florida and the U.S. Federal Government, and the resolution of these challenges in settlement agreements, have resulted in a tremendous amount of research and monitoring focused on the role of total phosphorus in ecosystem functions of the region. Monitoring and reporting of this constituent will continue for many years.

Periphyton (Freshwater)

The community of cyanobacteria, algae, and zooplankton that are found wrapped around submerged aquatic vegetation are the most sensitive indicators of elevated total phosphorus concentrations in the water column. The species composition of these microscopic organisms demonstrate rapid, perceptible shifts in response to nutrient loading, and as a result are monitored to demonstrate the shifts in flora and fauna which define violations of the Clean Water Act.

Phytoplankton (Marine)

Algal blooms in Florida Bay and red tide events along the Gulf coast occur in response to nutrient loading interacting with other physical factors (i.e., flushing rates in coastal basins). Nutrient sources can be natural or human-delivered (source: Floridahealth.gov). These events can trigger cascading

ecological impacts, affecting the entire spectrum of resident organisms, including direct effects on humans and their pets.

Coastal Geomorphology

Storm surges, sea-level rise, and high productivity mangrove forests interact to determine net rates of soil elevation changes along nearly 100 miles of dynamic coastline in EVER. Coastal waterways and creeks are interlaced with islands and a ragged coastline to produce hundreds of miles of coastal interface.

Geology and Soils

Protection of peat soils is a fundamental management function that is used to connect water patterns to the development of the food web. Everglades crayfish are an important food item that are much more resilient to seasonal drydowns when their habitat contains a thick, healthy peat soil. Peat soils are destroyed by hot fires during extreme dry conditions, and slowly decompose and lose volume when the proportion of the year that water is above the soil surface is too short. The upper portion of the regional aquifer is essentially unconfined (strongly connected with surface water) and karst (highly transmissive, fractured, potentially linked to coastal springs with strong seasonal flows that emerge from the ocean floor). Monitoring of the surficial aquifer and near-surface geology is ongoing. Mapping near surface profiles is key for seepage management projects along the eastern boundary of EVER. Monitoring and modeling of the groundwater system will continue to be very important given the current trajectory of sea-level rise.

3.3.4. Biological Integrity - Plants

Vegetation Communities Extent & Distribution

The ridge, slough, and tree island patterned landscape is a self-organizing system that requires long hydroperiods and periodic high flow volume events to be sustained. The spatial extent, physical shape, directional orientation, and species composition of this landscape type are meaningful indicators of the ecological health and resilience of the landscape. Dehydrated portions of EVER have lost this vegetation pattern, along with peat soils, and have often shifted from native plant communities into stands of invasive exotic plants.

Seagrass Communities

The spatial extent, patch-level biomass, and local species diversity of seagrass beds are important indicators to differentiate severity of impacts from nutrient loading and high salinity events. Seagrass beds are critical habitats for many marine species and can be indicators of nutrient impairments.

Forest Ecotone and Community Structure

The physical structure and species composition of boundaries between forests and marshes are early indicators of environmental deterioration due to shifts in hydrology, fire intensity/frequency, or invasive exotic species. The community structure of forest canopies, saplings, and seedlings are indicators of forest health and resistance/resilience from hurricanes or other disturbances.

Wetland Ecotones and Community Structure
Transitions between marshes and wet-prairies are leading indicators of water flow volumes across years, and are linked to the health of deer populations in areas where hydropatterns have been distorted by water management infrastructure and operations.

Mangrove-Marsh Ecotone
The ecotone between mangroves and marshes are an indication of shifts in groundwater salinity that can be caused by sea-level rise and/or changing volume of freshwater deliveries to EVER. The ecotonal boundary is also shaped by fire frequency and intensity.

3.3.5. Biological Integrity - Animals

Estuarine Sport Fish and Invertebrates
Pink shrimp, red drum, spotted sea-trout, snook, gray snapper, stone crabs, lobsters and other sportfish populations are regularly harvested in the region. Long term monitoring of these organisms is limited to catch-per-unit effort estimates based on interviews of recreational anglers. The spatial distribution, age/size structure of the populations, habitat quality, and abundance of prey items are important (but often unmeasured) indicators of the health of the world class sport fishery that is present in EVER.

Freshwater fish and aquatic invertebrates
Freshwater fish in the marsh and coastal creeks form the basis of the food web for wading birds, marine fish, crocodiles and alligators, and fish-eating eagles and hawks. Species composition and biomass of prey-base fish groups are indicators of shifts in hydrology.

American Alligator
The abundance, nesting effort, and nesting success of the American alligator are useful indicators of regional scale and long term shifts in water and nutrient patterns.

Amphibians
The spatial distribution and species composition of amphibians are indicators of contaminants, water, and nutrient patterns.

Wading Birds
Indicators of the status of wading birds in the region include: the total number of nesting pairs; month of wood stork nest initiation; proportion of nests in EVER headwaters; mean interval between exceptional ibis nesting years; and ratio of wood stork and white ibis nests. The wood stork is also a special status species (recently reclassified by the federal government from endangered to threatened).

Marine Invertebrates- Rare, Threatened, Endangered species
Total population size and critical habitat areas of rare, threatened, endangered, or exploited marine invertebrates.

Sea Turtles
Nest counts, spatial distribution of nests, egg counts per nest, and hatching success rates are indicators of the health of the nesting beaches and the turtle population for these endangered marine reptiles. The presence of exotic plants in coastal environments can shade turtle nests reduce nest success. Presence of exotic predators (black rats) and native predators (raccoons) – whose populations are artificially enhanced through access to human garbage can also reduce nesting success. Sea turtles are a popular species of interest to the public, but success of their recovery is dependent upon the management of beaches over large areas - often beyond the extent of national parks.

American Crocodile
Abundance trends, nesting trends, and hatchling/juvenile growth/survival are indicators of health of this special status species. The Florida population of American crocodile is listed as threatened, while the species is considered endangered across the rest of the United States. Recent modifications to canals in Flamingo have resulted in a significant positive response from the American crocodiles in that area.

Florida panther
The abundance, spatial distribution, reproductive success, and mortality of the Florida panther are indicators of the health of this large cat that is listed as Endangered by the United States Fish and Wildlife Service (USFWS). Large cats are globally imperiled.

3.3.6. Agents of Change (Stressors)

Air pollution
See Air Quality discussion above.

Mercury
Mercury concentrations in tissues have been sampled across a wide range of organisms.

Altered Fire Regime
Roughly 70% of terrestrial EVER contains habitats that are either fire-dependent (e.g., pine rocklands), or contain many fire-adapted species (marl prairie, sawgrass marshes). Each year the location, size, and intensity of all fires are recorded and added to a geodatabase. Fire is an essential part of a healthy Everglades ecosystem. Frequent, low-intensity fires are desired, but arson-caused fires during the dry season have been a challenge to resource management since the inclusion of the East Everglades Addition Lands in 1989. Fires can be safety concerns, can have human health impacts, and the absence of fire can produce severe risks to the well-being of adjacent landowners when plant biomass accumulates and the risk of uncontrolled fires becomes high. Fire management is one of the most difficult natural resource challenges in EVER.

Climate change
Sea-level has risen 8 in over the last century, and is forecast to rise 1–6 ft in the coming century. A six foot rise in sea-level would convert most of the lands in EVER into an estuary (Pearlstine et al. 2009).

Exotic invasive plants

The total occupied area, percent cover for the top four exotic invasive species, a regional list of all exotic plant species, and the number of exotic plant species known to be present in EVER are indicators of the ecological risks posed by exotic invasive plants.

Exotic animals

The rate of new species introductions, relative abundance of exotic species, containment area size, and activity levels near invasion points are indicators of the risks posed by exotic animals.

3.3.7. Human Experience

Night Skies

Luminance and the number of countable stars are indicators of the amount of ambient light pollution present that affects the view of the night sky in any measured location in the park.

Indicators (Metrics)

Resource monitoring information is used to design each indicator metric. To facilitate a meaningful, non-technical discussion, each metric is summarized by a status/trend/confidence icon using the scheme outlined in Table 3.2. The color of the icon indicates condition, the arrow indicates trend, and the outline indicates the degree of confidence in the assessment. Icons that summarize undetermined conditions have no color, and resources that have not been monitored long enough to discern trends have icons with no arrow.

Each resource assessment delivers a tabular summary of indicator metrics (see Table 3.3 for an example), since the condition of a focal resource is often affected by more than one aspect of the surrounding environment. The tabular summary contains four columns of information – criteria (a.k.a. the name of the indicator metric), status/trend/confidence icon, the rationale for the icon, and the Desired State of Conservation. A narrative condition assessment completes the resource summary. Occasionally the narrative assessment is supported by a subject-specific conceptual model that describes the cause-effect relationships between drivers, stressors, ecological processes, and attributes of the ecosystem. Most natural resources are “attributes” in a conceptual ecological model. Inventory and monitoring programs most often measure attributes of an ecosystem. Agents of change are “stressors” or “drivers” in a conceptual ecological model.

Table 3.2. Symbol key for resource indicator metric status/trend/condition icons.

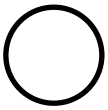
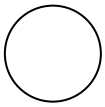
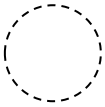
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3.3. Example summary table of a resource condition assessment (Hole-in-the-Doughnut [HID] Condition Assessment permit related metrics are shown here).

Criteria	Condition & Trend	Rationale	Desired State of Conservation or Reference Condition
Proportion of area with acceptable soils		70% of the HID has acceptable soil conditions. Significant progress continues.	Continuous marl soils or peat soils, no crushed soils present
Proportion native wetland plants		Self-sustaining native wetland plant community is present on all restored sites. Exotic species abundance is less than 1% permit threshold in monitored plots.	Native wetland plant community.
Hydrology restored		Hydrology is effectively restored across sites where agricultural soils were removed, demonstrated by elevation model and local observations.	Standing water aboveground for at least two weeks per year. Up to 50 weeks standing water aboveground acceptable in low elevation areas.
Graminoid Prairie		All restored sites >90% coverage graminoid prairie shown by aerial photography.	Wetland plant community dominated by grasses, sedges, rushes or slender emergent wetland plant species.

Natural resource management is focused on affecting drivers and stressors of ecological systems through planning, infrastructure development/operation, or directly affecting the stressors through actions like prescribed fire, exotic plant removal, captive breeding and reintroduction of rare species, or planting/installation of native species to facilitate habitat restoration. The narrative resource assessments and tables are distilled and synthesized into a Park-wide indicator summary in Chapter 5.

3.4. Resource Condition Summary Reference States

Assessments of status and trends of all resource categories are made in the context of the reference state – a Desired State of Conservation for the resource. This term was coined for several reasons. It should not be confused with "Desired Conditions" – a similar concept, but distinct because the Desired Condition is a statement of goals that represents official policy of a park (set by the superintendent), while Desired State of Conservation is simply a statement from well informed resource scientists about what type of condition is possible for each resource category when the resource system is uncompromised. Desired State of Conservation can be based on historical observations (e.g., prior to drainage of the Everglades there were several years per decade when more than 30,000 wading bird nests successfully fledged young in Florida Bay), or based on our understanding of the biological system in reference locations (e.g., water column phosphorus concentration in freshwater marshes is 10 ppb or less in the absence of agricultural runoff, marsh collapse, canal influence, or peat soil consuming fires).

The approach to reference state development for the EVER NRCA is similar to the approach described in the Sequoia and Kings Canyon National Parks (NPS 2013c). The authors of the SEKI NRCA simply used status, trend, and relative condition as the three criteria for assessing each natural resource. The EVER NRCA uses status, trend, and Desired State of Conservation to produce each assessment. Ultimately the goals for natural resources in National Parks are statements of values. The deep interdependency between human-created systems and the natural resource systems present in National Parks requires us to make value judgments based on our best understanding of how these systems function. The NRCA is focused on informing these judgments, and as a result, it is essential that the dedicated scientists who develop condition assessments be allowed to clearly articulate what they understand to be the potential functions of these systems. The Desired State of Conservation is an essential aspect of effective resource condition assessment because identifying what is possible provides the basis for considering tradeoffs and making informed decisions about what type of natural resource system is acceptable given the larger spectrum of ecological, economic, and social conditions. Specific policies that are made by NPS for parks must take into account the larger spectrum of conditions, and the NRCA does not contain the type of analysis that is required to create policy, although the findings present in the NRCA are an important part of the process of creating policy.

3.5. Thematic summary of indicators

Ideal assessments of natural resource categories, stressors, or specific areas in EVER are composed of a set of indicators that are known to affect the status, trend, and desired state of conservation of the focal resource. The NRCA aspires to create a set of ideal resource assessments, succeeds in some areas, but may identify gaps in information or assessment process that prevent the ideal assessment from occurring. It is expected that not all resources will have ideal assessments.

3.6. Review

NRCAs are published as part of the Natural Resource Report (or NRR) series. NRRs are used to: "disseminate high-priority and current natural resource management information with a managerial application. The series targets a general, diverse audience, and may contain NPS policy

considerations or address sensitive issues of management applicability". These reports are reviewed by peers either within the National Park Service, USGS, universities, or non-governmental organizations. Every section of this NRCA received review by one or more individuals from among these groups.

Administrative/policy review was conducted by the Deputy Chief of the South Florida Natural Resource Center (SFNRC) or staff members that she designates. The Deputy Superintendent and Superintendent of EVER also reviewed the document prior to its publication. Administrative review does not mean that the perspectives presented in the NRCA represent official policy of EVER. The NRCA project manager for the southeastern region (Dale McPherson) also reviews the entire document to ensure consistency of methods, adequacy of content and potential connections to Resource Stewardship Strategies.

3.7. Data Management and Synthesis

A large number (probably over 100) datasets were used to create the resource summaries presented in this NRCA. The South Florida Natural Resource Center has a centralized database named DataForever that contains the datasets most commonly used for EVER resource management. Data for individual resources are often kept by the primary investigators as spreadsheets or in some cases MS Access databases. There are 10–20 geographic summaries of EVER which are maintained by EVER GIS technicians, and which were shared directly with the NRCA ecologist. Occasionally there was a well-developed and thoroughly documented database that contained contributions of information from multiple technicians and/or research groups who all investigate a similar theme in different areas, or during different eras of monitoring.

The NRCA guidelines include a goal of developing metadata for each of the datasets that are used to develop resource summaries. Since many of the reports included in the EVER NRCA are also in development for other regional and international reporting documents that receive contributions from EVER staff, there was no aggregation of databases and systematic verification of metadata done by the NRCA ecologist. Instead, the responsibility for fulfilling this goal remains with the scientists who developed each resource report and their supervisors.

When ArcGIS files were used, the NRCA ecologist encouraged the use of the EPA's metadata editor to facilitate the filling of metadata in compliance with the standards described by the Federal Geographic Data Committee (FGDC). Fulfilling this goal remains the responsibility of EVER staff and cooperating researchers. The most common form of synthesis conducted by the NRCA ecologist was compiling data collected over multiple years into spatially explicit summaries. These processes were conducted by integrating databases into personal geodatabases through ArcGIS. Any resulting personal geodatabases that were created by the NRCA ecologist were filled with metadata and returned to the EVER staff person who transferred the initial dataset. On a few occasions, the data synthesis process was complicated enough to require the development of a Standard Operating Procedure (SOP) that described each step of the synthesis process. These SOPs were reviewed by SFCN staff and returned to EVER staff. Often EVER staff tested the SOPs and adapted them to meet their own needs.

Several of the larger scale synthesis efforts were conducted by the NRCA ecologist and collaborating data analysts using R version 3.0.2 (Copyright (C) 2013 The R Foundation for Statistical Computing). The analysis code was documented, archived, and shared with reviewers when appropriate. Many of the summary analyses are intended to be refreshed annually, so it is expected that the R code and SOPs will be used subsequent to the completion of this report. Also, all of these documents are shared with the NRCA project manager for the southeastern region who may wish to utilize and adapt these processes for other parks.

One of the major distinctions between the data management process for the EVER NRCA and NRCAs for other parks is the type of development that occurred. The EVER NRCA is focused mostly on the synthesis of data across different subjects over large spatial scales. NRCAs for other parks have often been focused on discovering information and developing a shared awareness about data gaps among researchers and managers. EVER is generally data rich. The spatial scale of EVER makes assessment of data and synthesis among different resources more challenging, and it is this aspect of data summary that received the most effort by the NRCA ecologist.

3.8. Summary of Methods and General Approach

There is quite a bit of similarity between the methods used for the NRCA for EVER and those used for Sequoia/Kings Canyon National Parks. As a result much of this chapter is closely modeled on the SEKI NRCA (NPS 2013c). The correspondence between methods for these two NRCAs was not pre-planned, but the similarities are striking. Many of the challenges and successes that were recognized by authors of the SEKI NRCA are the same challenges and successes that occurred while writing the EVER NRCA. Perhaps the most important shared challenge is addressed by the development of the Desired State of Conservation (or the "Relative Condition" comparison done in the SEKI NRCA). In the simplest sense, this issue is a consequence of the need for contrast when assessing status and trend. Contrast is needed to concisely state whether the resource is in good or bad condition, and to differentiate among degrees of challenges when planning the appropriate response (i.e., cautious observation is appropriate, escalating research is necessary, or rapid intervention is essential). The most important shared success between the SEKI and EVER NRCAs was the nested spatial summary process. The proliferation of GIS use throughout the NPS and other resource management agencies, combined with the design of the NRCA report, seems to have converged to make these reports particularly useful laboratories for the development of spatially explicit summaries of natural resources and the agents of change that influence them.

The key elements of the EVER NRCA are:

3.8.1. Apply Hierarchical Framework

We used a two-way framework that allowed watershed-scale summaries and thematic summaries (see Figure 3.3 above). The framework used in this NRCA borrows from "The State of the Nation's Ecosystems" framework (Heinz 2002).

3.8.2. Multi-disciplinary (Ecological) in Scope

The focal resources and agents of change (stressors) chosen for analysis represent a broad cross-section of ecological attributes and a suite of anthropogenic stressors. An explanation of the focal resources and stressors selected was provided in section 3.3 (Table 3.1).

3.8.3. Rely on Existing Data

EVER is fortunate to have a wealth of science-based natural resource datasets. Data also were pulled in from external NPS data repositories (e.g., the air quality and NPScape datasets); and from other sources such as Comprehensive Everglades Restoration Plan (CERP), the US Forest Service (USFS) Forest Inventory Assessment (FIA), and the NPS Inventory & Monitoring Program.

3.8.4. Emphasize Spatial Analyses and Report Products

Extensive spatial analyses were performed resulting in many new spatial datasets and products. When appropriate, some of these products were experimentally integrated into geospatial analyses beyond the NRCA (e.g., RECOVER 2014 System Status Report).

The lead scientist for each resource or stressor provided generalized status and trends using a combination of maps and time series graphs displayed across the portion of the watershed or estuarine basins that are relevant to their resource. The expertise of the lead scientist determined appropriate condition thresholds, and the degree of certainty in the condition assessment. For many resource categories, these thresholds have been identified in peer-reviewed articles published prior to the development of the NRCA.

Data used for condition assessments were drawn from many different formats (e.g., continuous data; plots or polygons of interest; points where data were collected; lines representing transects or natural features; or any combination of the above). Then the quality of the information going into the resource or stressor assessment, at the scale of the physiographic regions was evaluated. The evaluation of the quality of data used to inform the composite scoring synthesis of information to each physiographic region requires characterization of the data sources used in the original analysis. For example, focal resource leads had to consider the number of observations in each physiographic unit, the temporal extent of these observations, the proportion of the region they occupy, and whether the assessment results are extrapolated from other locations (for example, using the vegetation map to link results from other locations to a particular region of the park).

3.8.5. Report on Current Conditions Across the Entire Park

The national NRCA guidelines require that parks report "current conditions across the entire park." To meet this requirement, each lead scientist aggregated monitoring and inventory information and presented an assessment of conditions of each resource in each geographic region where the resource is known (or expected) to occur. Reporting condition by physiographic region in three condition units (good, moderate concern, significant concern) allowed for aggregating results across resources.

1. Experts spatially mapped the integrity metric of their resource or stressor across the park, based on where data were collected. The spatial coverage of monitoring varies widely across different natural resource categories. This is a result of the properties of the resources themselves (e.g., water surface monitoring in EVER produces daily water surface coverages

using a 400 m grid with known range of certainty, while tree islands are monitored using a combined approach of aerial photographs interpreted on roughly decadal intervals, with species composition of a representative subset of tree islands sampled using a multi-stage spatially stratified monitoring design with 5-year resample intervals).

2. Physiographic regions and surface watershed delineations are superimposed on top of spatial integrity metric maps.

3. Thresholds for condition were applied to the spatial integrity map and reported by physiographic region. The resulting condition map shows condition based on measured or inferred status in each individual region, along with the estimated size of the entire resource within that unit.

4. A watershed-scale synthesis of status/trend across many resource categories is conducted. Watershed-scale impairment is a known cause of a large number of management challenges for EVER. Linking the status of resources to overland water flows, and the specific water management infrastructure that controls those flows (either directly, or indirectly due to upstream operational rules and/or infrastructure design) is an essential aspect of assigning cause for natural resource challenges across much of EVER.

Resource and stressor condition data were simplified to visualize conditions relative to the desired state of conservation of each resource throughout the park. Watershed-based condition syntheses (located in chapter five) create an "executive level perspective" of resource conditions across the park. The resulting tabular summary of status/trend/confidence icons is useful for strategic planning, management, and communication purposes.

Thus, reporting condition across the parks required creating simple graphics of relative condition by physiographic region. These graphics simplify potentially complex discussions about resource conditions, and are used to identify when resources are outside of the range of variability established for natural resources that are in a desired state of conservation. Aggregating individual assessments supports a meaningful characterization of resource and stressor conditions across the entire landscape.

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Chapter 4: Natural Resource Conditions

4.1 Landscape dynamics

Everglades National Park is the downstream end of the Greater Everglades Ecosystem. The Everglades was once a huge watershed that received runoff water from the Kissimmee River, through Lake Okeechobee, and into the Everglades Basin. The installation of regional-scale water management infrastructure facilitated development that supports millions of people, but which disarticulated the Everglades watershed. Negative impacts from regional development peaked in the 1970's. Since the 1970's, the regional scale ecosystem has stabilized and some aspects of the system have improved moderately. The operations of water management systems are the primary reason for improvement. Expansion of ecologically protected areas is notable. Regulation of non-point source pollution from industrial-scale agriculture has produced improvements. An expanding human population (Figure 4.1) has introduced additional challenges. Planning for the restoration of the regional ecosystem indicates that further improvements are possible.



Figure 4.1. Millions of people live less than 50 miles away from Everglades National Park. Most of the population is concentrated in urban areas.

4.1.1 Natural Areas spatial extent and land uses

Status and Trend

Attribute: Spatial extent and connectivity of natural areas in the Greater Everglades Ecosystem.

Overall Condition & Trend:



Rationale: Spatial extent of natural areas in the region is significant – currently >8,500 square miles of land and marine areas under protection south of Lake Okeechobee.

- Connection between Lake Okeechobee basin and Everglades Basin is not yet established.
- Abandoned roads have penetrated deep into East Everglades Addition Lands.
- Industrial scale agriculture exists on eastern boundary of EVER, and dominates the area where Lake Okeechobee and Everglades basins were once connected (Figure 4.2)
- Regional planning efforts indicate that opportunities for effective restoration exist.

Highlights

- The population of humans has increased from less than 10,000 in 1900 to over 7,000,000 in 2010 (Figure 4.1).
- Agriculture and urban are the predominant land use types in the portions of the region that are not protected lands (Figure 4.2).
- Total quantities and application rates of pesticide, fertilizer, and fungicide use in southern Florida are among the highest in North America.

Bottom line: The spatial extent and interconnectedness of natural areas in southern Florida is gradually improving over the last two decades. As land uses intensify, it is important to remain vigilant about water quality impacts that are likely to emerge.

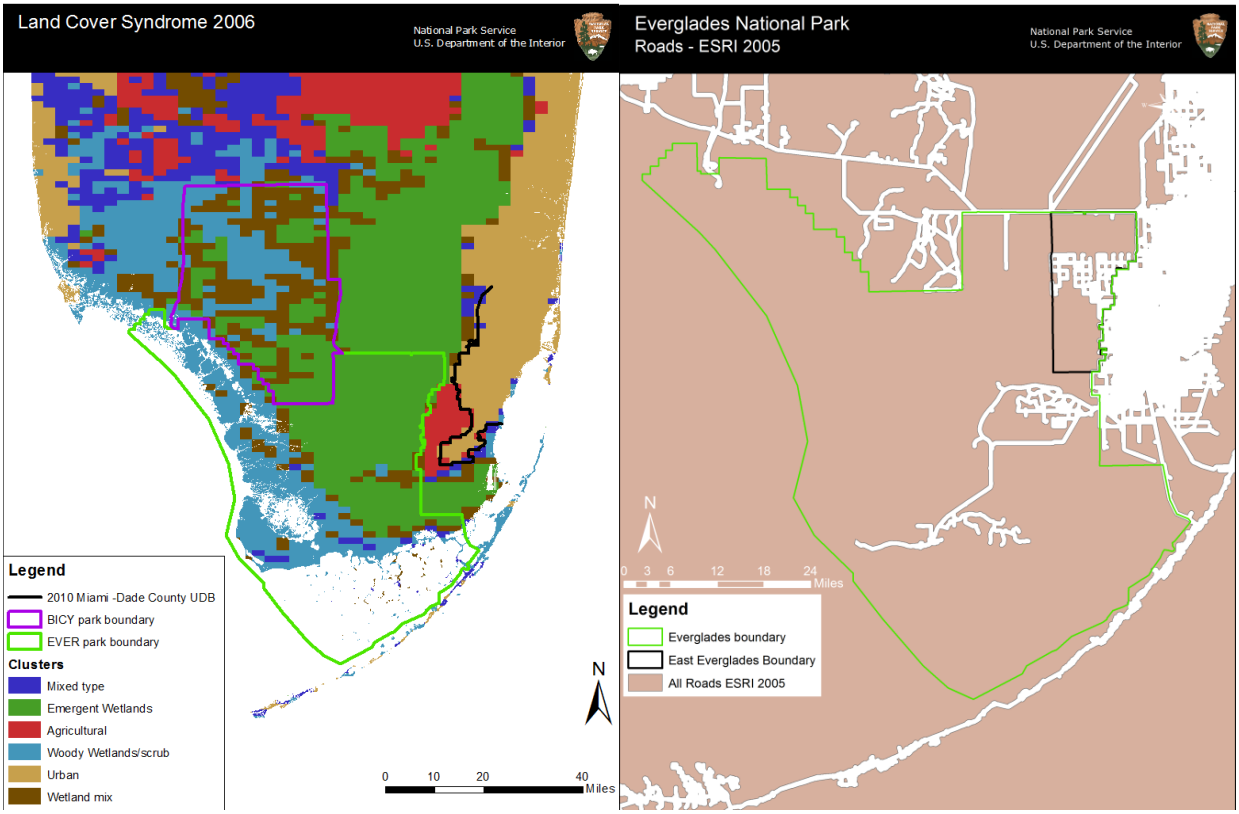


Figure 4.2. Roads and land uses can have significant impacts on natural resources. Six types of land use are predominant in the region. Urban and agricultural uses dominate areas outside of protected watersheds.

Background and Importance

The federally owned lands of southern Florida are contiguous with a growing network of state and privately owned lands that are managed for natural resource goals These protected lands cover much of the historical Everglades with the notable exception of the area immediately south of Lake Okeechobee (Figure 4.3). Currently these lands are only divided by water management infrastructure, but the process of reconnecting the main flowpath of the Everglades has been extensively planned (known locally as CEPP – the Central Everglades Planning Project) and is ready for Federal appropriation. A second observation is that the Atlantic coast and "upland" areas between Ft. Myers and BICY are the main remaining fragmented landscapes and thus opportunities for establishment of additional natural areas.

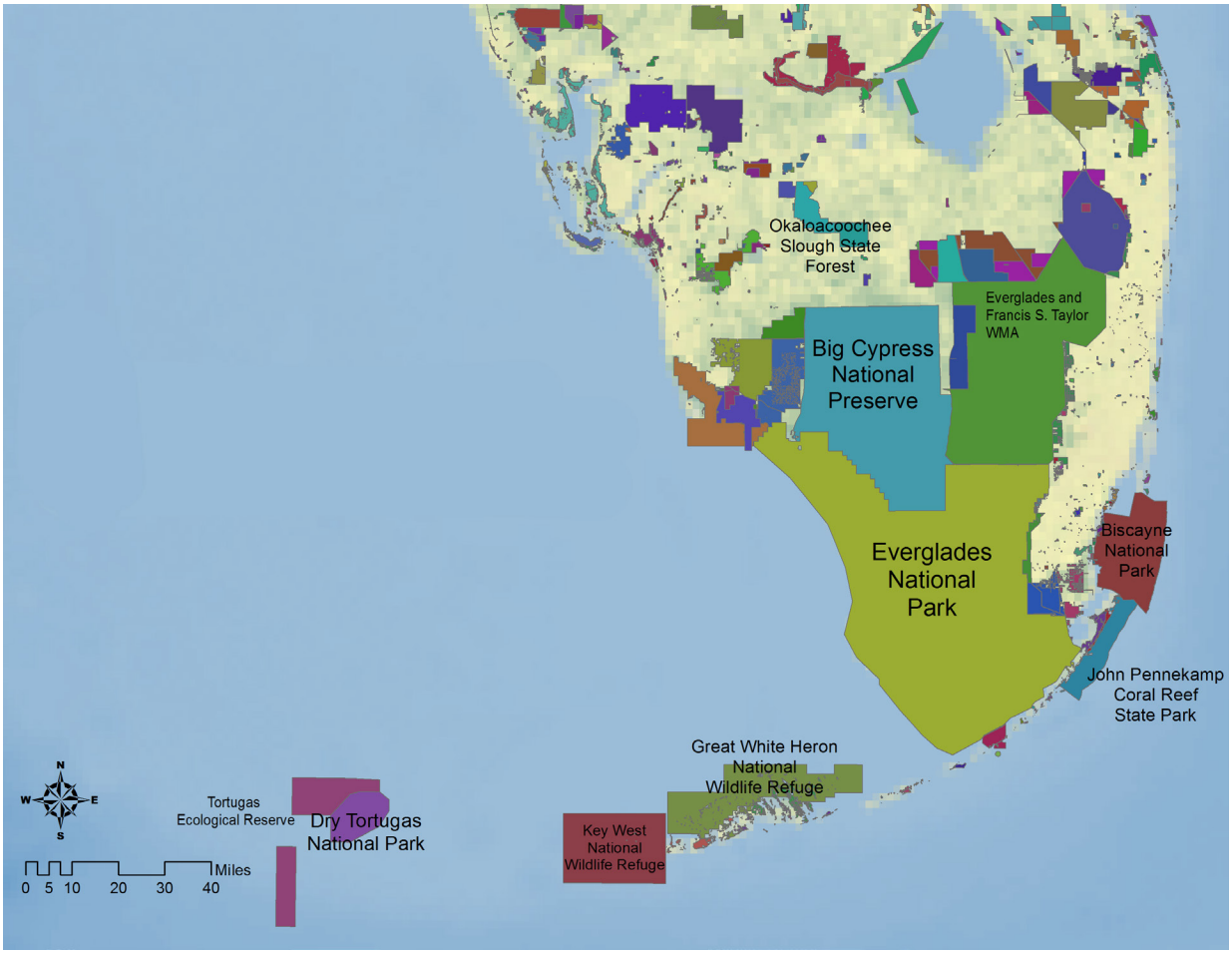


Figure 4.3. Areas in southern Florida where natural resource management is a priority for the owners. Over 8,500 square miles of land, coastal, and marine areas are identified in this figure.

Southern Florida has been transformed by humans since 1900. The vegetation patterns observed in 1914 by Harshberger (1914) are similar to what is found today in wilderness areas. This map identified coarse scale vegetation patterns that were highly correlated to elevation contours/basin formation processes. The regional water management system is either built on these boundaries, or positioned to replace the natural boundaries (particularly on the eastern portion of the peninsula – Figure 4.4).

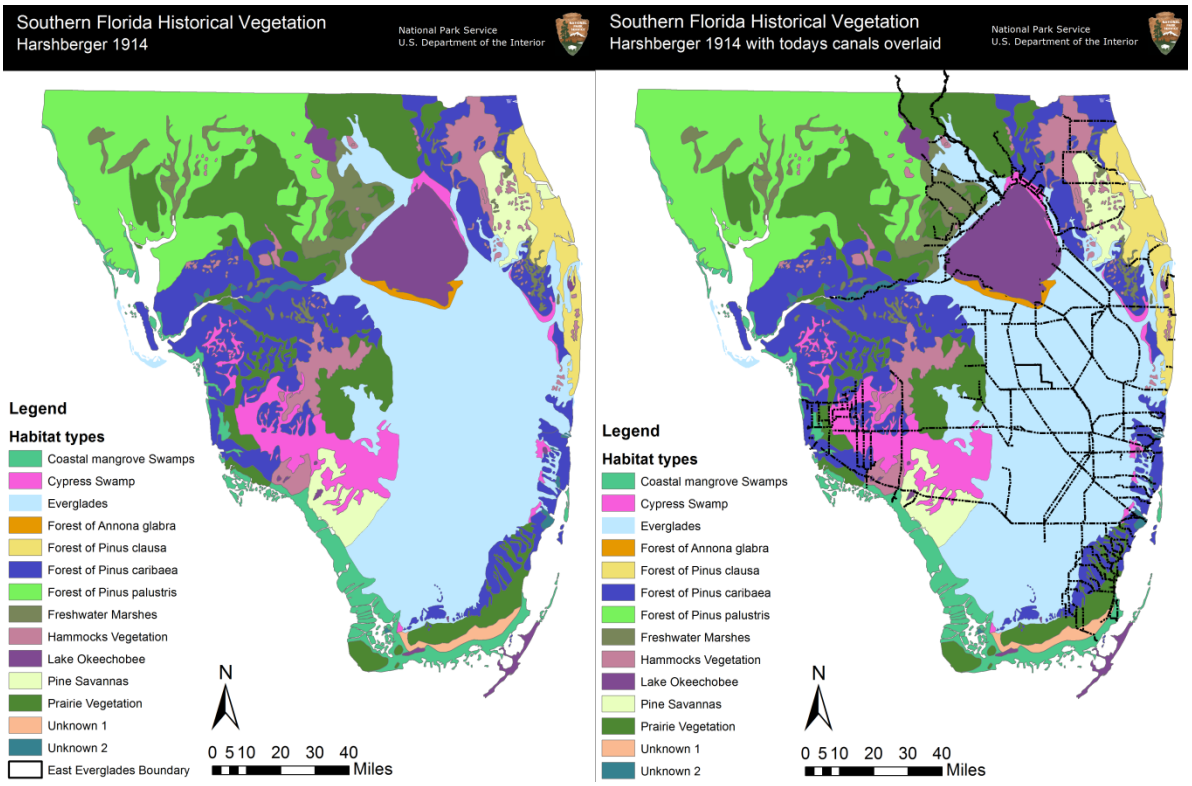


Figure 4.4. A digitized version of Harshberger 1914 (left panel) and the same map with the current canal system overlaid (right panel).

Harshberger (1914) surveyed vegetation, elevation, geology, and as much of the available literature as he could find to produce this first comprehensive map of the vegetation of southern Florida. The patterns he identified and the ecological processes that underpin those patterns are effectively described in his report. One century later, this map remains an effective summary of the potential regional condition, and can be used to identify restoration/conservation goals with a concise display of the historical vegetation pattern – that is stable over multiple centuries in the absence of widespread human-introduced stressors.

A more precise statement of the regional condition is that humans have systematically modified the region, as indicated in Table 4.1. These modifications support local land uses, and some modifications (e.g., the Herbert Hoover dike that surrounds Lake Okeechobee) have enabled state agencies to fundamentally alter the properties of the regional system. The timeline of modifications to the regional system was effectively described by the 1970's (see Duever et al. 1986, which references Klein et al. 1975). The acquisition of Big Cypress National Preserve in 1972, the addition of the water quality lawsuit (begun in 1988), East Everglades Addition Lands in 1989, and the establishment of the Comprehensive Everglades Restoration Plan are evidence of a shift away from systematic alteration and toward a management process that is based on our best understanding of the regional ecosystem. The success of restoration hinges on the ability of the regional infrastructure to effectively support the desirable ecological functions (or fundamental values) of the Everglades

Ecosystem. A more comprehensive discussion of the history of the Everglades is available through Florida International University library.

Table 4.1. Landscape dynamics condition assessment metrics.

Criteria	Condition & Trend	Rationale	Reference Condition
Conserved lands across the regional watershed		Significant proportions of the regional watershed are managed with natural resources as a priority. Effective planning for improvement to the regional watershed is occurring. Watershed has improved since 1970's and water management continues to improve.	Harshberger (1914) provides general objectives. McVoy (2011) provides extensive evidence for detailed goals.
Roads		The effects of abandoned roads are being addressed in East Everglades Addition lands. Permanent roads in EVER have been extensively modified and improved to reduce hydrologic impacts.	No roads is the goal for wilderness areas. Minimizing impacts of roads is the goal for the roads that remain.
Regional water management		Regional practices are improving, extensive planning has occurred, significant actions are still needed to enhance the condition of the watershed.	Water management in natural areas should match the water patterns described by the Natural Systems Model (see McVoy 2011) to the maximum possible extent. Significant changes are still needed to infrastructure and water management rules.
Water Quality risks		Intense land uses that are associated with known water quality impacts are found on the boundary of the park. Land use intensity has been increasing for ~100 years. Water quality rules exist, but effective enforcement remains a challenge.	Background nutrient levels in marsh are 10 ppb (Noe et al. 2001 and many others). Land use intensity is > 80% along the eastern boundary of EVER and in the Everglades Agricultural Area (south of Lake Okeechobee).

Concerns

While the extensive set of protected areas is encouraging, these areas are not all healthy, and there is no guarantee that the status of the region will continue to improve. As the population continues to grow, with so many conserved lands, the expectation is that land use will to intensify. Figure 4.6 identifies areas that already have more than 80% converted lands. These are the areas where we expect phosphorus-related water quality challenges (as indicated by Flanagan and Richardson 2010). A careful investigation of the underlying land use classification layer (provided by the USGS) suggests that the actual rate of conversion is underestimated 1–5% across the southern Florida region, so risks of water quality impairments are probably a bit higher than demonstrated in Figure 4.5. Both the agricultural and urban land use types demonstrated the highest frequency of conversion-related water quality risks. The major sources of water quality challenges are fertilizers/pesticides/fungicides

that are applied to croplands and septic tank systems which are still prevalent throughout southern Florida.

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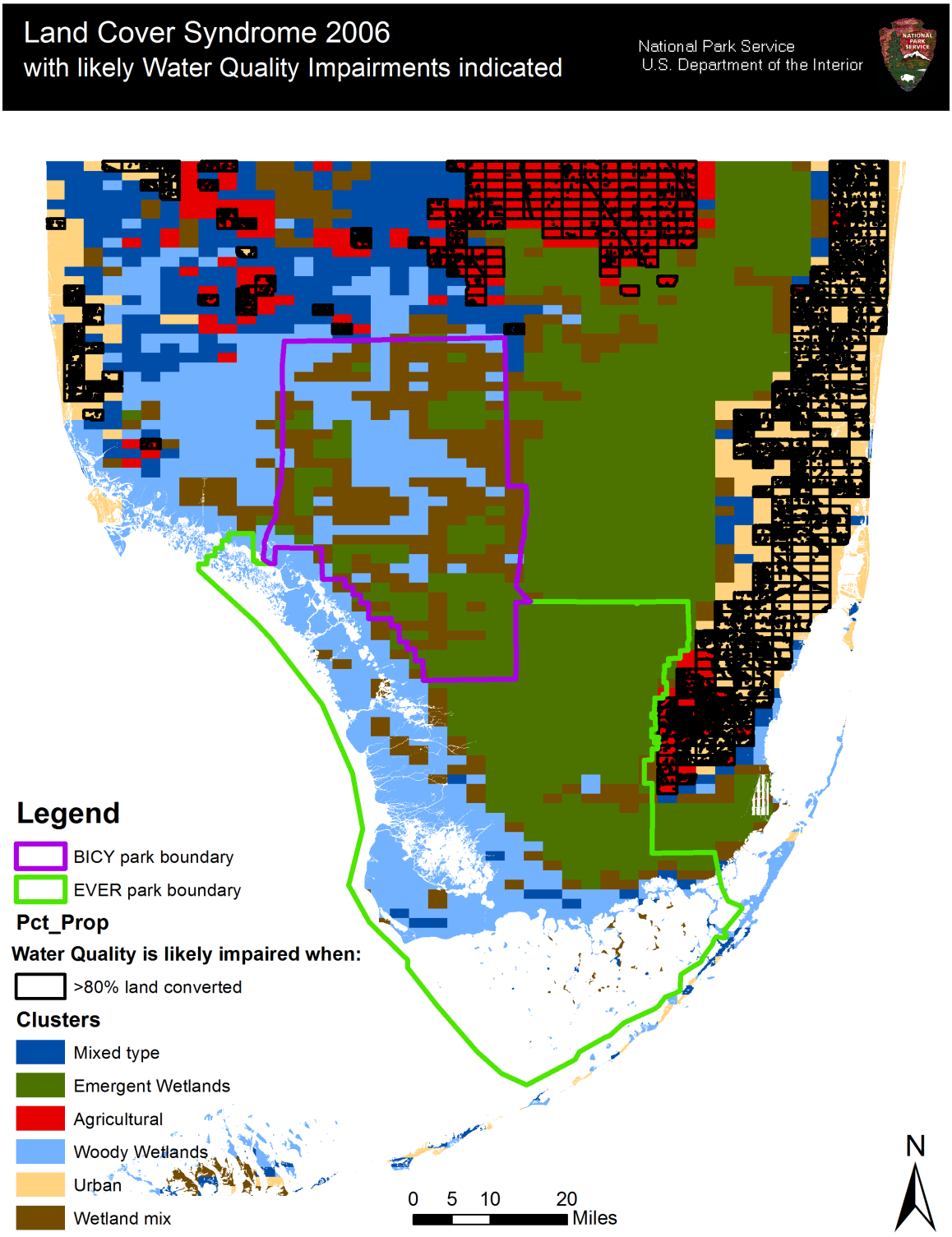


Figure 4.5. Land use types summarized at a 2x4 km grid scale. Rectangles where more than 80% of land has been converted to human uses are indicated with black outlines. These areas are likely sources of Water Quality challenges.

4.2. Hydrology

Hydrology of the Everglades is naturally divided into three categories: Freshwater marshes; coastal creeks, lakes, and rivers; and the estuaries of the Gulf Coast and Florida Bay.

4.2.1. Freshwater marsh water pattern and levels

Status and Trend

Attribute: Freshwater marsh water pattern and levels

Overall Condition & Trend:



Rationale: The total volume of water that is delivered to EVER is usually less than half of what is desirable given historical patterns and the needs of desired habitat types. The location of deliveries is mismatched to downstream land and management goals.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

The natural resource management objectives for freshwater marshes are not being achieved, and there is no evidence of a trend in either the magnitude and direction of sheetflow or water pattern and levels. This result is not surprising given that, while some of the corrective measures necessary to meet these targets have been completed, obstacles remain in the path of establishing a comprehensive water control plan. Ultimately, it is the water control plan that will allow regional water managers to take advantage of the land that has been acquired and the infrastructure that has been constructed to improve the hydrology of Northeast Shark River Slough (NESRS).

There continues to be reason for significant concern about the magnitude and direction of sheetflow in EVER. The average annual water volume into NESRS is too low, and the timing and spatial distribution of surface water depth patterns are inconsistent with desired conditions. Metrics used to assess the status of these indicators fell well below the rigorously established conservation targets (Tables 4.2 and 4.3). Since 1980, 77% of the flows that enter Shark River Slough have been directed through the western flowpath, while only 23% have been delivered into NE Shark River Slough. The total volumes delivered to EVER have only met the target once in 33 years, and this was during a very dry year (1986). Water levels in NESRS have never reached the lower threshold of the target range (7.5 -8.8 ft. NGVD). Several of the regression lines of flow magnitude and direction show a trend with a reasonable statistical significance. However, while these statistics are instructive, there is too much influence of rainfall variability and too few points to ultimately conclude that there is truly a temporal trend in these data that is a result of controllable factors (i.e., hydrologic system

operations). Therefore, Indicators 1a and 1b each receive horizontal arrows representing no temporal trend.

Table 4.2. Water volume and distribution indicator metrics.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
1a. Magnitude and distribution of sheetflow		A large disparity continues to exist in the distribution of flows between Western Shark Slough (WSS) and NESRS. Over the long term, 77% of the total Shark River Slough flow distribution was delivered to WSS and 23% to NESRS. In 2011, 78%, or almost double the WSS target volume, was delivered to WSS and only 22% was delivered to NESRS.	On an average annual basis, 55% of flows should come through NESRS and 45% of flows should come through WSS.
1b. Average annual water volume into NESRS		Over the period from 1980 to 2013 (34 years), the target was met only 1 time, in 1986 during a dry year. During average and high rainfall years, flow to NESRS was generally less than half the target.	On average, a total annual volume of water should be delivered to NESRS of 550,000 acre-feet (acre-ft.) with a range of 200,000 to 900,000 acre-ft. during years of below- and above-average rainfall, respectively.

Table 4.3. Water pattern and water levels.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Water pattern and water levels (timing and spatial distribution of surface water depth)		NESRS water levels are always significantly lower than targets. In no year has the average water level in NESRS even reached the lower range of the target (7.5 ft. NGVD).	The target is to achieve annual average water levels (stage) in NESRS of approximately 8.0 ft. National Geodetic Vertical Datum 1929 (NGVD) during years of average annual rainfall. During years of below and above average annual rainfall, the average water level in NESRS would be 7.5 and 8.8 ft., respectively.

Metrics used to assess the status of Indicator 2 also fell well below the conservation targets established. For this reason, and because a water control plan is still years away from realization, Indicator 2 receives a red light and remains a significant concern, but no trend was identified in the water level record.

Background and importance

The peat lands of the Everglades form a pattern of corrugations that are parallel to the direction of water flow. This defining characteristic is referred to as the ridge and slough landscape, the largest

landscape type in the Everglades (Figure 4.6). Hydrology plays a supporting role in forming and maintaining this landscape and associated habitats.

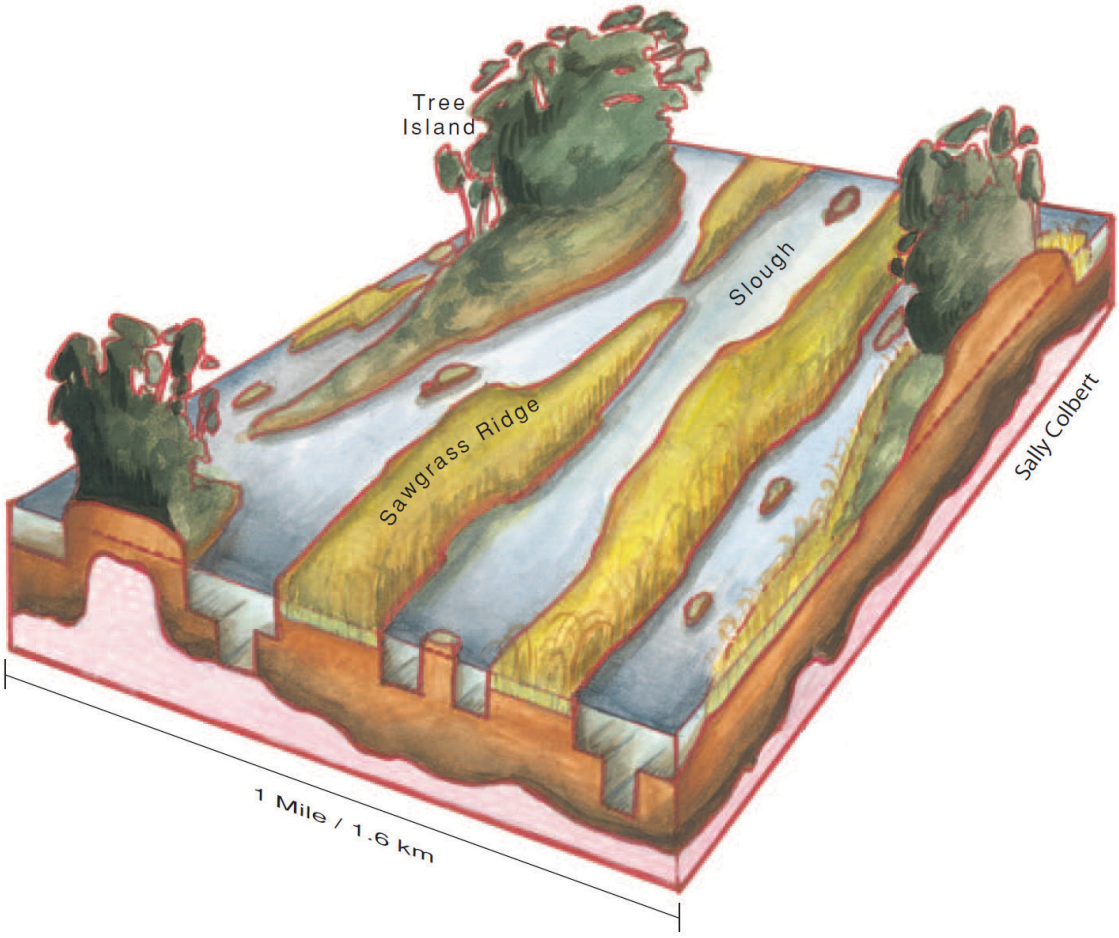


Figure 4.6. Ridge and slough patterned landscape. Illustration by Sally Colbert; modified from McVoy et al. (2011, p.67).

One of the areas dominated by the ridge and slough landscape is Shark River Slough (SRS), the primary drainage in Everglades National Park (EVER). SRS is, by convention, divided into Western Shark Slough (WSS) and Northeast Shark River Slough (NESRS). This convention stems from the original boundaries of ENP, established in 1947, which did not include NESRS inside the park. Land parcels in NESRS remained privately owned by parties anticipating future development. The main channel of SRS is located in NESRS, whereas WSS is at a higher elevation on the edge of the main channel.

The Central and Southern Florida Project (C&SF), authorized in 1948, set out to manage regional water resources, primarily to control flooding and provide water supply for agricultural and urban uses. In doing so, by 1962, all of the free-flowing Everglades system, except for EVER and NESRS, was converted to large, shallow reservoirs (Water Conservation Areas, or WCAs) surrounded by earthen levees. Because NESRS was not part of EVER at that time, the C&SF focused on supplying

water to EVER via WSS while the private property in NESRS was “protected” from regional inflows by the C&SF levee system. NESRS was always considered a key component of SRS; however, it was not until it was cut off from the Everglades system that the consequences of not including it in the original park boundary were fully realized. One of the consequences was a degradation of the ridge and slough landscape as a result of reduced surface water flow and water levels. Without sufficient depths of water, NESRS experienced soil loss as well as vegetation encroachment into the sloughs, eventually filling them and eliminating open water habitat.

The changes in water distribution between WSS and NESRS that were the result of impounding the WCAs can be seen in Figure 4.7, which shows the depth of water in the Everglades following two large rainfall events. Panel A shows the water-level distribution after a large rainfall event in 1959 prior to the impoundment of the WCAs and the panel B shows the water-level distribution after a large rainfall event in 2005. This figure illustrates how the deeper water, and consequently water flow, has been redirected to the west and away from the main channel of SRS. Prior to impoundment of the WCAs, approximately 70% of the total flow went to NESRS compared to less than 20% in more recent times.

In 1989, more than 40 years after the original park boundaries were established, Congress authorized the expansion of ENP to include NESRS. Re-establishing the hydrology and restoring the ridge and slough landscape feature in this area has been a major focus of Everglades restoration and a fundamental aspect of characterizing the desired State of Conservation for freshwater marshes in Everglades National Park. The targets for the desired State of Conservation were derived from analysis of observed data as well as model simulations that mimic the natural, undeveloped system.

Desired State of Conservation

The desired state of conservation for hydrology in EVER is broadly defined as a system in which more natural water depths, distributions, and sheetflow patterns have been reestablished in the park. The majority of the water should flow through the historic flow path of NESRS, the Slough should dry out only very infrequently (a few days per decade), and operation of the water management system should allow for natural seasonal patterns of the rise and fall of water levels, in concert with rainfall.

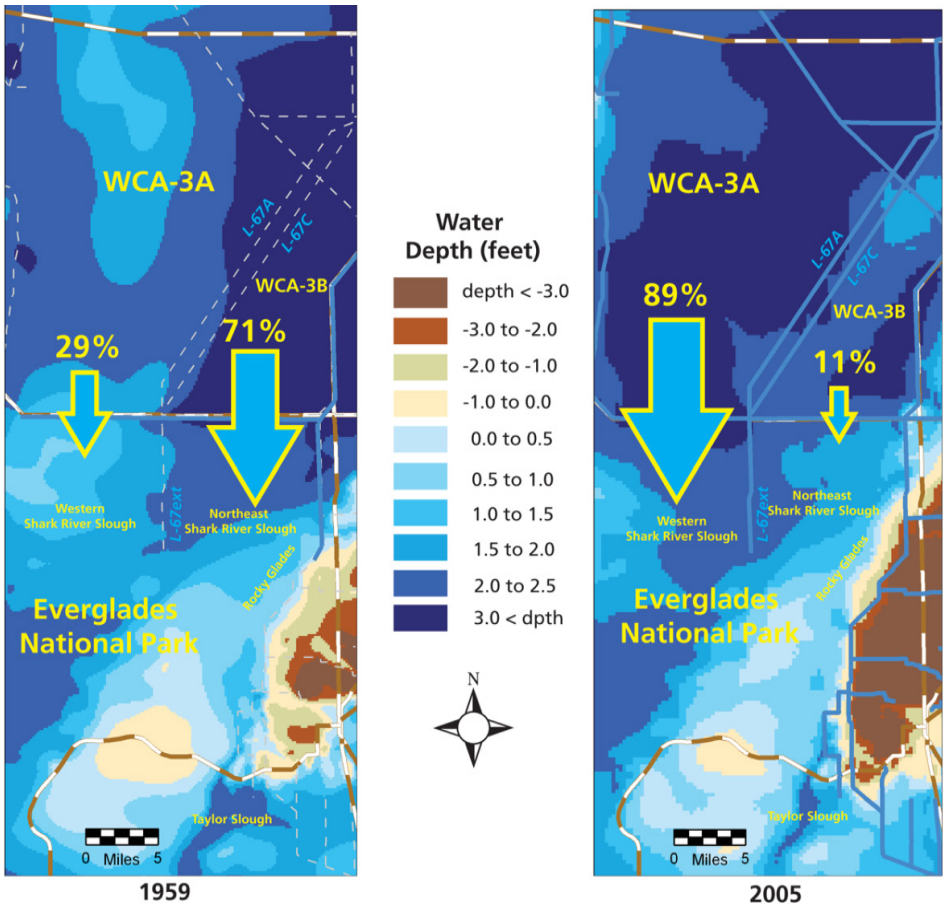


Figure 4.7. Water depths and flow distributions for two wet years (1959 and 2005) when more than 1 million acre-feet of water was discharged to Shark River Slough, Everglades National Park. These two years correspond to the period prior to compartmentalization (1959) and post-compartmentalized Water Conservation Area (WCA) 3 (2005). Prior to compartmentalization, the higher water depths and flow volumes were more confined to the eastern flow-way through Northeast Shark River Slough (NESRS). Today, as depicted in 2005, the deeper water and greater flows are more confined to Water Conservation Area 3A and Western Shark River Slough.

Description of Indicator Monitored

Flow measurements and water level monitoring, conducted by the U.S. Geological Survey (USGS), provides the information necessary to evaluate the hydrologic indicators. The USGS has been measuring the flow of water across the Tamiami Trail since 1939. The dataset consists of daily flow values and is used to evaluate the magnitude and distribution of sheet flow (Indicator 1a) and the average annual water volume to NESRS (Indicator 1b). Indicator 2, water pattern and water levels, is evaluated using water level monitoring at USGS gage NESRS2, which has a period of record that began in July 1976.

The hydrologic indicators are sensitive to both climatic conditions and water management operations. Given that rainfall amounts vary naturally, an effort is made to factor rainfall out of the indicator to focus on the effects of water management operations. That is, for example in the case of Indicator 2,

the target water level is lower for the drier years and higher for the wetter years. Similarly, rainfall is also a factor for Indicator 1b, in which the flow target is higher for wetter years.

Given that the water management system is regional in nature, we use a regional rainfall dataset provided by the National Oceanographic and Atmospheric Administration (NOAA). This regional dataset, Florida region 5, is a composite of all NOAA rain gages that are located within the Lake Okeechobee – Everglades drainage basin. For this evaluation, below average rainfall years are defined as the lowest 37.5% of annual total rainfall, above average rainfall years are defined as the highest 37.5% of the annual total rainfall, and average years are defined as the central 25% (i.e., from the 37.5 to 62.5 percentile) of the annual totals.

Status of the Indicators in the Current Year and Trends during 1980–2013

Indicator 1a: Magnitude and Distribution of Sheet Flow

The spatial distribution of water is evaluated by comparing the portion of flow that was directed to NESRS relative to the total flow delivered to both WSS and NESRS. Because the target for this metric does not vary with rainfall, there is no need to segregate the data based on annual rainfall. A stacked bar graph of annual total NESRS (bottom portion) and WSS (top portion) flow is shown in Figure 4.8. The 55% NESRS target for each individual year is represented as a light blue dash. If the NESRS bar is higher than the blue dash (i.e., the target), then the NESRS flow target (55% of total flows) was met for that year. Based on these data, the target of passing 55% of the total flow to NESRS was only achieved in 3 of the 34 years (1990, 1991, and 2008) with 1988 coming very close to the target. These were years of very low total flow into the park (Figure 4.8), and they correspond to rainfall years in the low category. This graphic illustrates that, in general, the higher the total flow, the farther we are from the target.

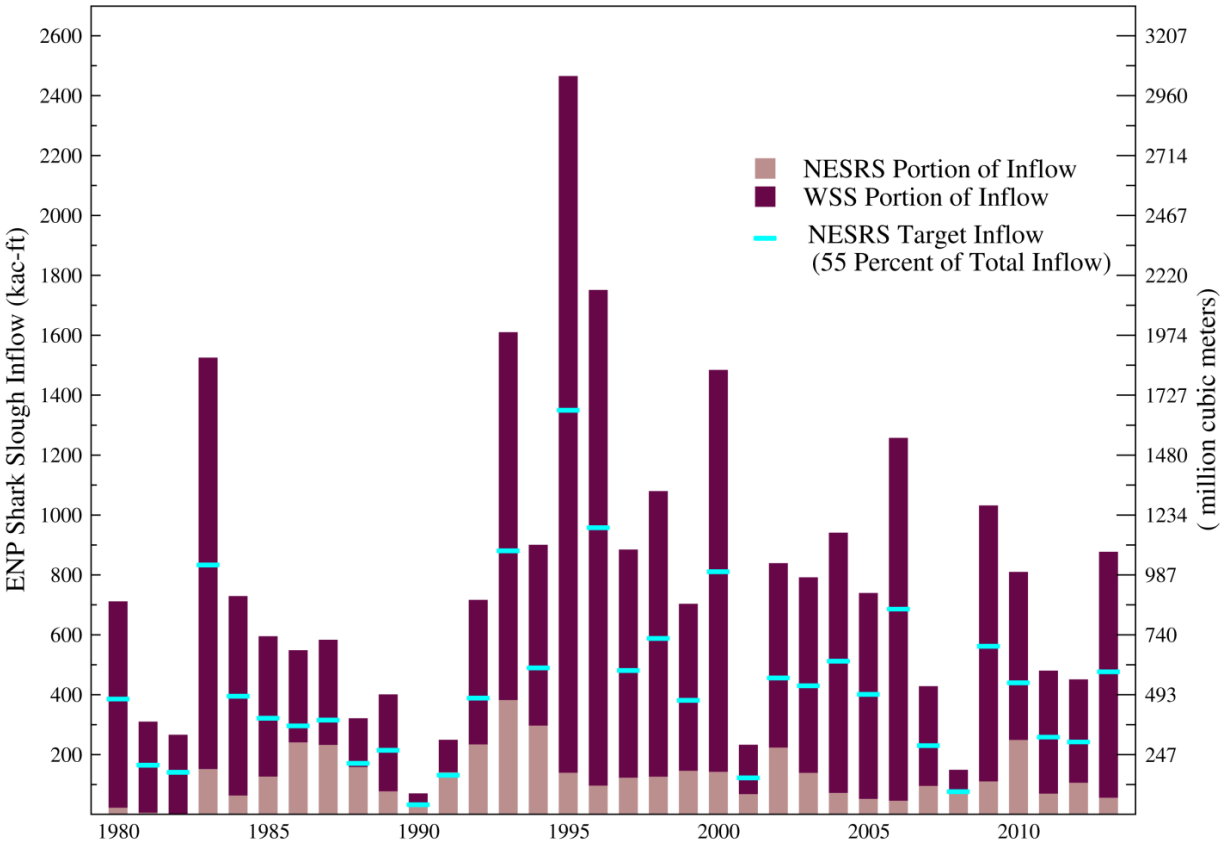


Figure 4.8. Annual total flow into Shark Slough by region and in relation to annual target for Northeast Shark River Slough.

Although the target ratio for this indicator does not vary with rainfall conditions, we tend to be closer to the target during low flow/rainfall years. Therefore, for the trend analysis, the years were categorized by rainfall and the trends are shown in Figure 4.9. The slope of the least squares regression line through the data points varies from slightly negative to slightly positive; however, none provide a level of confidence necessary to confirm a trend given the variability and small number of data points.

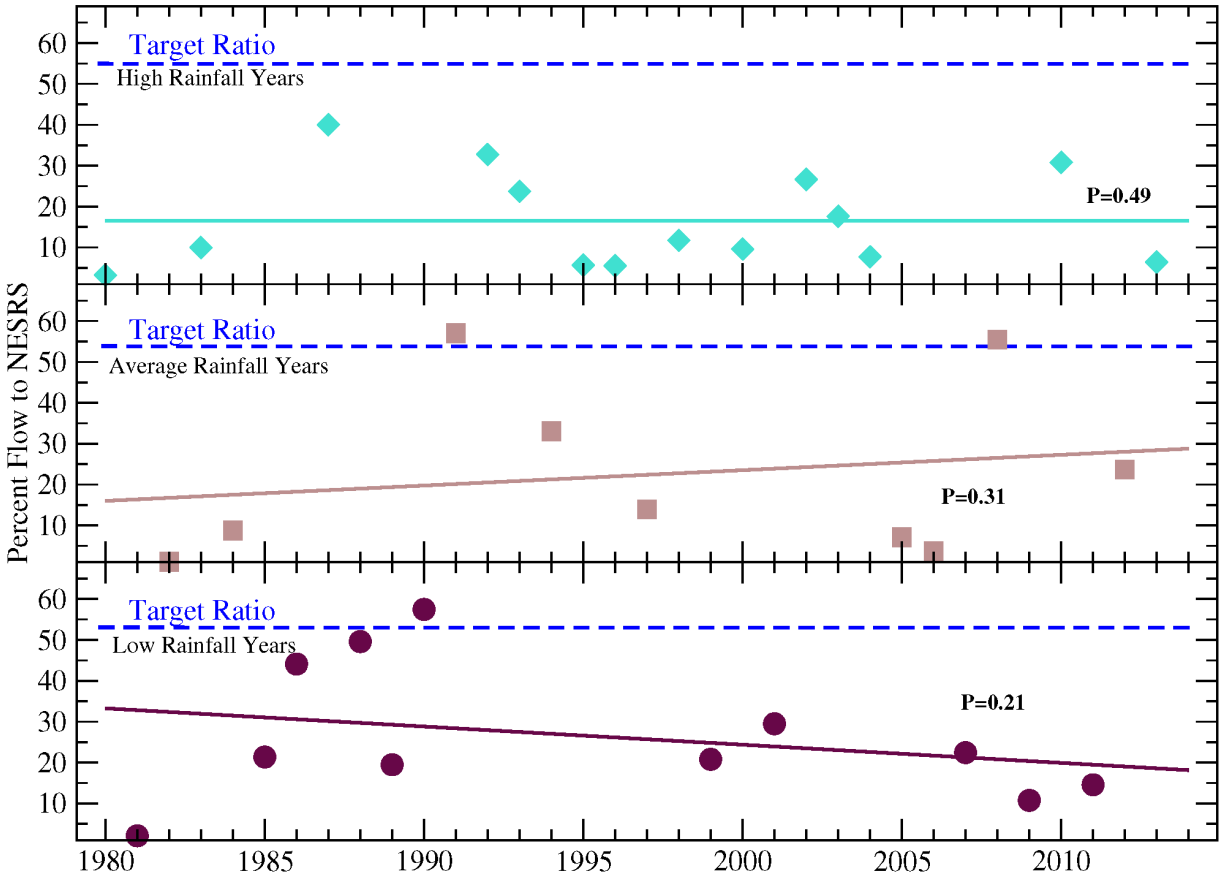


Figure 4.9. Trends in percent flow to Northeast Shark River Slough (NESRS) by rainfall category. The p-values are the result of one-tailed statistical tests of the slope of the regression line. In this context, p-values above 0.05 indicate that there is not enough evidence to confidently declare that the trend shown actually exists.

Indicator 1b: Average Annual Water Volume to Northeast Shark River Slough

Flow targets vary depending on the amount of annual rainfall; consequently, the years were segregated to evaluate the water volume indicator. Each year is categorized by the rainfall as low, average, or high, and the annual flow is presented in a box plot for each category (Figure 4.10). The whiskers of the box plots extend up and down to the 90th and 10th percentiles. These data indicate that the NESRS target is only approached during dry years and then, only at the 90th percentile of the low rainfall years (approximately once every 10 low rainfall years). This graphic also illustrates a trend in that NESRS tends to receive less water during the wetter years such that, as the rainfall increases, inflows into NESRS decrease. Conversely, and more intuitively, flow to WSS increases as rainfall increases. Trend lines for this indicator are displayed in Figure 4.11. Again, the annual data points are categorized by rainfall conditions and there is no statistical confidence of a trend for any of the rainfall categories.

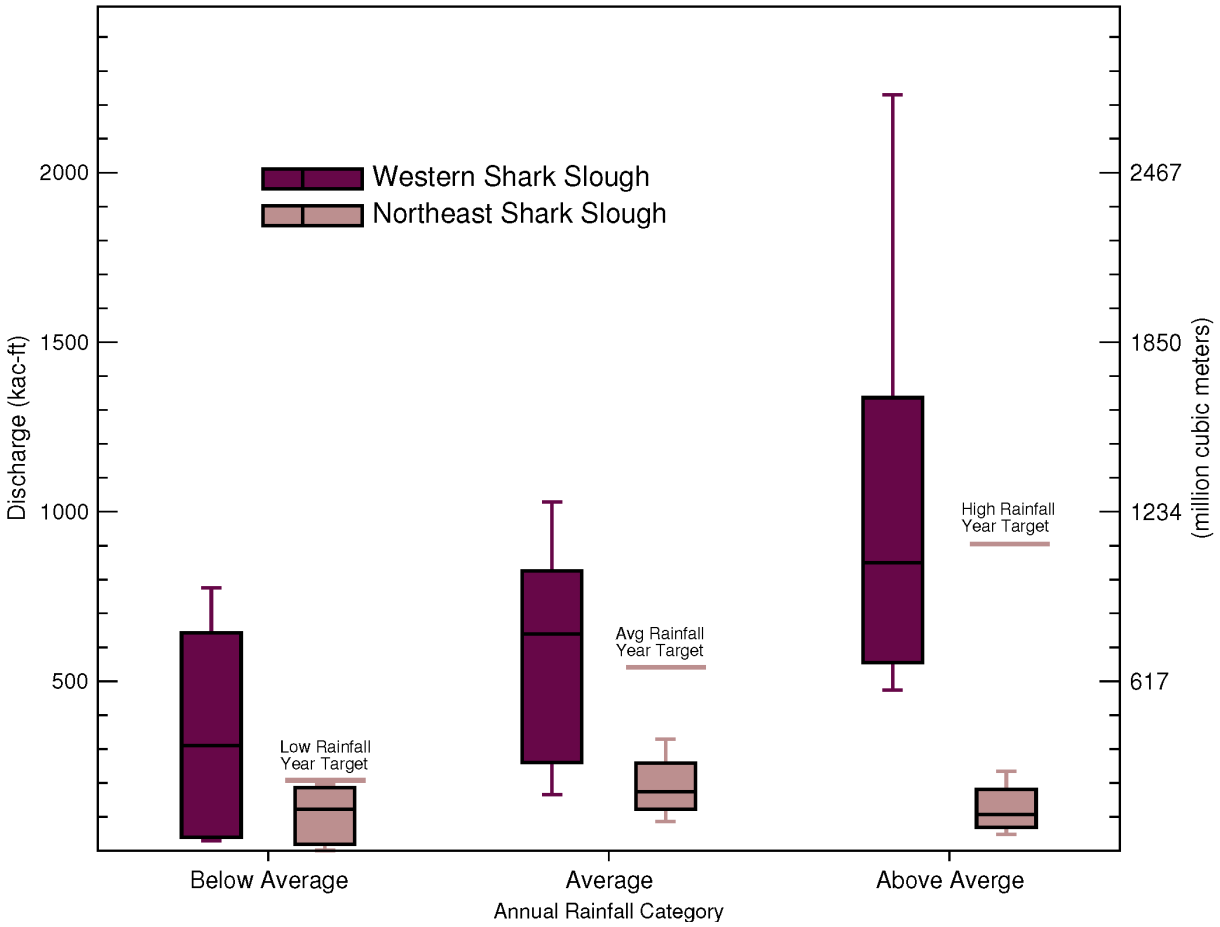


Figure 4.10. Annual flow in Western Shark Slough and Northeast Shark River Slough by annual rainfall category and target.

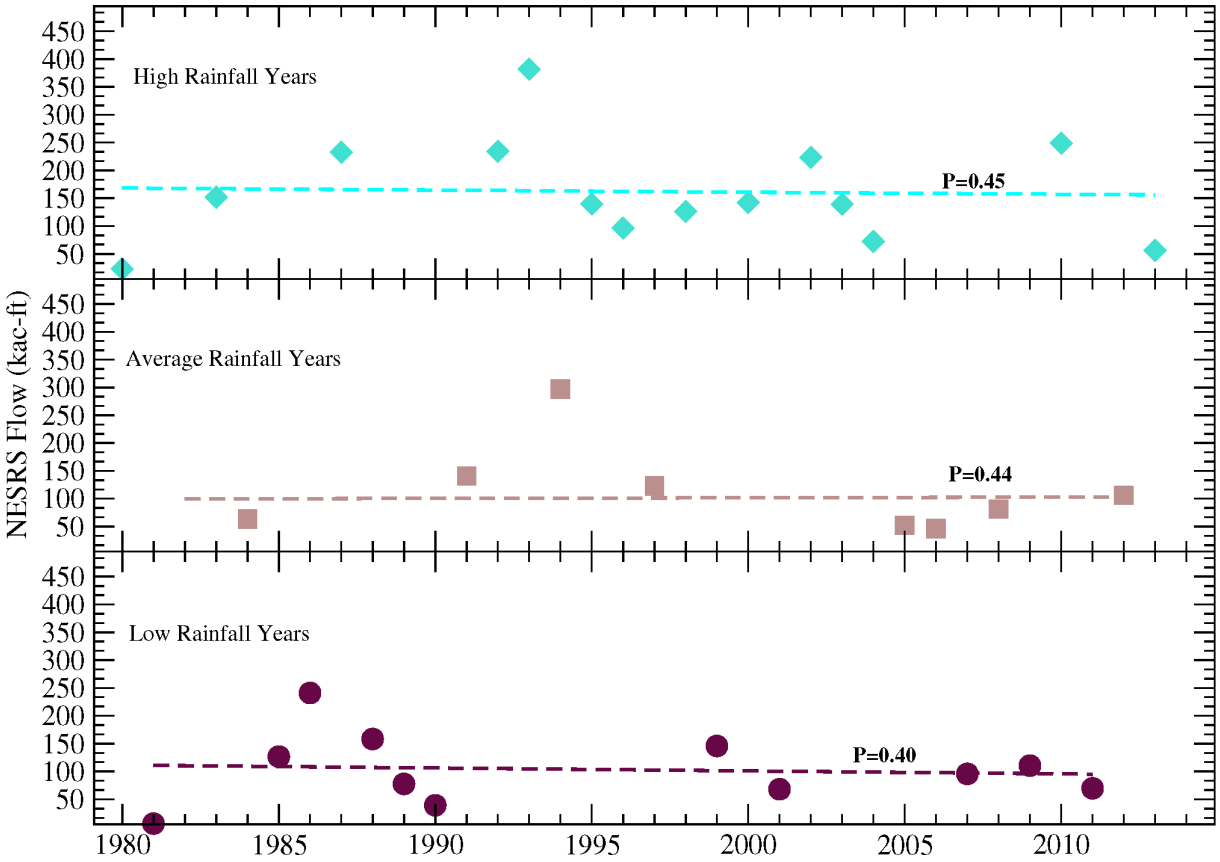


Figure 4.11. Trends in flow to Northeast Shark River Slough (NESRS) by rainfall category. The dry year target of 250 kac-ft was met once in 1986. Average and high rainfall year targets were not met during these years.

Indicator 2: Water Pattern and Water Levels

The NESRS2 gage, located in the central portion of NESRS, is used to evaluate this metric and the target water level varies with annual rainfall. For wet years, the target is for the annual maximum water level to reach 8.8 ft., 8.0 ft. in average years, and 7.5 ft. in dry years. The annual maximum water level for each year is plotted in Figure 4.12 along with the three targets. The data again have been categorized by the amount of rainfall in each year as described in the Table 4.3. The target is met if the annual maximum water level for a given year equals or exceeds the target for that year's rainfall category. These data indicate that the target has been met twice in the last 32 years. In both instances, the target was met during a low rainfall year. The target was not met for either the average or high rainfall years. Looking at the temporal trends for each of the rainfall categories in Figure 4.13; it is evident that, while the regression line for each has a positive slope, the cumulative probability values, i.e., the p-values, are too high to confidently declare that there is a trend over time.

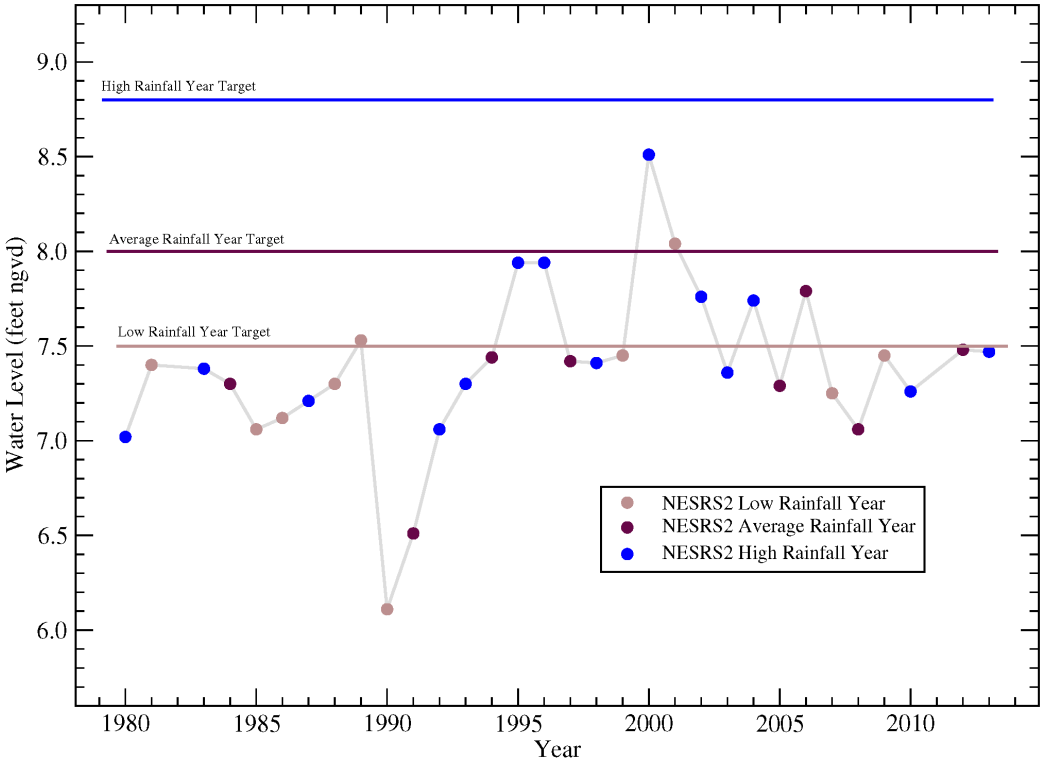


Figure 4.12. Annual water levels with targets by rainfall category.

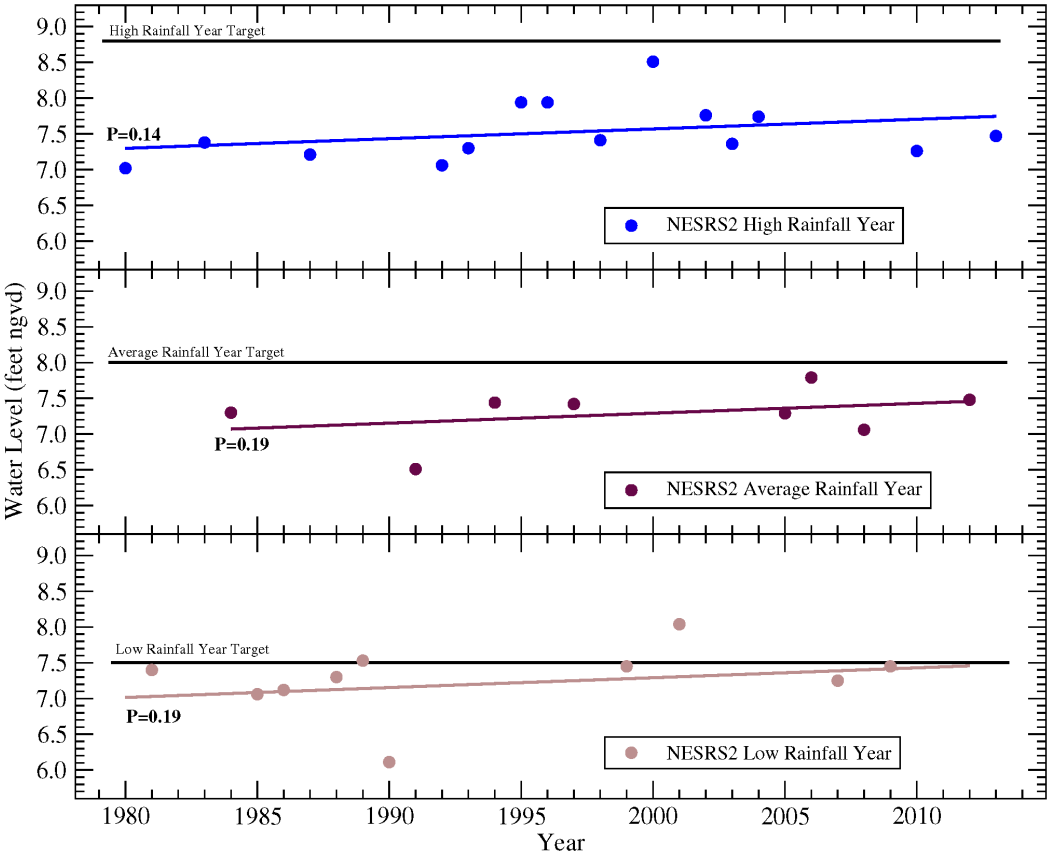


Figure 4.13. Trends in annual water levels in low, average, and high rainfall years.

References

McVoy, C.W., W.P. Said, J. Obeysekera, J. Van Arman, and T. Dreschel. 2011. Landscapes and hydrology of the predrainage Everglades. University Press of Florida, Gainesville, Florida, 576 pp.

4.2.2. Salinity patterns in Florida Bay

Status and Trend

Attribute: Salinity patterns in Florida bay

Overall Condition & Trend:



Rationale: Florida bay is too salty every year. In dry years, salinity can become much higher than the open ocean, particularly in the Central and Eastern coastal zones. Region's status has not change for several decades.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

Salinity in Florida Bay is not meeting the targets that have been developed for the system (Figure 4.14, Table 4.4). Observed salinities are higher than the target condition throughout the year, and hypersaline events are far too common. It is recognized that there is currently no discernible trend toward the desired salinity conditions for the bay and that improvement in these conditions hinges on successful implementation of restoration efforts ranging from the Central Everglades Planning Project (CEPP) to the C–111 South Dade project.

Table 4.4. Salinity patterns in Florida Bay (overall).

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Amount of time during the year that salinity is in the desired range		Salinity conditions overlap with desired conditions only during 2 months at the end of the dry season. Conditions are variable but exhibit no year-to-year trend.	Salinity is within the interquartile range of the desired pre-drainage conditions 50% of the time.
Difference between observed mean salinities and desired mean salinities		The mean salinity is above desired mean salinity throughout the year. The degree of difference over the period of record is variable but is largely driven by precipitation and shows no year-to-year trend.	The mean salinity is within the variability of the mean salinity of desired pre-drainage conditions.
Occurrence of extreme high salinity events		Salinity exceeds the 90th percentile of the desired conditions much more frequently than desired and shows no year-to-year trend.	Salinity does not exceed the 90th percentile defined by the desired conditions more frequently than the 10% of the time.

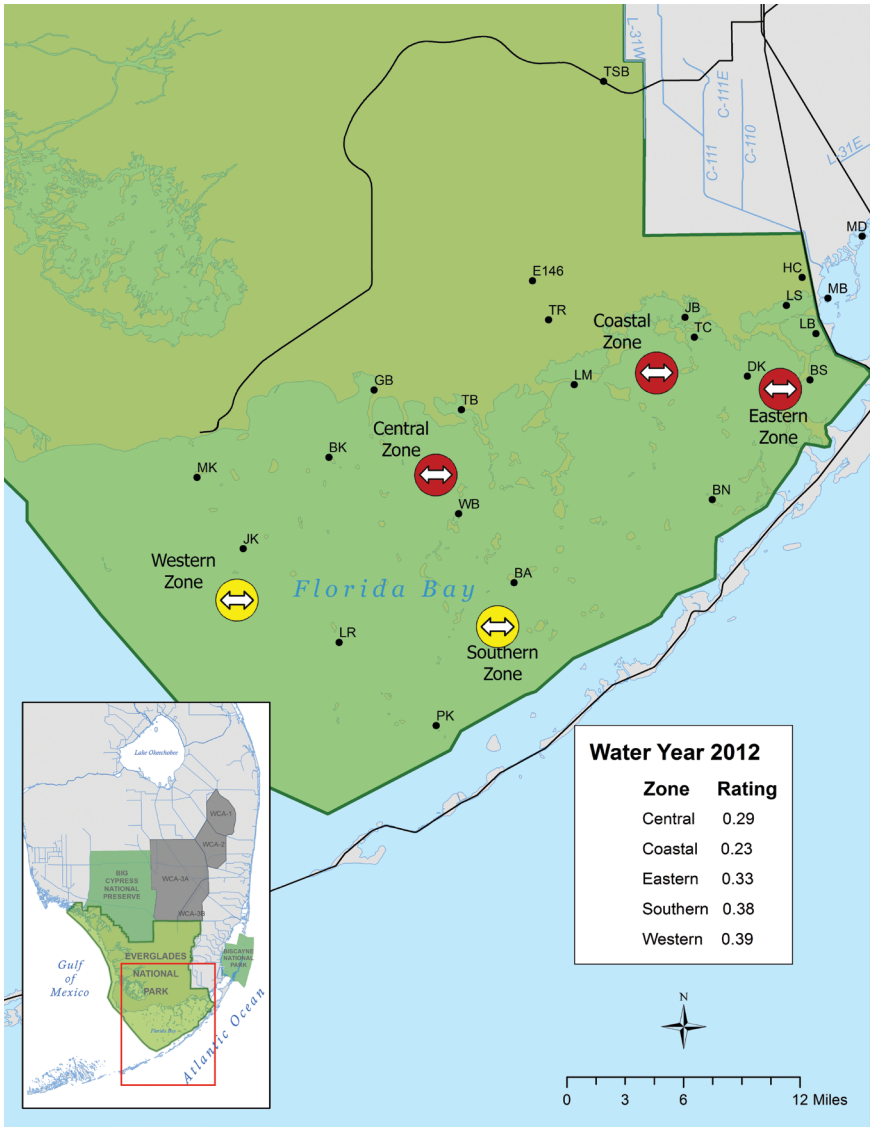


Figure 4.14. A map depicts the location of monitoring stations and ecological zones in Florida Bay. Ecological indicator ratings and trends are included in the figure and inset table.

All three measures of salinity status (summarized as "performance metrics") are displayed for a single year in Whipray basin in Figure 4.15. The figure shows the range of values that are in the middle 50% of the estimated hourly salinity target values (gray shading) along with the middle 50% range of observed values (orange shading). Whipray basin exhibits the highest average salinity and most frequently hypersaline conditions in the region. Maps similar to Figure 4.15 are now developed annually for each station in Florida Bay for each year in the period of record, 1991–2012, to assist in the evaluation of salinity conditions over time for each station. Careful inspection of these summaries reveals that the salinity conditions vary but show no long-term trend (summarized in Table 4.5). Annual differences in the severity of high salinity conditions in Florida Bay are related to precipitation, with relatively wetter years resulting in lower salinity and better conditions baywide than relatively dryer years.

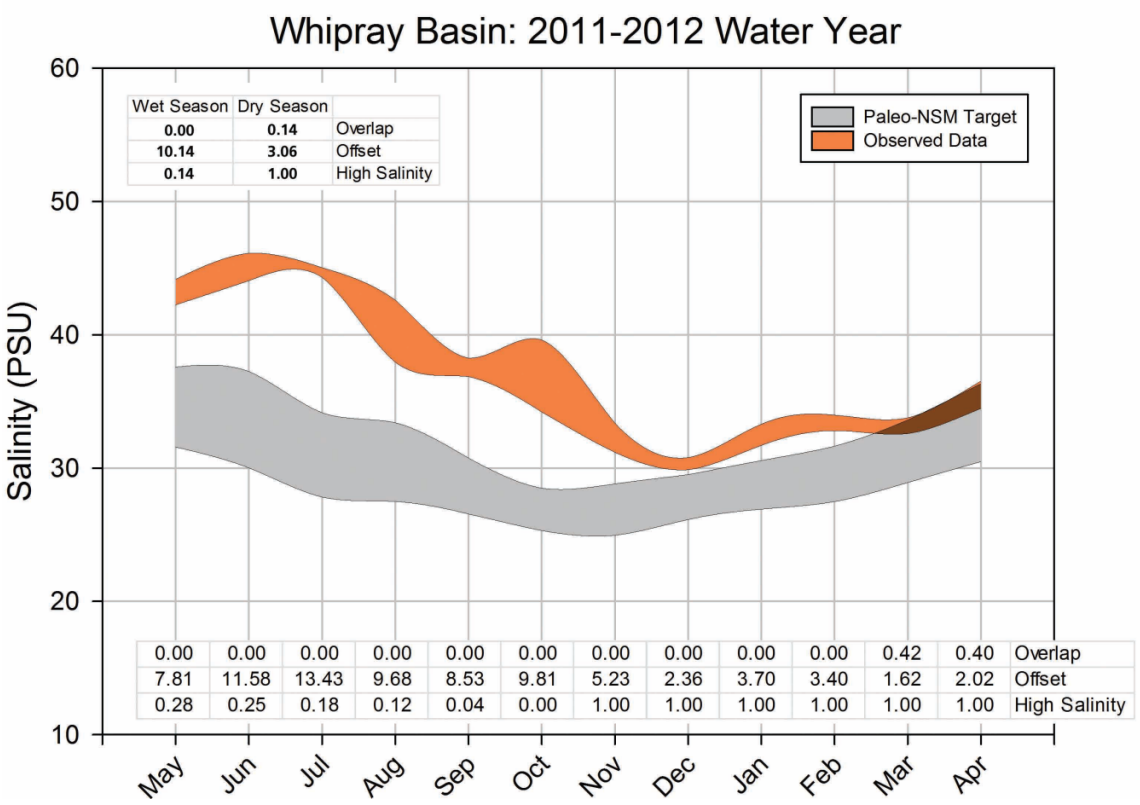


Figure 4.15. Overlap, mean offset, and high salinity performance metrics for Whipray Basin salinity presented as a plot with overlaid monthly and seasonal tables. The data describes the behavior of the observed salinity data relative to the paleo-NSM salinity target.

Table 4.5. Annual performance metric composite scores by ecological zone for 1991–2012. These scores are influenced by all three salinity metrics described above – mean, offset, and high salinity summary metrics. Lower values indicate worse conditions.

Water Year	Western	Southern	Central	Coastal	Eastern
2012	0.39	0.38	0.29	0.23	0.33
2011	0.38	0.47	0.42	0.36	0.46
2010	0.41	0.38	0.38	0.28	0.34
2009	0.39	0.31	0.28	0.19	0.23
2008	0.35	0.45	0.47	0.41	0.44
2007	0.56	0.41	0.44	0.29	0.30
2006	0.29	0.43	0.43	0.44	0.47
2005	0.20	0.21	0.22	0.34	0.18
2004	0.51	0.55	0.57	0.54	0.53
2003	0.37	0.49	0.48	0.52	0.55
2002	0.51	0.48	0.54	0.45	0.43
2001	0.34	0.34	0.27	0.45	0.50
2000	0.49	0.49	0.56	0.54	0.54

* Values estimated by linear interpolation between neighboring years (also in red).

Table 4.5 (continued). Annual performance metric composite scores by ecological zone for 1991–2012. These scores are influenced by all three salinity metrics described above – mean, offset, and high salinity summary metrics. Lower values indicate worse conditions.

Water Year	Western	Southern	Central	Coastal	Eastern
1999	0.29	0.45	0.52	0.59*	0.49
1998	0.59	0.61	0.60	0.64	0.61
1997	0.57	0.67	0.56	0.54	0.61
1996	0.64	0.60	0.60	0.73	0.67
1995	0.47	0.46	0.51	0.58	0.48
1994	0.51*	0.37	0.26	0.46*	0.43
1993	0.56	0.50	0.58	0.35	0.56
1992	0.24	0.25	0.25	0.25	0.34
1991	NULL	0.11	0.31	NULL	0.09
Average	0.43	0.44	0.44	0.44	0.45
Std. dev.	0.12	0.11	0.13	0.14	0.13

* Values estimated by linear interpolation between neighboring years (also in red).

For 2012, all three metrics rated low enough to be a cause for concern (Table 4.4). The overlap, mean offset, and high salinity metrics all reflect the same problem: salinity for Florida Bay is higher than the targets and there is no trend toward the targets at this time.

Differences in connectivity and mixing between basins result in differences in salinity conditions across the bay. Results indicated that conditions during the 2011–2012 water year were closer to the target along the western and southern zones of Florida Bay relative to the central, eastern, and coastal zones (Figure 4.15). This distribution was expected since the western and southern zones exchange water more freely with the Gulf of Mexico. In the coastal zone, where managed changes in freshwater delivery have their greatest effect, the average of the three performance metrics was 0.23, the lowest metric in the bay for the study year. The central and eastern zones scored slightly better at 0.29 and 0.33 respectively. The resultant metrics for 2012 showed lower values than the previous year but were within the year-to-year variability for the period of record for salinity observations.

Background and Importance

Salinity is a defining feature of the ecosystem in coastal estuarine regions, including Florida Bay. Since 1990, EVER and its federal and state partners have been involved in an extensive monitoring program with the overarching goal of understanding conditions affecting salinity within Florida Bay and in the coastal estuaries. Salinity within Florida Bay is primarily affected by four factors: evaporation, precipitation, freshwater inflows, and exchange with the coastal ocean. Evaporation is driven primarily by temperature, humidity, and wind. Precipitation over the period of record indicates higher quantities of rain in the coastal and eastern zones. Freshwater flows off the southern coastline of EVER and into the bay. This flow is driven by precipitation and water management activities, and is seasonally concentrated in the wet season. Freshwater flows represent the primary component of the water budget that is manageable. Long-term measurements of inflows show

relatively greater quantities of flows into the eastern zone of Florida Bay; flow into the coastal zone is limited by topography. In contrast, exchange with the open ocean is greatest in the western zone of the bay, with shallow banks increasingly limiting the transfer of water into the interior of Florida Bay. These large-scale processes produce salinity conditions that range from estuarine during the wet season to hypersaline during the dry season.

Measures of historical conditions indicate that Florida Bay was substantially fresher in the past than it is today, suggesting that substantially more freshwater entered the bay prior to the advent of water management activities in south Florida. The salinity performance metrics are determined for the period of 1991–2012 for each station in Florida Bay, and a summary of the annual statistics is provided in Table 4.5 (a comprehensive description of the performance measure and restoration goals is available online). The fresher conditions that prevailed prior to installation of the regional water management infrastructure supported a dynamic abundance of estuarine-dependent species and associated estuarine benthic conditions.

Desired State of Conservation

The assessment of salinity patterns in southern Florida is among the most developed assessment processes in the region. Several decades of development culminated in June 2012, when the South Florida Ecosystem Restoration Task Force agreed on a salinity performance measure to be used to track conditions and evaluate the effect of restoration activities on Florida Bay (CERP 2012). This performance measure was developed based on the output of a 36-year run of the South Florida Water Management District's Natural Systems Model (NSM) version 4.6.2 (SFWMD 2005). This model was designed to represent the depth and flow conditions of the pre-drainage Everglades. Output from this model was then adjusted to agree with paleographic information - derived from analysis of faunal assemblages in sediment cores collected in the bay - to produce a reasonable estimate of the historic salinity regime (Marshall et al. 2009, Marshall and Wingard 2012). The following restoration goals represent the desired state of conservation:

- Restore oligohaline (without salt) to mesohaline (less salty than open ocean) salinity patterns in the nearshore environment
- Lower the average salinity in the bay
- Reduce the frequency, duration, magnitude, and spatial extent of hypersaline conditions throughout the bay, and
- Restore seasonal deliveries of freshwater more typical of the natural system, e.g., extension of water deliveries into the dry season.

Description of Indicator Monitored

For this report, the desired state of conservation is evaluated by comparing observed salinity to the paleo-adjusted NSM targets using the methods described in the Restoration Coordination and Verification Program's (RECOVER) salinity performance measure for Florida Bay (CERP 2012). The indicator is evaluated by calculating metrics that quantify the 1) overlap, 2) mean offset, and 3) relative occurrence of high salinity events between observed and desired conditions. The overlap metric is defined as the number of days that the interquartile range of salinity observations overlaps

with the interquartile range of the salinity target. The mean offset metric is a measure of the difference between the means of the observed and target conditions on a monthly, seasonal, and annual basis. The high salinity metric is defined as the ratio of the number of high salinity days under desired conditions to the number of observed high salinity days. High salinity is defined as the 90th percentile of the target salinity.

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CERP. 2012. RECOVER: Southern Coastal Systems Performance Measure: Salinity in Florida Bay webpage. Available online at: http://www.evergladesplan.org/pm/recover/perf_se.aspx (Accessed 5/23/2013).

Marshall, F.E., G.L. Wingard, and P. Pitts. 2009. A simulation of historic hydrology and salinity in Everglades National Park: Coupling paleoecologic assemblage data with regression models. Estuaries and Coasts 32(1):37–53.

Marshall, F.E., and G.L. Wingard. 2012. Florida Bay salinity and Everglades wetlands hydrology circa 1900 CE: A compilation of paleoecology-based statistical modeling analysis. U.S. Geological Survey Open-File Report 2012–1054, 32 pp. Available online at: http://pubs.usgs.gov/of/2012/1054.

SFWMD. 2005. Documentation of the South Florida Water Management Model. South Florida Water Management District, West Palm Beach, Florida. Available online at: http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/sfwmm_final_121605.pdf (Accessed May 23, 2013).

4.3. Nutrients and Contaminants

When nutrients enter EVER at high concentrations, they are considered pollution (per the Clean Air and Water acts). Contaminants can be human-sourced substances (pesticides, herbicides, industrial wastes) or naturally occurring substances (like mercury).

4.3.1. Air Quality in Everglades National Park

Status and Trend

Attribute: Air quality

Overall Condition & Trend:



Rationale: Air quality in EVER warrants significant concern. Ozone sensitive plant species are reasonably likely to be injured each year, particulate deposition of nitrogen and sulfur are high, visibility is poor (relative to natural conditions), and there is a concern about atmospheric deposition of toxic materials (including mercury). Air quality in EVER is similar to conditions throughout the US east of the Mississippi River (Figure 4.16).

Highlights

- Visibility and wet deposition of sulfur and nitrogen are a significant concern
- Ozone is a moderate concern
- Atmospheric deposition of mercury and other contaminants are evaluated locally

Overall air quality in Everglades National Park (Photo 6) warrants significant concern and the trend is stable (Table 4.6). Trend analysis shows a possible (but not statistically significant) reduction in haze and wet deposition of sulfate in EVER since 2005 (NPS 2013). Ammonium sulfate and particulate organic matter account for almost 90% of the visibility impairing substances found in the air in Everglades National Park (Florida DEP 2010). The state's strategy for reducing ammonium sulfate is focused on retrofitting electricity generating utilities, as these utilities produced over 85% of SO_2 emissions in 2002 (Florida DEP 2010). Particulate organic matter is primarily derived from non-point source processes in urban/suburban areas and wildland fires (Florida DEP 2010).

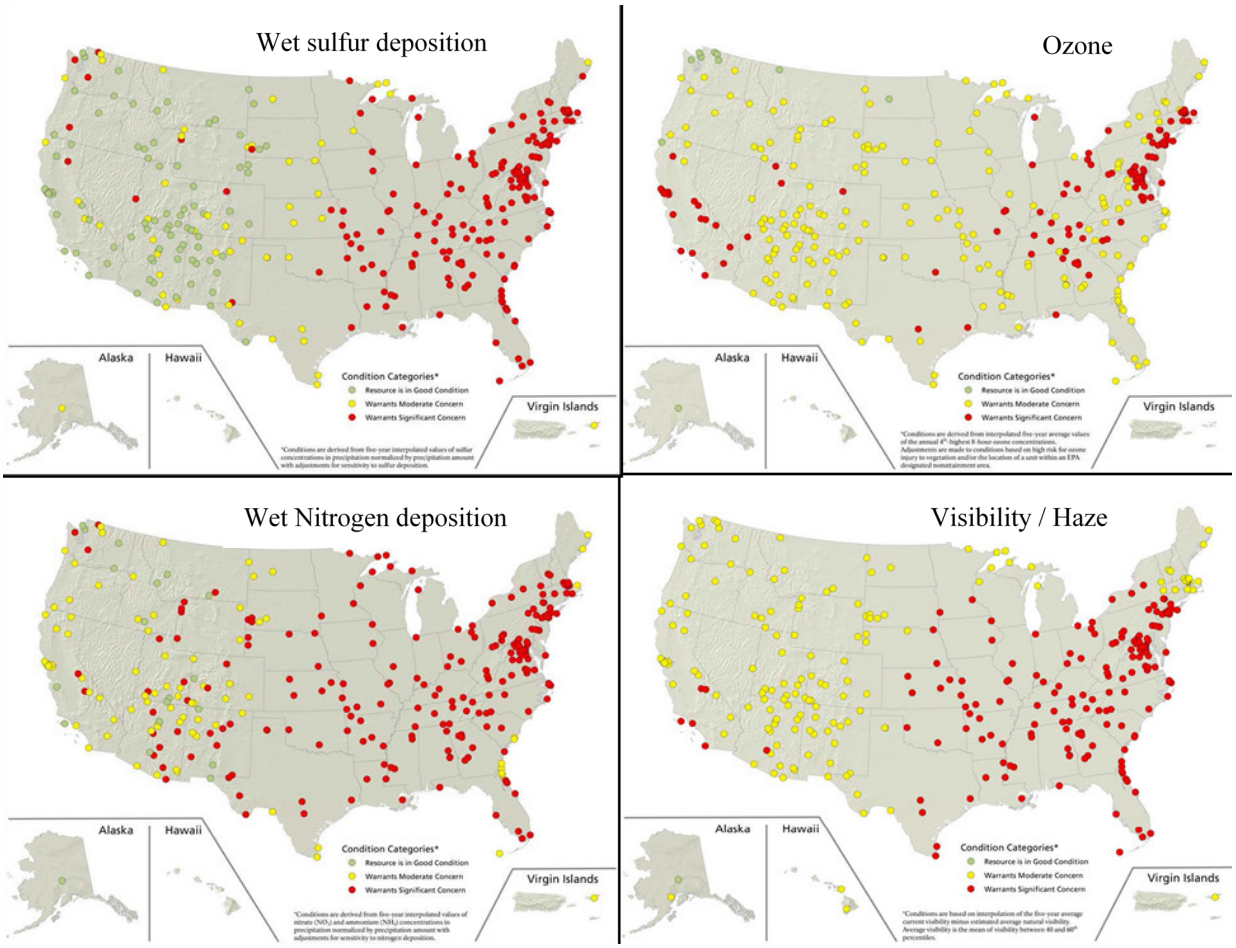


Figure 4.16. A nationwide assessment of air quality conditions in National Park Service lands throughout the 50 states and US territories.

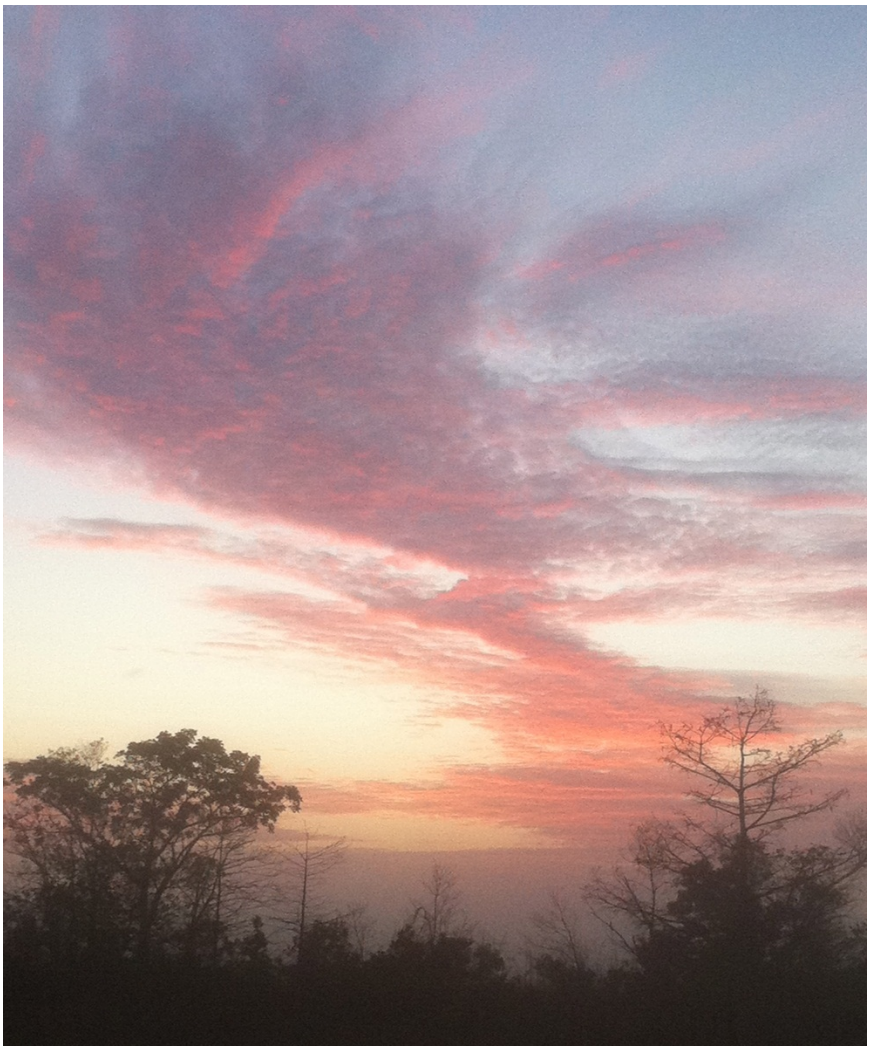
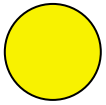


Photo 6. A windswept evening in Everglades National Park, 2012. Photo provided by Joaquin Alonso.

Table 4.6. Air Quality in Everglades National Park.

Indicators of Condition	Condition & Trend[a]	Rationale
Ozone		**Condition**: The estimated ozone level for 2005–2009 at Everglades NP was 67.5 parts per billion (ppb), therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. Ozone-sensitive plants in EVER include *Sambucus canadensis* (American elder) and *Spartina alterniflora* (smooth cordgrass). **Trend:** No trend information is available because there are not sufficient on-site or nearby ozone monitoring data. **Confidence**: The degree of confidence at Everglades NP is medium because estimates are based on interpolated data from more distant ozone monitors.
Sulfur Wet Deposition		**Condition**: For 2005–2009, estimated wet sulfur deposition was 3.2 kilograms per hectare per year (kg/ha/yr.), therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. Sulfur has an essential role in the methylation of mercury, leading to toxic accumulation of mercury in fish and wildlife. Although the main source of sulfur is runoff from northern Everglades agriculture, emissions from coal-burning power plants might contribute to this problem. **Trend:** For 2000–2009, the trend in total wet sulfur concentrations[b] in rain at Everglades NP remained relatively unchanged (no statistically significant trend). **Confidence**: The degree of confidence at Everglades NP is high because there is an on-site wet deposition monitor.

[a] Interpolations of air quality monitoring data averaged over a five-year period (2005–2009) are used to evaluate conditions. Trend analyses are completed using 10 years (2000–2009) of data from on-site or nearby monitors.

[b] Reporting units for wet deposition conditions and trends are different. Wet deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trends analyses. Wet deposition conditions are based on nitrogen and sulfur loading (kilograms per hectare per year) to ecosystems.

[c] Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment. The Clean Air Act established a goal of restoring visibility in all Class I areas to natural conditions. Estimated annual average natural condition equals 7.1 deciviews (dv) at Everglades NP.

[d] Visibility trend and condition calculations are expressed in terms of a Haze Index in deciviews (dv); however, the benchmark metrics are different. Condition assessments are based on interpolation of the five-year average current visibility minus estimated average natural visibility, where average visibility is the mean of visibility between 40th and 60th percentiles. 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 Clean Air Act.

Table 4.6 (continued). Air Quality in Everglades National Park.

Indicators of Condition	Condition & Trend[a]	Rationale
Nitrogen Wet Deposition		**Condition**: For 2005–2009, estimated wet nitrogen deposition was 3.1 kilograms per hectare per year (kg/ha/yr.), therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. The park may be highly sensitive to nitrogen-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011c; Sullivan et al. 2011d). Wetland plant species adapted to low nitrogen environments are particularly sensitive to the effects of nutrient nitrogen enrichment as species relationships are altered, sometimes increasing the establishment of non-native species at the expense of the rare species. **Trend:** For 2000–2009, the trend in total wet nitrogen concentrations[b] in rain at Everglades NP remained relatively unchanged (no statistically significant trend). **Confidence**: The degree of confidence at Everglades NP is high because there is an on-site wet deposition monitor.
Visibility		**Condition**: For 2005–2009, estimated average visibility in Everglades NP was 8.5 deciviews (dv) above natural conditions, [c] therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. **Trend[d]:** For 2000–2009, the trend in visibility remained relatively unchanged (no statistically significant trend) both on the 20% clearest days and 20% haziest days. The Clean Air Act visibility goal requires visibility improvement on the 20% haziest days, with no degradation on the 20% clearest days. **Confidence**: The degree of confidence at Everglades NP is high because there is an on-site or nearby visibility monitor.

[a] Interpolations of air quality monitoring data averaged over a five-year period (2005–2009) are used to evaluate conditions. Trend analyses are completed using 10 years (2000–2009) of data from on-site or nearby monitors.

[b] Reporting units for wet deposition conditions and trends are different. Wet deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trends analyses. Wet deposition conditions are based on nitrogen and sulfur loading (kilograms per hectare per year) to ecosystems.

[c] Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment. The Clean Air Act established a goal of restoring visibility in all Class I areas to natural conditions. Estimated annual average natural condition equals 7.1 deciviews (dv) at Everglades NP.

[d] Visibility trend and condition calculations are expressed in terms of a Haze Index in deciviews (dv); however, the benchmark metrics are different. Condition assessments are based on interpolation of the five-year average current visibility minus estimated average natural visibility, where average visibility is the mean of visibility between 40th and 60th percentiles. 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 Clean Air Act.

Background and Importance

Clean air is an essential natural resource. The National Park Service evaluates air quality conditions in NPS lands across the US. Four indicators are developed in order to capture the major types of air pollution, and to connect these pollutants to specific natural resource conditions. Ozone, Visibility (or Haze), and atmospheric deposition of nitrogen and sulfur in rainwater are the main indicators of air pollution that are systematically monitored across the United States.

Everglades National Park has the highest level of air quality protection present in U.S. law (a "Class 1" area – based on the Clean Air Act of 1977). During the period between 2000–2009 air quality improved or stayed the same throughout the vast majority of National Park Service lands. The causes of improvements in visibility are mostly associated with reduction in sulfur dioxide and nitrogen oxide emissions from electric utilities and industrial boilers that are required by a group of Clean Air Act programs (EPA 2010). Most visitors to Everglades National Park would identify the park as having better air quality than the surrounding urban and agricultural areas, but the Park still has significant air quality challenges when compared to a rigorous environmental standard.

Since passage of the Clean Air Act in 1977, air quality has improved markedly across the US. Even with the amount of improvement that has been realized, there are still many opportunities for further enhancement of air quality, and continued enforcement of the Clean Air Act should lead to additional improvements.

Importance**:** Poor air quality in EVER is typical of air quality conditions in the eastern half of the United States.

Description of Indicators Monitored

Air quality indicators are selected to help tell the story about what is happening in the atmosphere from the perspective of human and environmental health (Table 4.7). Visibility (summarized as a Haze index) is an important part of visitors' experience in the park, as it determines how far they can see into the River of Grass on a given day (Photo 7). Ground level ozone (or O_3) is indicative of industrial activity around the park, and is important for visitors with asthma, as high ozone levels can trigger asthma attacks. Ozone can also directly injure plants, and some species have been demonstrated to be more sensitive to ozone damage than others. The wet deposition of sulfur and nitrogen is indicative of regional/international industrial activity and can have effects on the food web and plant species assemblages through several causal pathways.

Table 4.7. Air Quality indicators for Everglades National Park are evaluated at a park-wide scale and condition assessments are based upon quantitative thresholds designed by the Air Resources Division of the National Park Service.

Measurement	Metric	Scale	Threshold
Ozone	Annual 4th-highest 8-hour concentration	Park-Wide	• Resource is in Good Condition: ≤ 60 ppb • Warrants Moderate Concern: 61–75 ppb • Warrants Significant Concern: ≥ 76 ppb

Table 4.7 (continued). Air Quality indicators for Everglades National Park are evaluated at a park-wide scale and condition assessments are based upon quantitative thresholds designed by the Air Resources Division of the National Park Service.

Measurement	Metric	Scale	Threshold
Sulfur Wet Deposition	Kilograms per hectare per year	Park-Wide	• Resource is in Good Condition: < 1 kg/ha/yr. • Warrants Moderate Concern: 1–3 kg/ha/yr. • Warrants Significant Concern: > 3 kg/ha/yr.
Nitrogen Wet Deposition	Kilograms per hectare per year	Park-Wide	• Resource is in Good Condition: < 1 kg/ha/yr. • Warrants Moderate Concern: 1–3 kg/ha/yr. • Warrants Significant Concern: > 3 kg/ha/yr.
Haze Index[§]	Deciviews above natural conditions	Park-Wide	• Resource is in Good Condition: < 2 dv above natural conditions[‡] • Warrants Moderate Concern: 2–8 dv above natural conditions[‡] • Warrants Significant Concern: > 8 dv above natural conditions[‡]



Photo 7. Clear blue skies over the coastal marshes of EVER. Photo provided by Joaquin Alonso – 2012.

Ozone forms on hot, sunny summer days, as a by-product of chemical reactions of nitrogen (usually NO_x forms of nitrogen) and volatile organic compounds (VOC's). These substances are usually emitted from industrial facilities, motorized vehicles, electric utilities, gasoline vapors, and chemical solvents. Ozone levels above 51 ppb can trigger asthma attacks in people who are sensitive to ozone levels, and repeated exposure can permanently damage the lining of the lungs (source: EPA). Ozone also damages plant leaves when it enters the plant during normal gas-exchange processes that occur during photosynthesis, and can inhibit normal plant growth process without evidence of damage. Everglades National Park has only four plant species known to be ozone sensitive, although most of the plants in EVER have not been tested for ozone sensitivity.

Wet sulfur and nitrogen deposition is linked to acid rain, fertilization effects, and to the formation of very toxic forms of mercury (methyl-mercury). The calcium dominated surface geology of EVER can neutralize acids in rain and generally reduces the region's vulnerability to the negative impacts of acid rain, but the large scale seasonally inundated wetland is vulnerable to mercury bioaccumulation. Although EVER receives high levels of sulfur deposition, ecosystems in the park are not typical of acidification-sensitive systems and were rated as having low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a, Sullivan et al. 2011b). The park may be highly sensitive to nitrogen-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011c, Sullivan et al. 2011d). Wetland plant species adapted to low nitrogen environments are particularly sensitive to the effects of nutrient nitrogen enrichment as species relationships are altered, sometimes increasing the likelihood that non-native species establish and displace rare native species. The shallow seagrass beds of the Gulf Coast and Western Florida Bay have more access to phosphorus from enriched Gulf waters, and are more likely to respond sensitively to nitrogen enrichment compared to freshwater wetlands or seagrasses in eastern Florida – where ambient phosphorus concentrations are very low.

Sulfur has an essential role in the methylation of mercury. Acid volatile sulfides are thought to be an important part of the process of mercury methylation (Gilmour et al. 1992). Although the main source of sulfur is runoff from northern Everglades agriculture, emissions from coal burning power plants might contribute to this problem. Mercury has been documented in many ecosystem components and different levels of the food chain at the park. Elevated concentrations in invertebrates, frogs, fish, wading birds, pythons, and alligators exceed environmental and human health thresholds (Guentzel et al. 1998, Rumbold et al. 2002, Rumbold 2005, Ugarte et al. 2005, Krabbenhoft 2010). Mercury contamination has been suspected in the death of some Florida panthers and attributed to high liver mercury levels (Roelke et al. 1991, Barron et al. 2004). Mercury in wading birds is at levels known to cause neurologic and reproductive impairment (Sundlof et al. 1994, Frederick and Jayasena 2010). Ongoing mercury research at the park continues to assess mercury cycling in the environment and accumulation in sediments, fish, and wildlife. There is a statewide mercury fish consumption advisory for freshwater, coastal, and other water bodies in Florida (EPA 2008).

Everglades National Park has air quality conditions that are typical of a natural area that has nearly eight million neighbors within a hundred miles of the boundary. Industrial activities, along with use

of petroleum products by individuals, contribute to haze, ozone formation, and the deposition of sulfur and nitrogen in rainwater. The level of these activities around the park produces moderate risks to human health on hot summer days, and poses a significant concern to plants and the food web.

It is essential to note that the NPS method for evaluation of air quality is based on the EPA Clean Air Act criteria (EPA 2007), but it differs from the EPA's method in a few important ways (Figure 4.17). The National Park Service evaluates air quality using three categories that are based on a relative comparison of current observations with natural (i.e., pre-human) conditions. The EPA uses this same comparison, but has five condition summary categories instead of three. The first three categories are similar between the EPA and NPS, but the EPA adds two more categories for evaluating very bad air quality conditions that occur in the most polluted conditions (like smog events in Los Angeles, the immediate vicinity of a wildland fire, or dust storms that can occur in deserts). It is important to note that Air Quality conditions in Everglades National Park are poor relative to the rigorous environmental standard, but are clearly not as bad as the conditions that are often experienced in urban areas, industrial corridors, or landscapes susceptible to severe wind erosion.

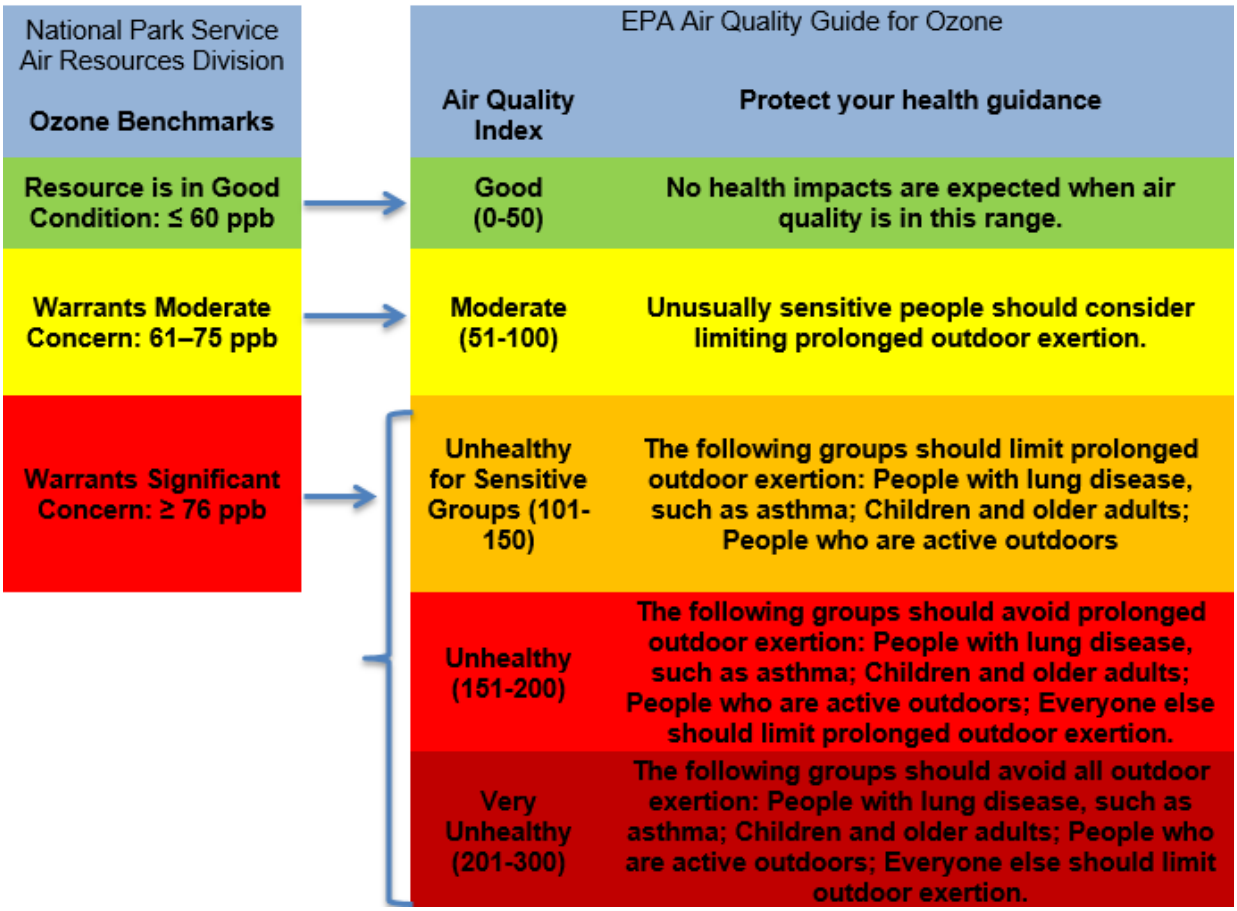


Figure 4.17. The relationship between National Park Service and EPA air quality standards for ozone shows that the significant concern category defined by the NPS is associated with three distinct concern categories defined by the EPA.

Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units, and provide air quality analysis and expertise related to all air quality topics. For current air quality data and information for this park, please visit the NPS Air Resources Division website at https://www.nps.gov/subjects/air/index.htm.

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4.3.2. Total Phosphorus in Freshwater Wetlands

Status and Trend

Attribute: Total phosphorus in Freshwater Wetlands

Overall Condition & Trend:



Rationale: Phosphorus concentration in waters flowing into EVER are between the long-tern limit and the phosphorus target.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

Inflow phosphorus concentrations to the park are monitored across the northern boundary with WCA 3 and along the eastern boundary where Taylor slough headwaters are sourced (Figure 4.18). Inflow waters are at an undesirable level, while interior marsh phosphorus concentrations have stabilized at concentrations below the targets (Table 4.8). Any future water management plans that further reduce water levels in the headwaters to the park have a potential to increase phosphorus concentrations in runoff to the park. However, the marsh along the eastern boundary of the park appears to have benefited from increased water stages (Surratt et al. 2012) resulting from the implementation of water detention basins designed to reduce seepage from the park (SFNRC 2005, Surratt et al. 2012). Based on the performance of these basins, implementation of projects that promote longer duration of marsh inundation and higher water depths, particularly along the eastern boundary of the park, has the potential to further reduce phosphorus concentrations in the marsh and ultimately long-term impacts to the ecosystem.

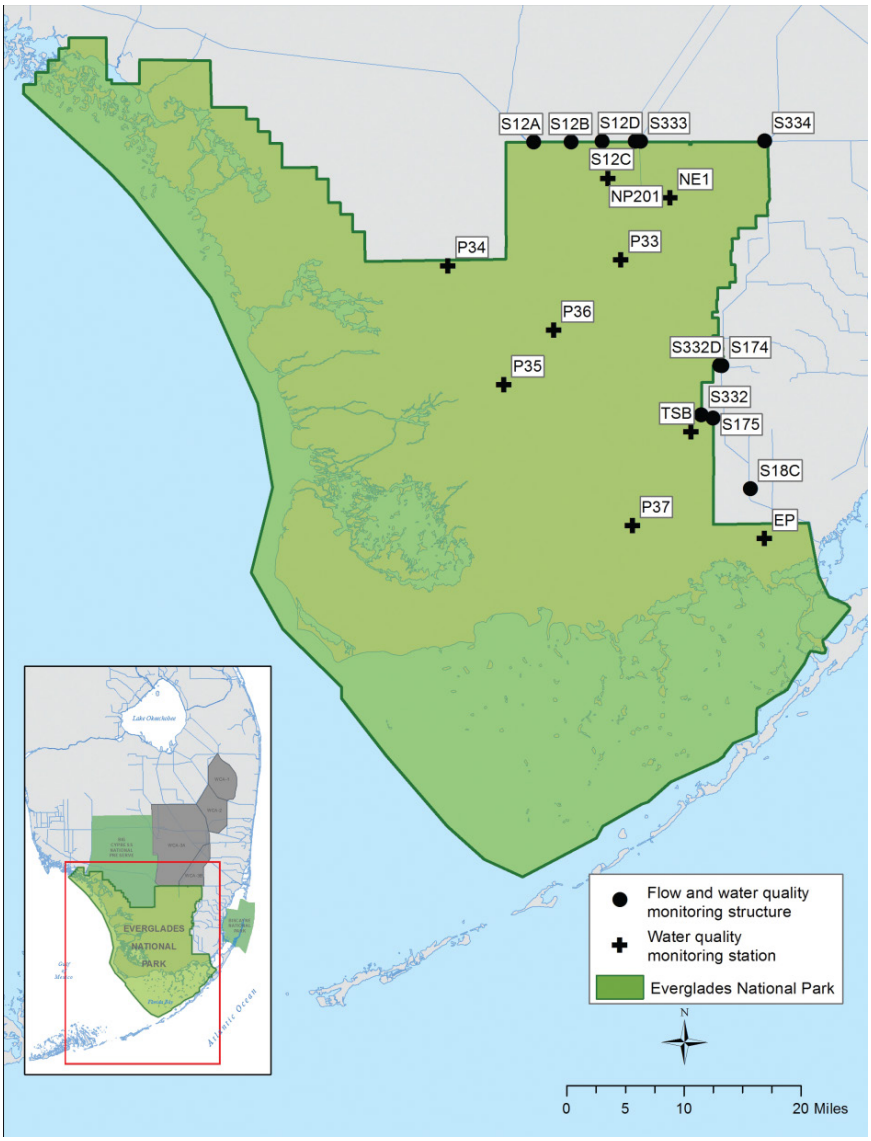


Figure 4.18. Location of surface water phosphorus concentration monitoring stations.

Table 4.8. Summary of current status and trends in phosphorus concentrations delivered to Shark River Slough as well as to Taylor Slough and Coastal Basins.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Shark River Slough inflow phosphorus concentration		Inflow phosphorus concentration is between the long-term limit and phosphorus target.	Inflow phosphorus concentrations to Shark River Slough below the target.
Shark River Slough interior marsh phosphorus concentration		Interior marsh phosphorus concentration is below the target.	Interior marsh phosphorus concentrations in Shark River Slough below the target.

Table 4.8 (continued). Summary of current status and trends in phosphorus concentrations delivered to Shark River Slough as well as to Taylor Slough and Coastal Basins.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Taylor Slough and Coastal Basins inflow phosphorus concentration		Inflow phosphorus concentration is between the long-term limit and phosphorus target this year, but concentrations have increased since October 1992.	Inflow phosphorus concentrations to Taylor Slough and Coastal Basins below the target.
Taylor Slough and Coastal Basins interior marsh phosphorus concentration		Interior marsh phosphorus concentration is below the target and concentrations have declined since October 1992.	Interior marsh phosphorus concentrations in Taylor Slough and Coastal Basins below the target.

Desired State of Conservation

The Consent Decree established limits and targets for total phosphorus concentrations in surface water delivered to the park and in the marsh. Inflow points have both an upper limit and a desired low phosphorus target. The limit on inflow flow-weighted mean phosphorus concentrations for Shark River Slough varies seasonally depending on flow conditions, while the limit for Taylor Slough and Coastal Basins (combined) is constant at 11 µg L-1. The Consent Decree also provided total phosphorus targets for these inflows that should result in flow-weighted mean phosphorus concentrations downstream of these inflows being at or below 8 µg L^{-1} for Shark River Slough and 6 µg L^{-1} for Taylor Slough and Coastal Basins. Overall, phosphorus concentrations in surface water alone indicate that the marsh in Shark River Slough, as well as Taylor Slough and Coastal Basins, is meeting expected targets. However, nutrient loading still is occurring and impacts are evident in marsh periphyton (see section 4.3.3 Nutrients in Freshwater Wetlands and Periphyton).

Description of Indicators Monitored

Compliance for the inflows is assessed as a 12-month rolling flow-weighted mean phosphorus concentration assessed on September 30 of each year. A 12-month rolling flow-weighted mean phosphorus concentration greater than the long-term limit is coded red in the stoplight table, between the limit and the target is coded yellow, and at or below the target is coded green (Table 4.8). Interior marsh stations have only targets. Phosphorus targets in the downstream, interior marsh are evaluated as the annual median phosphorus concentration assessed on September 30 each year. An annual median phosphorus concentration greater than the target is coded red, while a concentration at or below the target is coded green.

Total phosphorus concentrations in surface water were monitored at water quality stations identified in Figure 4.18. Data at the inflow structures were collected biweekly using autosamplers or by grab samples (manual collection using clean bottles), while marsh samples were collected as grab samples on a monthly basis. Samples were collected by South Florida Water Management District (District) staff and the resulting data are stored on the District's data web portal, DBHYDRO. Flow data were

collected by the U.S. Geological Survey or U.S. Army Corps of Engineers for each of the inflow structures and these data are reported on the District's web portal. The water quality and flow period of record for this analysis is from October 1986 through June 2012.

Status of the Indicator in the Current Year and Trends over Time

For most years since October 1992, inflow phosphorus concentrations for Shark River Slough (Figure 4.19), as well as Taylor Slough and Coastal Basins (Figure 4.20), were close to or lower than identified long-term limits, but generally higher than the targets. Lowest inflow phosphorus concentrations were observed from October 1995 through much of 1997 and these concentrations were below the targets for Shark River Slough, as well as Taylor Slough and Coastal Basins. Following this period, phosphorus concentrations returned to levels higher than the targets and generally coincided with the variable long-term limits at Shark River Slough, while inflow concentrations at Taylor Slough and the Coastal Basins mostly remained below the long-term limit.

Lower inflow phosphorus concentrations were coincident with relatively high annual rainfall (69 in) and high water stages in the headwaters during the period from October 1995 through September 1996. Daily rainfall and stage data were derived from 59 stations situated across the Everglades and represent regional conditions (South Florida Natural Resources Center DataForEVER dataset, accessed 2012). Annual rainfall in the Everglades during this period was 17 in greater than mean annual rainfall. Mean annual stage in the headwaters of Shark River Slough for the period from October 1995 through September 1996 was 0.5 to 1 foot higher than mean annual stage over the period of record. Marsh water, in general, tends to contain lower nutrient levels than canal water from agricultural and urban runoff. During this period, high rainfall coupled with high water stages in Shark River Slough headwater marshes likely contributed to the movement of water from the marsh into the canals, diluting nutrient concentrations delivered to the park.

Increases in phosphorus concentrations in inflows were consistent with lower annual regional rainfall and water management operations, particularly at the inflows to Shark River Slough. For example, phosphorus concentrations peaked through much of 2001 coincident with (1) drought conditions from 1998 through 2002 (Verdi et al. 2006), (2) lowering of water stages in the park headwaters beginning in 2000, and (3) management-imposed limitations on flow through the most western inflow structures (S–12A and S–12B) for a large portion of the year. Drought conditions tend to result in lowering of surface water depths, which prevents peat soil development and promotes the concentration of water constituents (i.e., nutrients, minerals, etc.) in water delivered to Shark River Slough and thus within the marsh. Water stage reduction in the headwaters to the park and limitations imposed on flows through S–12A and S–12B were operational decisions intended to reduce the frequency of flooding in Cape Sable Seaside Sparrow habitat located in the western Marl Prairie (SFNRC 2005).

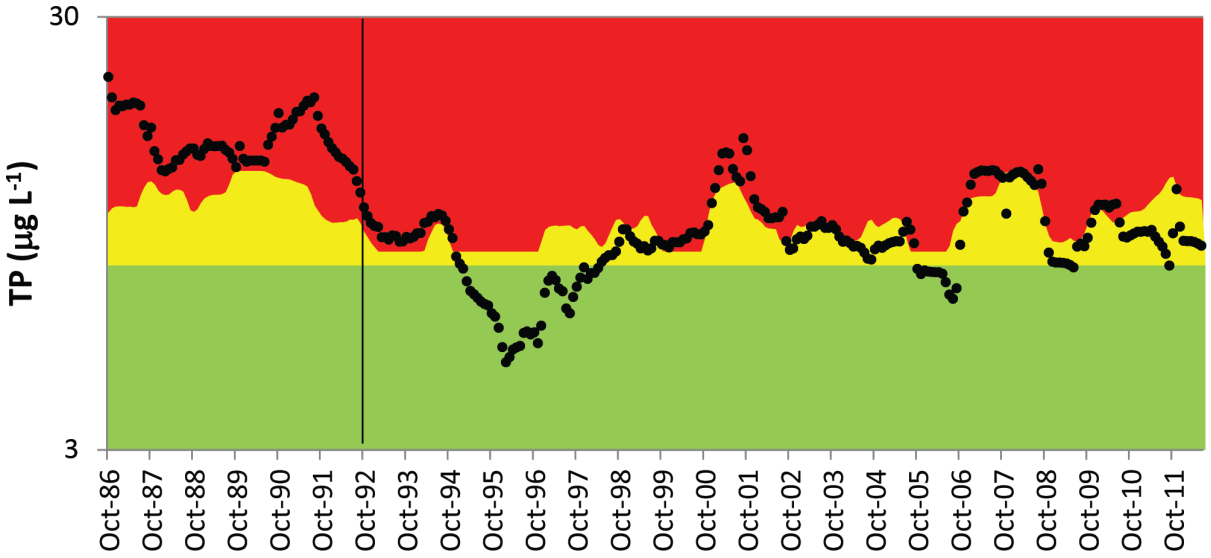


Figure 4.19. Inflow total phosphorus concentrations used to assess compliance with the long-term phosphorus limits and targets for Shark River Slough. Black dots represent 12-month flow-weighted mean phosphorus concentrations; green area represents phosphorus concentrations at or below the Consent Decree phosphorus target; yellow area represents phosphorus concentrations above the Consent Decree phosphorus target, but at or below the long-term limit; and the red area represents concentrations above the long-term limits for the park.

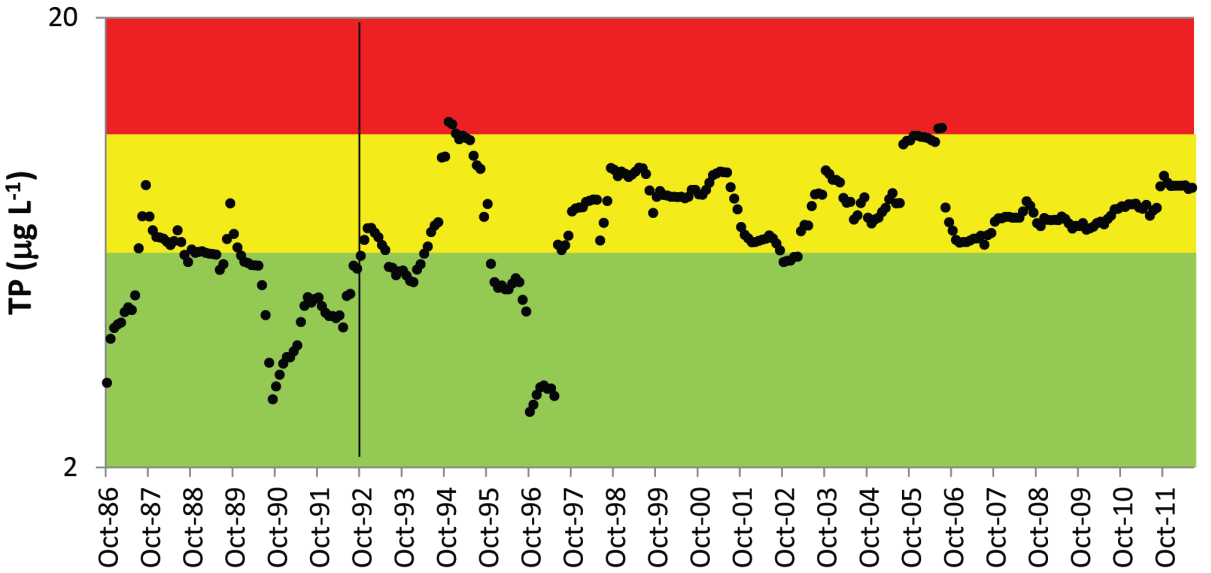


Figure 4.20. Inflow total phosphorus concentrations used to assess compliance with the long-term phosphorus limits and targets for Taylor Slough and Coastal Basins. Black dots represent 12-month flow-weighted mean phosphorus concentrations; green area represents phosphorus concentrations at or below the Consent Decree phosphorus target; yellow area represents phosphorus concentrations above the Consent Decree phosphorus target, but at or below the long-term limit; and the red area represents concentrations above the long-term limits for the park.

The stage reduction in Shark River Slough headwaters increases the concentration of surface water constituents, particularly when those stages recede below 9.5 ft. This concentration reduces the potential of marsh water to dilute nutrient concentrations in canal water prior to delivery to Shark River Slough. Limiting flows through S–12A and S–12B, where phosphorus concentrations are low because of nutrient-poor marsh water from the headwaters, forces more water to be delivered to Shark River Slough through S–12D and S–333. Of the structures delivering water to Shark River Slough, S–12D and S–333 receive the greatest influence from canal water (due to the direct connection to the L-67 A and C canals), and these structures had the highest phosphorus concentrations and account for the greatest fraction of water delivered to Shark River Slough. Further, because the flows to Shark River Slough rely heavily on S–12D and S–333, the overall phosphorus concentration (compliance concentration) delivered to Shark River Slough does not receive the full benefit of the lower concentrations at S–12A and S–12B.

Phosphorus concentrations at some inflow structures to Shark River Slough exhibited a decreasing trend since October 1986 and have been stable since October 1992 (Table 4.9). However, since October 1986 and October 1992, phosphorus concentrations exhibited upward trends at the inflows to Taylor Slough and Coastal Basins (Table 4.9). After the initiation of on-farm best management practices in 1993, phosphorus concentrations have remained below the high levels observed during the late 1980's at the inflows to Shark River Slough. Alternatively, at the inflows to Taylor Slough and Coastal Basins, phosphorus concentrations have generally remained above concentrations observed from October 1986 through October 1994 and concentrations appear to increase when drought conditions are prevalent and decline in years of high rainfall. Following the low inflow phosphorus concentration period from October 1995 through much of 1997 for Shark River Slough, as well as Taylor Slough and Coastal Basins, phosphorus concentrations increased at several of the individual inflow structures (Figures 4.19 and 4.20). The period of low phosphorus concentration was associated with high rainfall levels and high headwater stages. This period was followed by drought conditions and operational reductions in water stage that likely promoted concentrating of surface water constituents, ultimately increasing phosphorus concentrations. The lack of downward trends in phosphorus concentrations delivered to the park following the initiation of constructed treatment wetlands suggest that benefits from upstream phosphorus reductions may take longer to cascade down to the park, and that untreated sources of phosphorus may have an increasing influence relative to treated sources.

Currently, headwater phosphorus concentrations continue to be too high for park flora and fauna. Inflow concentrations hovering around or just below the long-term limits, but still above the target, indicate that these inflows still threaten park ecology and that additional phosphorus reduction measures need to be implemented, particularly for park water sources presently not treated.

Table 4.9. Long-term phosphorus trends for the inflows to the park and in the marsh interior. Trend values in bold represent significant trends.

Area	1986–2012		1992–2012	
	Trend	p-value	Trend	p-value
Inflow: Shark River Slough	**-1.098***	0.000	0.429	0.195
Interior: Shark River Slough	-0.008	0.268	-0.005	0.419
Inflow: Taylor Slough and Coastal Basins	**0.617***	0.002	**0.915***	0.009
Interior: Taylor Slough and Coastal Basins	**-0.037***	0.000	**-0.012***	0.000

*Trend values in bold represent significant trends

Median annual interior marsh phosphorus concentrations within Shark River Slough, as well as Taylor Slough and Coastal Basins, remained below the target since October 1992 (Figures 4.21 and 4.22), and the Taylor Slough and Coastal Basins interior marsh exhibited downward trends in phosphorus concentrations since October 1986 and October 1992 (Table 4.9). Since October 1992, there have been minor phosphorus concentration spikes in Shark River Slough during droughts, but even these spikes did not increase above the targets. Taylor Slough and Coastal Basins did not show this pattern except during the extreme drought of 2006 through 2007.

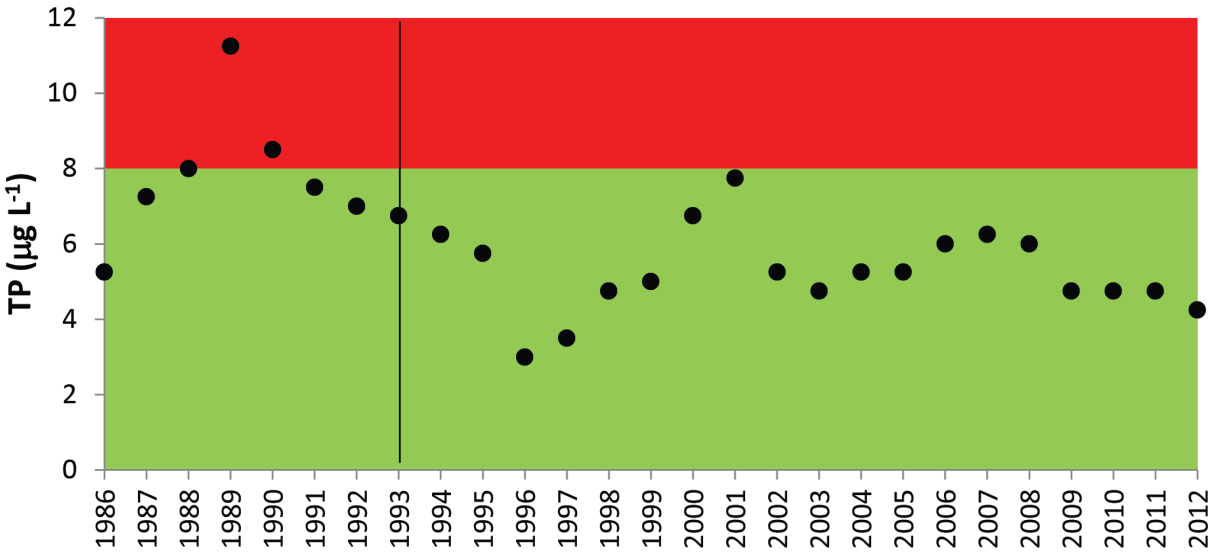


Figure 4.21. Interior marsh total phosphorus concentrations used to assess targets for Shark River Slough. Black dots represent the combined annual median phosphorus concentrations in the marsh; green area represents the Consent Decree phosphorus target; and the red area represents concentrations above acceptable levels for park ecology.

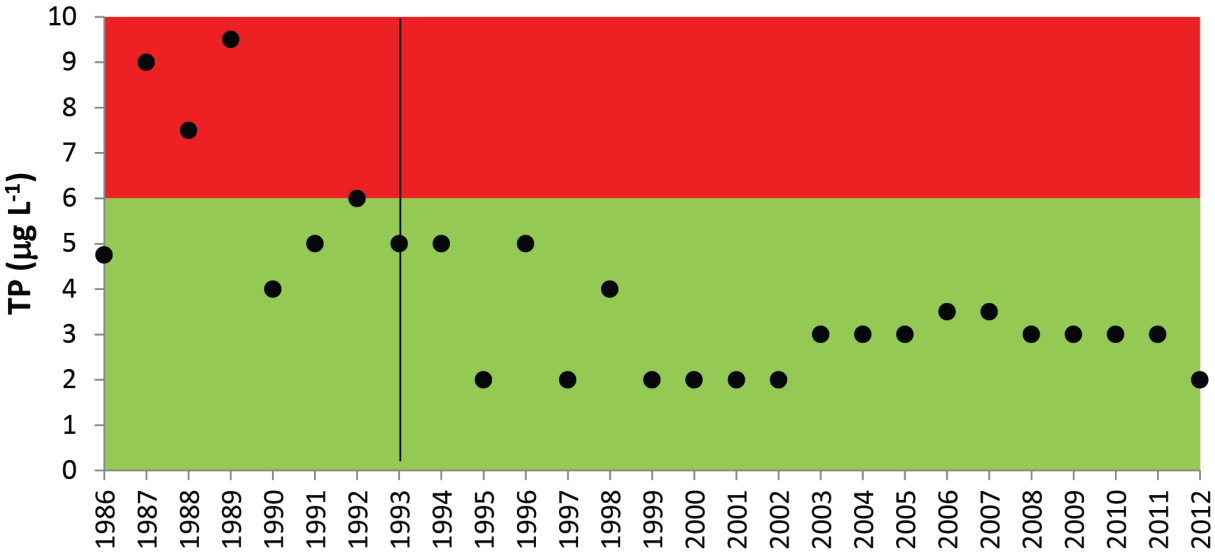


Figure 4.22. Interior marsh total phosphorus concentrations used to assess targets for Taylor Slough and Coastal Basins. Black dots represent the combined annual median phosphorus concentrations in the marsh; green area represents the Consent Decree phosphorus target; and the red area represents concentrations above acceptable levels for park ecology.

References

SFNRC. 2005. An assessment of the Interim Operational Plan. South Florida Natural Resources Center, Everglades National Park, Homestead, Florida. Project Evaluation Report. SFNRC Technical Series 2005:2, 47 pp.

Surratt, D., D. Shinde, and N. Aumen. 2012. Recent cattail expansion and possible relationships to water management: changes in upper Taylor Slough (Everglades National Park, Florida, USA). Environmental Management 49:720–733.

Verdi, R.J., S.A. Tomlinson, and R.L. Marella. 2006. The drought of 1998–2002: impacts on Florida's hydrology and landscape. U.S. Geological Survey Circular 1295, 35 pp. Available online at: http://pubs.usgs.gov/circ/2006/1295/ (Accessed 12/7/2012).

4.3.3. Nutrients in Freshwater Wetlands and Periphyton

Status and Trend

Attribute: Nutrients in Freshwater Wetlands and Periphyton

Overall Condition & Trend:



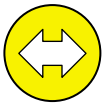
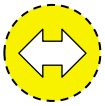
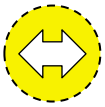
Rationale: Periphyton communities in Shark River Slough indicate slightly elevated nutrient concentrations at 25–50% of sampling stations, while periphyton communities in Taylor Slough and Coastal basins were similar to the desired reference conditions.

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Highlights

The prospect for periphyton in the next 2-years warrants concern. Shark River Slough, Taylor Slough, and Coastal Basins are at significant risk of increased nutrient enrichment due to upstream inflows, and pending water management operations. Shark River Slough receives water from a series of flow structures located at the northern boundary of the park, and these inflow structures have a phosphorus concentration between the long-term limit and the phosphorus target (colored yellow). Any future water management plans that further reduce water levels in the headwaters to Shark River Slough have a potential to increase phosphorus concentrations in runoff to Shark River Slough. Alternatively, the Taylor Slough area receives water from inflow structures located on the eastern park boundary and these inflows contain more phosphorus than desired concentrations (status colored yellow, Table 4.10). The marsh along the eastern boundary of the park appears to have benefited from increased water stages (Surratt et al. 2012) resulting from the implementation of water detention basins designed to reduce seepage from the park (SFNRC 2005, Surratt et al. 2012). Based on the performance of these basins, implementation of projects that promote longer duration of marsh inundation and higher water depths has the potential to further reduce phosphorus concentrations in the marsh. These factors are particularly important along the eastern boundary of the park. Ultimately, longer duration of marsh inundation and higher water depths are essential for avoiding long-term impacts to the ecosystem.

Table 4.10. Periphyton conditions assessment for Shark River Slough as well as Taylor Slough and Coastal Basins.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Shark River Slough periphyton tissue phosphorus content		More than 25% of monitored stations in Shark River Slough were colored yellow or red for periphyton tissue phosphorus content, exceeding the desired state.	25% or less of Shark River Slough stations are colored yellow or red.
Shark River Slough periphyton biomass		More than 25% of monitored stations in Shark River Slough were colored yellow or red for periphyton biomass phosphorus concentration, exceeding the desired state.	25% or less of Shark River Slough stations are colored yellow or red.
Shark River Slough periphyton composition		The condition was not assessed in 2012, but in 2011 more than 25% of monitored stations in Shark River Slough were colored yellow or red for periphyton composition and this pattern is expected to continue for the next few years, exceeding the desired state.	25% or less of Shark River Slough stations are colored yellow or red.
Taylor Slough and Coastal Basins periphyton tissue phosphorus content		25% or less of monitored stations in Taylor Slough were colored yellow or red for periphyton tissue phosphorus content, but the area is on the cusp of yellow and reductions in hydroperiods, water depth, or increased nutrient loading may lead to declines in the indicator.	25% or less of Taylor Slough stations are colored yellow or red.
Taylor Slough and Coastal Basins periphyton biomass		25% or less of monitored stations in Taylor Slough were colored yellow or red for periphyton biomass phosphorus concentration.	25% or less of Taylor Slough stations are colored yellow or red.
Taylor Slough and Coastal Basins periphyton composition		The condition was not assessed this year, but last year more than 25% of monitored stations in Taylor Slough were colored yellow or red for periphyton composition and this condition is expected to continue over the next few years, exceeding desired state.	25% or less of Taylor Slough stations are colored yellow or red.

Background and Importance

Water managers for Everglades National Park have identified periphyton biomass, tissue total phosphorus (phosphorus) content, and community composition as early indicators of nutrient enrichment. Periphyton is an important feature of the Everglades ecosystem and contributes a large portion of net primary productivity. Phosphorus in this oligotrophic ecosystem is quickly assimilated by periphyton and cycled through plants and ultimately stored in developing peat/muck soils. Periphyton responds to changes in environmental conditions at both small and large spatial scales in

a matter of days to a few weeks. Therefore, periphyton has the potential to be an early ecological indicator of impacts from management activities. In the Everglades ecosystem, even small increases in surface water phosphorus concentrations can decrease periphyton biomass and shift the periphyton community structure, ultimately impacting higher trophic levels (Gaiser 2009).

Desired State of Conservation

The desired state of conservation for the periphyton indicator is the restoration of periphyton biomass, tissue phosphorus content, and composition to conditions that support stable communities of aquatic fauna. Stoplight coloring methods for periphyton biomass, tissue phosphorus content, and periphyton community composition in Shark River Slough and the Taylor Slough areas are from Gaiser (2009) and are based on mean and one standard error of the mean for unimpacted marsh areas (areas with soil phosphorus concentrations lower than 500 mg per kg). If a monitoring station has a periphyton biomass, tissue phosphorus content, or composition within one standard error of the mean, the station is colored green; between one and two standard errors of the mean, the station is colored yellow; and if the station is greater than two standard errors, the station is colored red (Gaiser 2009). When fewer than 25% of the stations in an area (i.e., Shark River Slough, Taylor Slough, and Coastal Basins) are colored yellow or red, the area is colored green, but if more than 25% are colored yellow or red, then the area is colored yellow. When more than 50% of the stations in an area are colored red, the area is colored red. Areas colored green are in acceptable condition, areas colored yellow are experiencing low-level nutrient enrichment, and areas colored red are nutrient-enriched and considered degraded.

Description of Indicator Monitored

Periphyton biomass, tissue phosphorus content, and composition were monitored throughout the park at the suite of stations identified in Figure 4.23. Data were collected annually by Florida International University as part of a cooperative agreement with the park. Data are maintained by the university and delivered to the park annually. The periphyton period of record spans from 2006 through 2012.

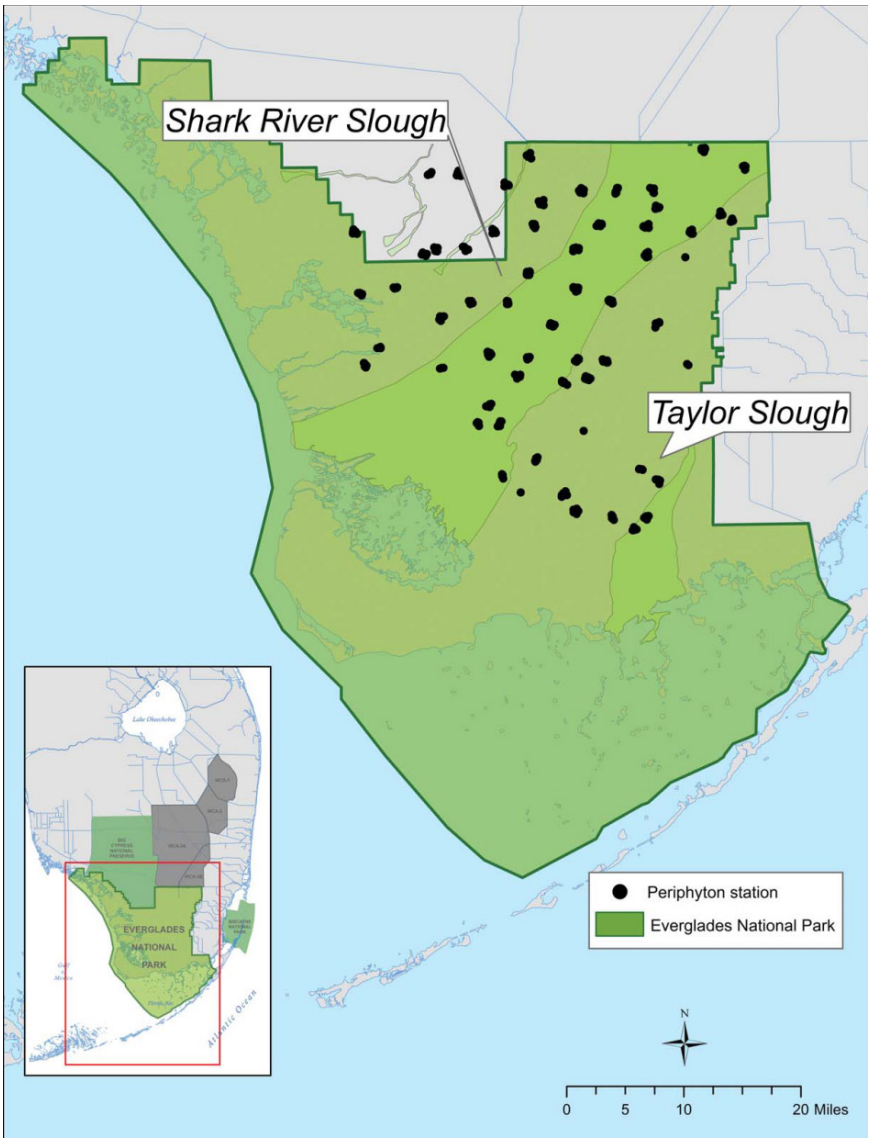


Figure 4.23. Location of periphyton sampling stations in Everglades National Park.

Status of the Indicator in the Current Year and Trends over Time

In the freshwater marshes of EVER, periphyton biomass (Photo 8), tissue phosphorus content, and composition suggest the park is experiencing low-level nutrient enrichment. Since 2006, periphyton biomass status in Shark River Slough has been categorized as receiving low-level nutrient enrichment and is colored as yellow (Table 4.10). This pattern also was observed in periphyton tissue phosphorus content, except in 2010 when Shark River Slough shifted from a category of low-level enrichment to an acceptable condition (i.e., from yellow to green). Periphyton composition was in acceptable condition (colored green) during 2007 and 2010, but the remaining years since 2006 indicated a low level of enrichment, colored yellow (no data were collected in 2012). Overall, the current status of Shark River Slough is one of low-level enrichment, colored yellow (Table 4.10). Periphyton biomass, tissue phosphorus content, and composition are projected to remain at a low

level of enrichment over the next 2 years as increased flows are forecast for Shark River Slough with no expected reductions in phosphorus concentrations over this period (Table 4.11).



Photo 8. Periphyton is found throughout the low nutrient freshwater marshes of EVER. NPS photo.

Table 4.11.Current (2012) status and patterns (2006 through 2012) in periphyton tissue phosphorus content, biomass, and composition. Blank symbols with dotted outlines indicate no samples were collected.

Location	Performance measure	2006	2007	2008	2009	2010	2011	2012	2-yr	Current status	2-yr prospect
Shark River Slough	Tissue phosphorus content									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading periphyton.	Increased flows under lower headwater stages may further degrade periphyton.
	Biomass									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading periphyton.	Increased flows under lower headwater stages may further degrade periphyton.
	Composition									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading periphyton.	Increased flows under lower headwater stages may further degrade periphyton.
Taylor Slough and Coastal Basins	Tissue phosphorus content									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading composition.	Periphyton may be degraded if hydroperiods or water depths decline.
	Biomass									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading composition.	Periphyton may be degraded if hydroperiods or water depths decline.
	Composition									Inflow phosphorus is resulting in low-level nutrient enrichment and degrading composition.	Periphyton may be degraded if hydroperiods or water depths decline.

Since 2006, Taylor Slough and Coastal Basins periphyton has generally been in acceptable condition (Table 4.10) with respect to phosphorus enrichment. The biomass indicator suggests the Taylor Slough area was experiencing low-level enrichment (colored yellow) in 2008, while the remaining years all indicated acceptable conditions (colored green). Tissue phosphorus content in Taylor Slough was categorized as experiencing low-level enrichment (colored yellow) in 2007, but the area was in acceptable condition (colored green) until 2012, when the condition reversed to indicate low-level enrichment again (colored yellow). Periphyton composition was acceptable for the area from 2007 through 2009, but declined back to low-level enrichment (colored yellow) thereafter (no data were collected in 2012). The periphyton biomass indicator is projected to remain acceptable (colored green) over the next 2 years, but if nutrient enrichment increases, or hydroperiod or water depth decreases along the eastern park boundary, the periphyton tissue phosphorus content and composition may increase and the area could decline to a status of low-level enrichment (colored yellow).

References

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Surratt, D., D. Shinde, and N. Aumen. 2012. Recent cattail expansion and possible relationships to water management: Changes in upper Taylor Slough (Everglades National Park, Florida, USA). Environmental Management 49:720–733.

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4.3.4. Nutrients and Florida Bay Algal Blooms

Florida Bay has a history of having highly variable water quality conditions, with algal bloom episodes that can last from weeks to even years. Blooms sustained for more than several months can be damaging to seagrass habitat and fauna (especially sponges). The last period of extended blooms was between 2005 and 2007. Conditions subsequently improved. In order to better understand causes of bloom variability and responses to Everglades Restoration, the park has deployed and tested new automated sensors that provide prolonged high-frequency measurements ("continuous monitoring"). Field methodologies and data analysis are still being refined, but initial results from continuous monitoring indicate the presence of much higher bloom concentrations (indicated by the algal pigment, chlorophyll *a,* in the water column as parts per billion, ppb) than has been detected recently by grab sampling and analysis. We are still investigating these findings and need to develop an understanding of "baseline" concentrations with this new methodology. Given the early stage of this methodological development, current data should be treated cautiously, but suggest elevated levels of chlorophyll *a* in the north-central coastal zone (Table 4.12).

Table 4.12. Algal blooms in Florida Bay: Chlorophyll concentration.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Central Florida Bay (Whipray Basin) chlorophyll *a* concentration		Levels have been below threshold levels throughout 2012. Continuous monitoring methods are still being refined, and elevated levels (up to 23 ppb) have been recorded in previous years.	Average monthly concentrations below 1 ppb.
Northern Florida Bay (Garfield Bight and Terrapin Bay) chlorophyll *a* concentration		Elevated levels were recorded in 2012 at both northern sites, including period of extremely high levels (12 to 21 ppb) for five months Terrapin Bay. Continuous monitoring methods are still being refined, but initial results indicate poor and declining conditions.	Average monthly concentrations below 1 ppb.
Western Florida Bay (Buoy Key) chlorophyll *a* concentration		Levels have been below threshold levels throughout 2012. Continuous monitoring methods are still being refined, and elevated levels (up to 25 ppb) have been recorded in previous years.	Average monthly concentrations below 1 ppb.
Southern Florida Bay (Peterson Key) chlorophyll *a* concentration		Levels have been below threshold levels throughout 2012. Continuous monitoring methods are still being refined.	Average monthly concentrations below 0.5 ppb.

4.3.5. Mercury and other contaminants

Status and Trend

Attribute: Mercury and other contaminants

Overall Condition & Trend:



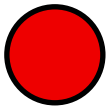
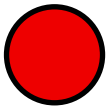
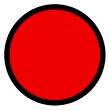
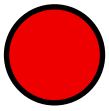
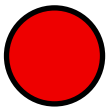
Rationale: Mercury deposition is high and is a significant concern for EVER. Most organisms sampled are above both wildlife and human consumption toxicity thresholds.

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Highlights

Mercury concentrations in fish tissue are the most consistently monitored aspect of the "mercury cycle" in EVER. Estimated fish tissue concentrations the two stations in Shark River Slough (L67F1 and NP) have substantially exceeded the EPA protection limits during the 18-year period that fish have been consistently monitored (Table 4.13, Figures 4.24 and 4.25). Similarly, elevated tissue concentrations have been observed in sunfish as well (Figure 4.26). As a result, mercury concentrations are assessed as of ***"Significant Concern"*** for both humans and wildlife because a high risk of exposure exists for any organism consuming fish in EVER. The long-term trend (Kendall's Tau) indicates that that contamination of the food web by mercury continues and that conditions are not improving. Short-term trends appear to be simply small oscillations of the data driven by long-term climate cycles rather than a response to sustained changes in atmospheric mercury inputs. In the 2012 water year, conditions slightly worsened for largemouth bass (LMB); and slightly improved for sunfish (SF). The 2-year prospectus suggests: (a) no change for largemouth bass (LMB) and possible a slight improvement for sunfish (FS).

Table 4.13. Fish mercury conditions indicator in Shark River Slough.

Group	POR	Last 5 Years	2012	2012 Status	2-Year Prospectus
Human Consumption (L67F1[a]—LMB[b])				Significant Concern. CI is five times over the EPA recommended limit	Conditions may slightly deteriorate
Fish-eating Wildlife (L67F1—SF[c])				Significant Concern. CI is nearly five times over the EPA recommended limit	Conditions may slightly improve
Human Consumption (NP[d]—LMB)				Significant Concern. CI is nearly four times over the EPA recommended limit	Conditions may slightly deteriorate

[a] L67F1: L67 Extension Canal Station;

[b] LMB: Largemouth Bass;

[c] SF: Sunfish (bluegill, redear, spotted, warmouth);

[d] NP: North Prong Station

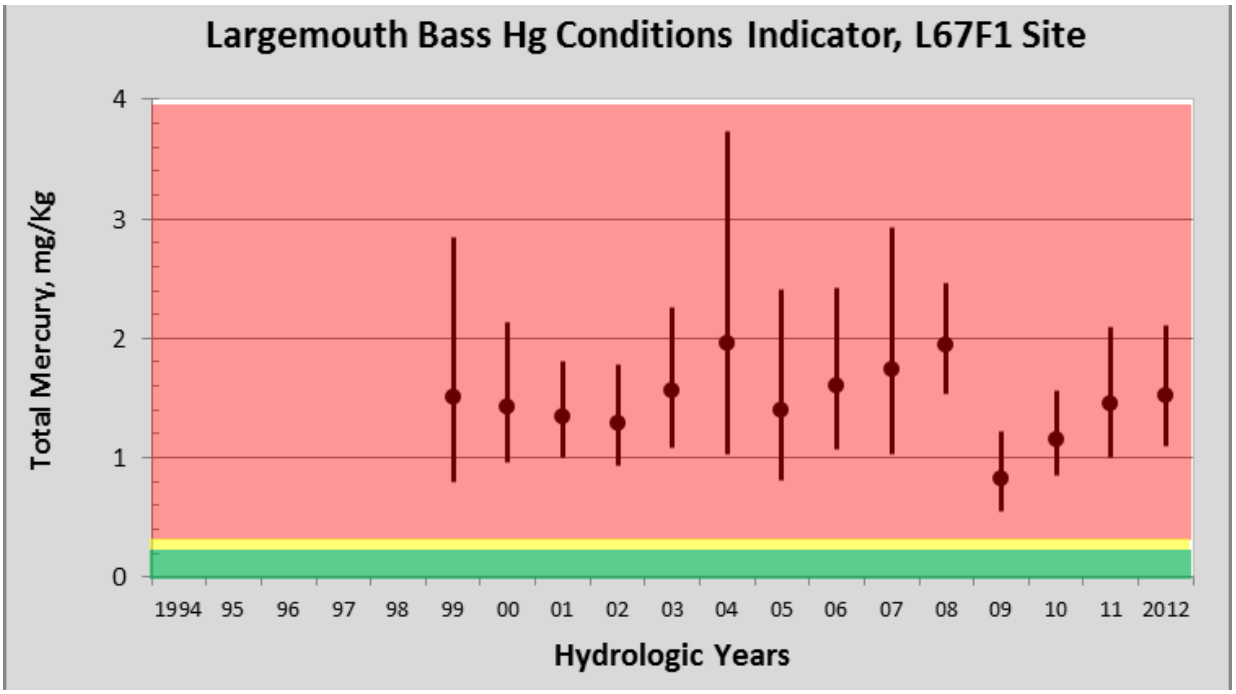


Figure 4.24. Yearly conditions indicator for largemouth bass at L67F1 station. The vertical bars are the 95th prediction intervals. Mercury concentrations were adjusted to a 14-in length. The assessment zones are: Concern (red), Caution (yellow), and Good (green).

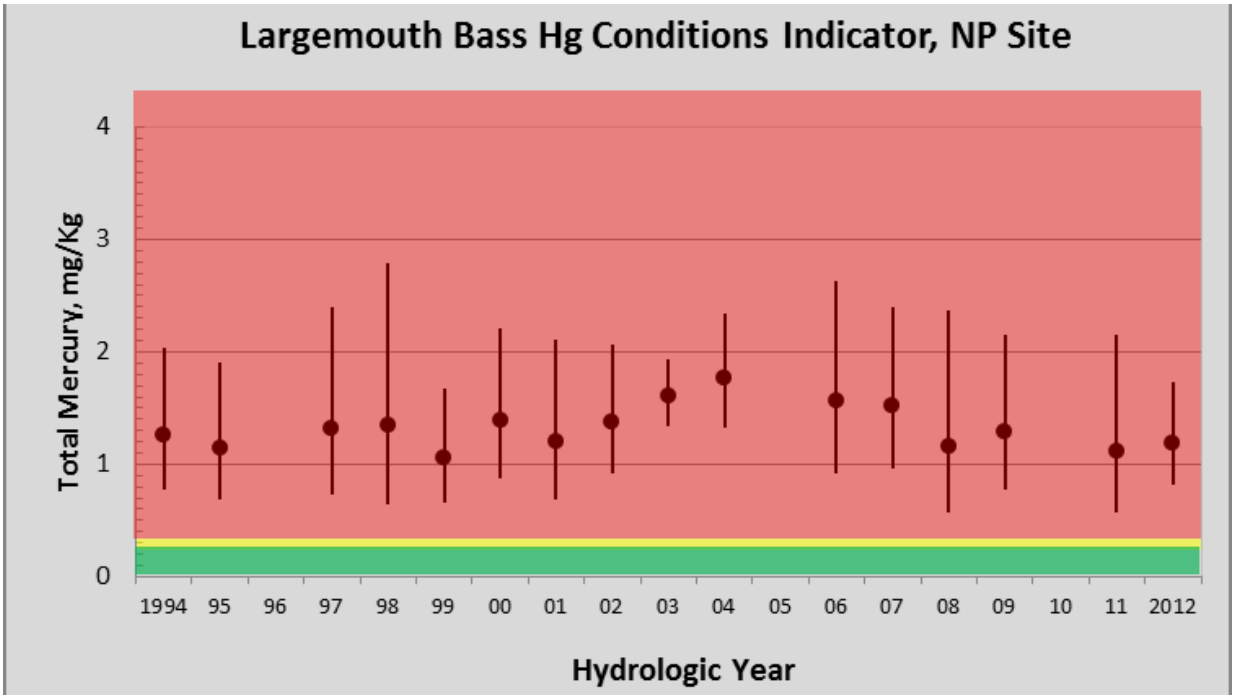


Figure 4.25. Yearly conditions indicator for largemouth bass at North Prong (NP) station. The vertical bars are the 95th prediction intervals. Mercury concentrations were adjusted to a 14-in length. The assessment zones are: Concern (red), Caution (yellow), and Good (green).

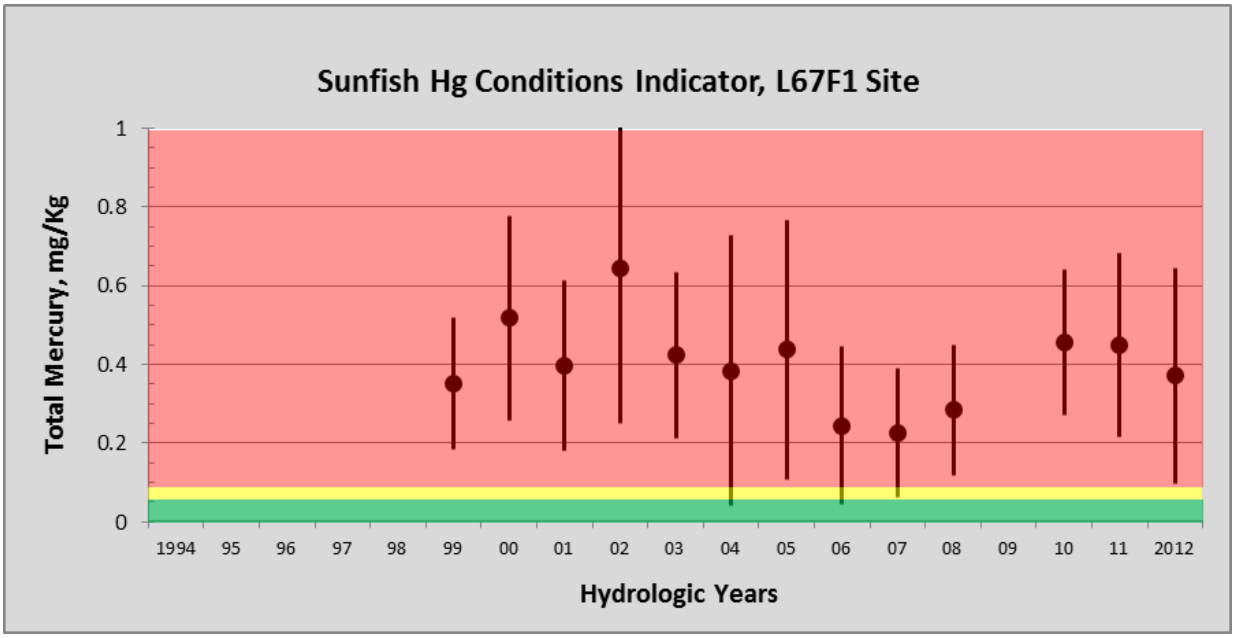


Figure 4.26. Yearly conditions indicator for sunfish at L67F1 station. The vertical bars are the mean ± one standard deviation. The assessment zones are: Concern (red), Caution (yellow), and Good (green).

It is noteworthy that, FDEP initiated (under Section 303(d) of the Clean Water Act) a process to establish mercury Total Maximum Daily Loads (TMDL) for atmospheric emission in 2012. TMDL's

are intended to address the mercury impartment in Florida waters. It will be interesting to detect whether tissue concentrations of mercury decline in the coming years.

Background and Importance

The Everglades currently is the subject of an ambitious restoration effort (CERP 2000) to preserve and protect the vast mosaic of ecosystems that provide essential habitat for multiple species, some of which are endangered and threatened. The Everglades restoration, however, faces many political, economic, and scientific challenges. One such challenge is to reverse the severe contamination of the wildlife food web with mercury (Hg), a problem that may be exacerbated by urban and agricultural development and by some of the restoration projects (in the short term; Photo 9). Across Florida, 20 species of freshwater fish and more than 60 species of marine fish were under some level of human consumption advisory by the Florida Department of Health in 2011. In south Florida, including in Everglades National Park, nine species of game fish in more than 2 million acres of wetlands were under restricted and no-consumption advisories (Scheidt and Kalla 2007).



Photo 9. Fish mercury warning at Everglades National Park.

Mercury is a toxic element that naturally occurs in the environment but also is an introduced contaminant from man-made pollution. The current source assessment figures estimate that coal-burning power plants and medical waste incinerators are the source of about 70% of the total atmospheric mercury input. Data from soil cores indicate that anthropogenic mercury contamination of the Everglades started in the 1890's, gradually increased throughout the 1920's, had a strong surge in the mid-1950's, peaked in the early 1990's, and significantly declined by the late 1990's. Annual atmospheric mercury emissions in south Florida decreased by 65% from 1991–1993 Florida (Atkenson et al. 2005) and statewide (local sources) by 20% from 2005–2009, mostly because of material controls and emission controls (FDEP 2012). However, Florida - in particular south Florida - receives one of the nation's highest atmospheric mercury deposition rates (14.5 - 22.9 $\mu g/m^2$)

from both local and global sources. The average annual atmospheric mercury deposition rate is 19.6 $\mu g/m^2$ in EVER, and this rate has not changed in the last 16 years (Hydrologic Year 1997–2012, start on May 1 and end on April 30, the number indicates the ending year), with 87% of the total deposition occurring in May through October, mostly in the wet season.

Atmospheric deposition includes three principal forms of Hg: Hg^0 (elemental), Hg^{2+} (inorganic), and MeHg (methylmercury). Whereas Hg^0 is mildly toxic, MeHg is a potent neurotoxic and mutagenic agent. After deposition in the marsh by rainfall and windfall, Hg changes its form as it moves from the water column to bottom sediment or back to the atmosphere again. Mercury enters the food web through a complex metabolic process. In the Everglades, sulfate-reducing bacteria convert inorganic Hg to MeHg as a byproduct during the oxidation of organic matter in the process of obtaining food and energy. Methylation of Hg in the park's freshwater marsh occurs within a narrow sulfate concentration range (2 - 15 mg/L). Too little sulfate or too much sulfide hinders the methylation process. Most of the sulfate in surface waters comes from agrochemicals used in the Everglades Agricultural Area, south of Lake Okeechobee.

Exposure to MeHg in the environment from the consumption of MeHg-contaminated fish and shellfish threatens both humans and wildlife alike. At high levels of exposure, human effects include mental retardation, cerebral palsy-like symptoms, deafness, blindness, and dysarthria; at low levels of exposure, effects include impaired neurobehavioral and motor skills, and loss of attention, memory, and visual-spatial coordination. The risk is higher in women of childbearing age and young children than in adults exposed to the same level of MeHg. Wildlife exposed to MeHg may suffer harmful effects ranging from death to reduced reproduction success, slower growth and development, and abnormal behavior.

Methylmercury contamination of park biota is evident at all levels of the food web, from the smallest invertebrates—such as snails, spiders, and insects—to top predators—such as wading birds, alligators, and panthers. Mercury concentrations measured in park biota from published literature are shown in Figure 4.27—most of the Hg in wildlife and fish is in MeHg form. At the bottom of the food web (left side of Figure 4.27) are aquatic plants and invertebrates (prey) with concentrations ranging from less than 0.01- to -0.30 mg/kg or ppm (parts per million). At the other end of the food web (right side of Figure 4.27) are the top predators—sharks, alligators, pythons, and the Florida panther—with concentrations ranging from less than 0.30- to -more than 10.0 mg/kg. Trophic level 1 through 5 (TL1 through TL5 in figure) are freshwater fish trophic levels, as described by Loftus (2000). In general, trophic levels increase with fish size. In TL1 are the very small fish, such as sheepshead minnow and sailfin molly and in TL5 are warmouth and largemouth bass. The Hg concentration in all fish trophic levels, arthropods, insects, and spiders are above the Environmental Protection Agency (EPA) guidance level for the protection of wildlife (dashed line in Figure 4.27). Presumably, predators feeding on these prey items may increase their Hg to levels above the EPA guidance values. Generally, MeHg concentration increases from plants to invertebrates to fish to birds and to top predators because of biomagnification. Methylmercury biomagnifies in the food web because predators feed on MeHg-contaminated small-size prey (bioaccumulation) and animal's intake MeHg-contaminated water and sediment (bioconcentration), and because MeHg ingestion

rates are faster than excretion or metabolization rates. MeHg concentrations may vary greatly depending on size and age of organisms as well as on type of specimen. For example, MeHg concentrations decrease from liver to muscle, brain, gonad, and red blood cells. In birds, MeHg levels are higher in feathers than in eggs. Figure 4.27 is provided as a reference and careful interpretation of the data is recommended. Often in the Everglades ecosystem and more often in the park, MeHg in the wildlife and fish exceed guidance levels provided by EPA for the protection of human health (0.3 mg/kg) and fish-eating wildlife (0.077 mg/kg).

What is known about mercury in the food web of EVER

There is clearly cause for concern about mercury throughout the food web in EVER. The vast majority of organisms measured since 1989 have tissue concentrations that are above the risk threshold for human consumption, and most are above the less stringent threshold for consumption by wildlife (Figure 4.27). The subsequent discussion catalogues what we know about mercury contamination levels and consequences for the major organism groups in EVER.

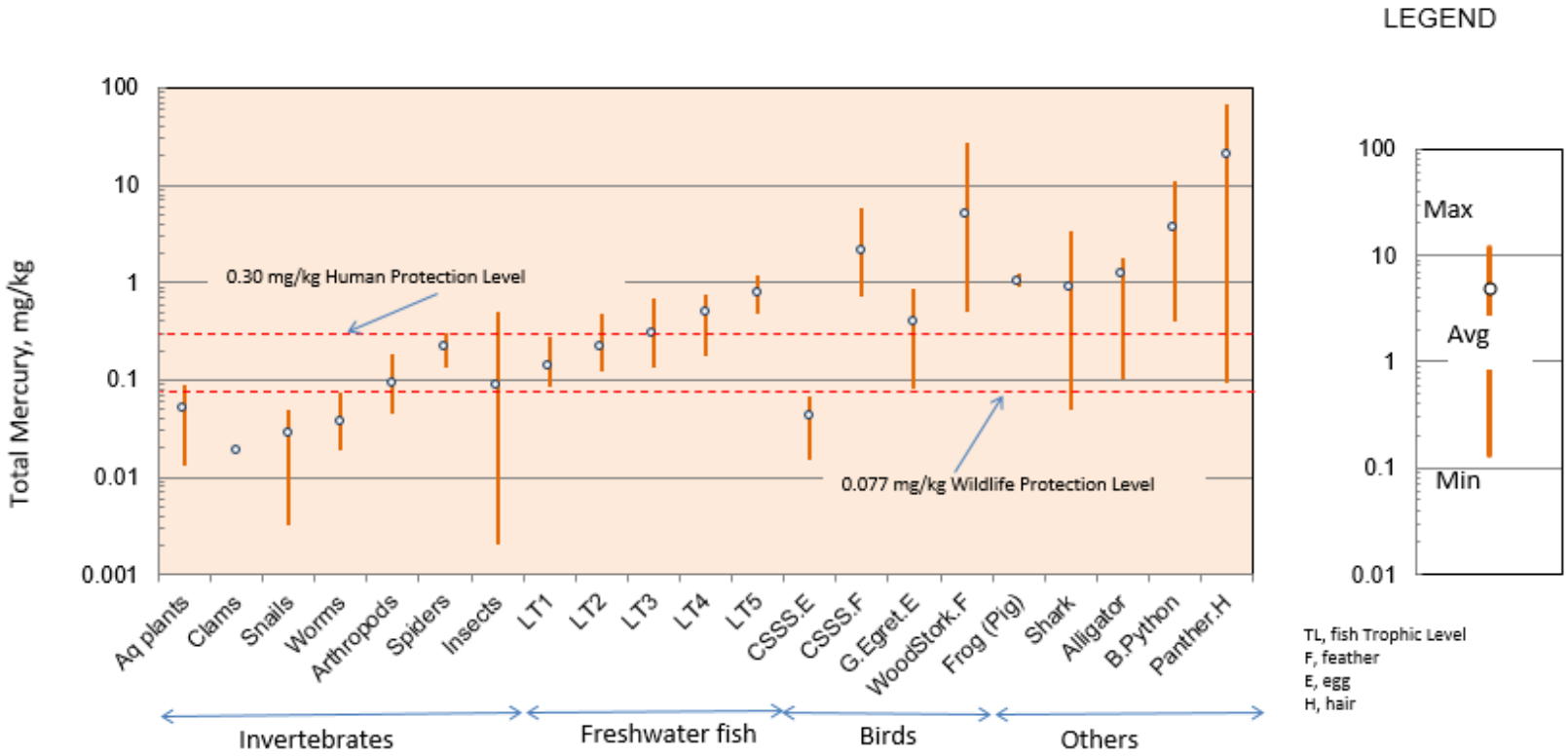


Figure 4.27. Mercury concentrations in Everglades National Park biota relative to EPA's protection levels.

Wading Bird

Large colonies of long-legged wading birds such as storks, spoonbills, egrets, herons, and ibises historically were a defining characteristic of the Florida Everglades (Photo 10). These colonial birds played an important role in the redistribution of nutrients and in the dynamics of fish and invertebrate populations by predation. Alterations of the natural system in the Everglades have resulted in extensive wading bird habitat loss and a drastic decline in breeding populations. Mercury (or Hg – the symbol for mercury used on the periodic table of elements) contamination of the Everglades was suspected to have played a role in the wading bird decline (Herring et al. 2009). Frederick and Jayasena (2010) reported increases in white ibis male-male pairing behavior and an associated decrease in the number of fledglings during a 3-year experimental exposure to relevant dietary MeHg levels. These MeHg effect levels (0.05 and 0.3 mg/kg) are frequently exceeded in ibis prey fish present in the park. Rumbold et al. (2008) estimated the probability that a bald eagle, wood stork, and great egret foraging in a MeHg-contaminated area in the park would experience exposure above the lowest observed adverse-effect level ranging from 14% for wood storks to 56% for bald eagles.



Photo 10. Roseate spoonbills, ibis, and woodstorks in a shallow pond in EVER.

Largemouth Bass, Mosquitofish, and Sunfish

In the park, mercury was detected in fish and other wildlife as early as the mid-1970's, but it wasn't until the late 1980's when systematic mercury sampling throughout Florida was implemented that very high mercury levels in largemouth bass (LMB) were detected. By the early 1990's, Loftus and Bass (1992) reported mercury concentrations exceeding 1.0 mg/kg in fish in the park. Mercury in fish is a chronic problem throughout the Everglades, including in the park, and has extended beyond freshwater systems into Florida Bay and the Gulf of Mexico. While reductions in mercury concentration in LMB have been observed in some areas of the Everglades, in Shark River Slough the mercury levels have not changed in the past 20 years, and these levels continue to substantially exceed EPA wildlife and human health guidance levels. During the fall of 2011, mercury

concentrations in mosquitofish were higher in Shark River Slough (0.073 mg/kg) than in WCA-1 (0.058 mg/kg), WCA-2 (0.052 mg/kg), Holey Land (0.050 mg/kg), and Rotenberger (0.045 mg/kg) and similar to those in WCA-3 (0.075 mg/kg). In addition, 10 out of the 12 sites in in Shark River Slough where sunfish were monitored for mercury concentrations exhibited mercury tissue concentrations above the EPA wildlife guidance level (SFWMD 2012).

American Alligator

Alligator (Photo 11) populations suffered great losses in the mid-1900's and reached record low levels by the 1960's. Hunting, habitat loss, and alterations of the ecosystem contributed to this drastic reduction in alligator numbers. By the late 1980's, population recovery was evident and licensed harvesting of wild alligators resumed in 1988, but hunting was soon closed again and it remained closed in the Everglades through 1990 because of high mercury levels. Rumbold et al. (2002) reported mercury concentrations in liver (10.4 mg/kg) and tail muscle tissue (1.2 mg/kg) from park samples that were two times higher than concentrations in samples collected from the rest of the Everglades. These mercury levels were significantly higher than the EPA human health guidance level for fish consumption (0.30 mg/kg).



Photo 11. American Alligator.

Florida Panther

The Florida panther (Photo 12), a state and federally listed endangered species, has suffered severe declines in population numbers because of environmental stressors, low genetic variability, and habitat loss. Mercury contamination continues to be a suspected contributing factor in the poor reproductive success of the species. Newman et al. (2004) reported that mercury concentrations were significantly higher in samples from the 1990's than in samples from the late 1800's. Roelke et al. (1991) reported that mercury levels in blood (0.794 mg/L) and hair (56.4 mg/kg) samples collected from panthers in Shark River Slough were significantly higher than mercury levels in samples collected from panthers in areas north of the park (blood 0.09 mg/L, hair 1.66 mg/kg). Brandon et al.

(2009) reported mercury concentrations in both the Everglades and the park, and found that the highest mercury values were associated with a panther that was eventually found dead in the park in 2004. Brandon et al. (2009) also reported that a spatial mercury gradient, first noted by Roelke et al. (1991), was still evident and that the park continued to have the highest mean concentrations in hair and blood of all four regions studied. The high mercury levels measured in panthers in the park have been attributed to a preferential diet consisting predominantly of fish-eating wildlife, such as raccoons and alligators, rather than of herbivores, such as deer.



Photo 12. Florida panther.

Burmese Python

Native to Southeast Asia but not to south Florida, Burmese pythons (Photo 13) were introduced into the park from captive animals. The Burmese python feeds on a variety of native wildlife including fish-eating species, such as raccoons, wading birds, and alligators. As most other carnivorous species in the park, pythons bioaccumulate mercury in their tissue and organs, mostly in the form of MeHg (80%). Mercury data collected from 136 Burmese pythons in the park from 2006- to -2009 averaged 4.3 mg/kg or ppm and ranged from 0.003- to -36.9 mg/kg or ppm (Krabbenhoft et al. 2012).



Photo 13. Burmese python.

Cape Sable Seaside Sparrow (CSSS)

The CSSS (Photo 14), a federally listed endangered species, has suffered severe declines in population numbers after 1992. Pimm et al. (2002) attributed the decline in population to high water flows and increased frequency of marsh fires. During a CSSS spring survey in 2008, eggs and feather samples were opportunistically collected from several populations in the park. Mercury concentration in eggs ranged from 0.015 - 0.067 mg/kg (reported as 0.106 - 0.468 mg/kg dry weight) and in feathers from 0.708 - 5.831 mg/kg (Krabbenhoft et al. 2010). These values are similar to those in eggs and feathers from other passerines and lower than in passerines foraging in known contaminated sites. The CSSS mercury values in the park were less than the lowest observed adverse effect level in swallow eggs (0.800 mg/kg); however, sublethal effects have been estimated to occur at lower levels (0.40 and 0.10 mg/kg; Lane and Evers 2007). Wada et al. (2009) noted that in tree swallow nestlings, mercury concentrations, although below typical thresholds for abnormal behavior or altered physiology, were high enough to disrupt endocrine systems. Effects of mercury contamination in passerines, like the CSSS, may include altered behavior of individuals to cope with stressful events; underdevelopment of the brain, which may result in abnormal behavior, impaired learning abilities, memory loss, and consequently, shorter lives.



Photo 14. Cape Sable Seaside Sparrow, Modified from Oberhofer, 2005.

Condition Indicator Metrics - Description

Contamination of the Everglades aquatic food web by mercury from anthropogenic sources is a threat to wildlife and humans that are exposed to methyl-mercury (MeHg)-contaminated fish and shellfish. On-going restoration projects may potentially exacerbate methylation of mercury in the marsh by altering hydroperiods, supporting water deliveries by canal rather than by sheetflow, increasing frequency and duration of dry-down events, and by discharging water of poor quality with elevated concentrations of sulfate, dissolved organic matter, and nutrients into the marsh.

The State of Florida, through the Fish and Wildlife Conservation Commission (FWCC), South Florida Water Management District (SFWMD), and Florida Department of Environmental Protection (FDEP), has been monitoring and reporting on body burdens of mercury in fish species, especially game fish, throughout the Everglades, including the park, since 1989. In response to these data, which show widespread mercury contamination in game fish, the Florida Department of Health has issued human health advisories, banning or restricting consumption of LMB and other game fish.

These data were used to develop mercury conditions indicators (CIs) because the mercury data are reliable and accurate, are recorded over multiple years, cover a wide area, and include several fish species. Mercury tissue data for largemouth bass (LMB), a top predator fish, are a suitable surrogate for mercury exposure in humans that consume MeHg-contaminated seafood. Largemouth bass is a popular game-fish species that is widespread and easily recognized by the public. Mercury tissue data for sunfish, a medium trophic-level fish, are an appropriate surrogate for MeHg exposure in top predator species, such as wading birds, alligators, and the Florida panther. The mercury condition indicators are well-developed, designed indicator metrics that have many important characteristics (Doren et al. 2009). The condition indicator for largemouth bass is relevant to the ecosystem, has wide-scale applicability, is sensitive to anthropogenic inputs, is easy to estimate and understand, and is scientifically defensible. Furthermore, the CI has clear, measurable targets.

Largemouth Bass (LMB) condition indicator (CI)

Methylmercury bioaccumulation in fish tissue is influenced by ambient factors and fish eating habits. For LMB and other top predatory fish, most (>95%) of the total mercury present in tissue samples is in the MeHg form. Thus, total mercury is a reasonable approximation for MeHg and was used to estimate the LMB CI. The LMB CI was estimated as a yearly mercury concentration adjusted to a 14-in fish. Standardization of observed values to an annual estimate that is adjusted to a single fish size facilitates comparisons across years where the number of sampled fish can be quite different. A yearly average concentration was estimated to account for natural variability in mercury input and methylation rates. Yearly mercury CIs were estimated at two stations in Shark River Slough: L67F1 and NP (locations shown in Figure 4.28). The upstream station, L67F1, is a freshwater station, located in the L67 Extension Canal near major surface water inflows to the park from WCA-3A, and the downstream station, NP, is a tidal station, located in North Prong Creek, between the saw-grass marsh in Shark River Slough and mangrove forests of Shark River. The mercury data for the L67F1 station were obtained from the SFWMD (DBHYDRO) and the mercury data for the NP station were obtained from the FWC (Ted Lange, written communication, 2012).



Figure 4.28. Location of mercury monitoring sites (L67F1 and North Prong-NP) in Shark River Slough.

The LMB CI are estimated as follows: (a) data were grouped by station (L67F1 and NP) and by hydrologic year (1994–2012 HY); (b) for each hydrologic year, a linear regression was built between fish length and the natural logarithm (ln) of mercury concentration; (c) outliers were removed from the regression to obtain an R^2 greater than 0.6; (d) for each year, a ln(Hg) was predicted (forecast) for a fish length of 14 in; (e) the 95th percentile predictive intervals were estimated; and (f) predicted and 95th values were transformed back to the original units, by taking the antilogarithm.

The EPA guidance level for the protection of human health, 0.3 mg/kg or ppm, is the threshold value used to assess the condition of the LMB CIs. Conditions Indicator values above 0.36 mg/kg (0.3 plus 20%) were assigned a "Significant Concern" status and fell within the red zone, values between 0.36 and 0.24 mg/kg (0.3 minus 20%) were assigned a "Caution" status and fell within the yellow zone, and values below 0.24 mg/kg were assigned a "Good Condition" status and fell within the green zone. The 20% increment value, which represents a small fraction of the mercury guidance level, was arbitrarily selected to define the Caution (yellow) status level.

Sunfish (SF) CI

Four species of sunfish SF (bluegill, redear, spotted, and warmouth) were sampled at the L67F1 station in Shark River Slough. Because a significant fraction (>95%) of total mercury in sunfish samples is MeHg (SFWMD 2012), total mercury is a reasonable approximation for MeHg concentration in sunfish and is used to compute the SF CI. Yearly CIs were estimated for station L67F1 only, because the other station, NP, in Shark River Slough did not have enough samples for the analysis. The yearly SF CIs were computed as follows: (a) an average concentration of mercury, for each hydrologic year, was estimated for the pooled data of all sunfish species; and (b) upper and lower bounds were estimated by adding and subtracting, respectively, one standard deviation from the mean. The EPA guidance level for the protection of wildlife, trophic level three, is 0.077 mg/kg or ppm and was used to assess the condition of the SF CI. Conditions Indicator values above 0.092 mg/kg (0.077 plus 20%) were assigned a "Significant Concern" status and fell within the red zone, values between 0.092 and 0.062 mg/kg (0.077 minus 20%) were assigned a "Caution" status and fell within the yellow zone, and values below 0.062 mg/kg were assigned a "Good Condition" status and fell within the green zone. The 20% value, which represents a small fraction of the mercury guidance level, was arbitrarily selected to define the caution (yellow) assessment zone.

The CIs for L67F1-SF averaged 0.40 mg/kg and ranged from 0.23- to -0.64 mg/kg. During the late 2000's, the CIs declined but increased again in 2010HY (Figure 4.26). During the last three years, the CIs have declined, and in 2012HY it was 0.37 mg/kg—slightly less than the average for the POR. Because the CIs have substantially exceeded the EPA guidance level of 0.077 mg/kg—sunfish are assessed as being within the red zone - ***"Significant Concern"***.

The CIs 95th percentile prediction intervals (vertical lines in Figures 4.24 and 4.25) at L67F1 and NP stations are large and reflect the wide spread of the LMB mercury fish data. The CIs average ± one standard deviation (vertical lines in Figure 4.26) at L67F1 station shows also a wide variation in the sunfish mercury data. Although there is a large variance, the lower bound of the LMB CI has never been below the "Caution" (yellow) or "Good" (green) status; and the lower bound of the SF CI has rarely reached the "Caution" (yellow) or "Good" (green) status.

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4.4. Fire and Fuel Dynamics

Fire management is among the most complex and challenging form of natural resource management that occurs in EVER. No other resource management group is required to tune its plans to so many different factors – ranging from weather conditions at the time of ignition to the status of any one of the nearly 200 special status species that are present in the park. An overarching goal for fire management is to maintain safe conditions for visitors to the NPS unit and in lands adjacent to the NPS unit. Public safety and resource protection requires fire managers to: suppress wildfires that occur when fire risks are unacceptably high; monitor and/or containing wildfires during naturally occurring fire seasons; set prescribed fires in areas that have not experienced fires for periods longer than the desired return time; and setting prescribed fires to reduce fuel loading in areas where the risk of future wildfires is too high.

Developing and implementing a fire management program in southern Florida is made even more challenging as a result of several issues: (1) The presence of invasive exotic plant species that are widely distributed across the landscape; (2) The history of land uses that has disturbed tens of thousands of acres of vegetation under management; (3) The continuing challenges associated with human altered hydrologic patterns; (4) the 4.95 million people that live within 50 miles of the park boundary. These factors may increase the likelihood that unnaturally intense fires or the absence of fires negatively impact pine rocklands, tree islands, marsh soils, and wetland vegetation. The application of prescribed fires on the landscape can mitigate these challenges to some extent.

4.4.1. Fire Activity Assessment

Status and Trend

Attribute: Fire and fuel dynamics in Everglades National Park

Overall Condition & Trend:



Rationale: Progress toward attaining desired state of conservation criteria

- Occurrence of severe (soil consuming) fires reduced since 1995
- Significant recent progress in applying fire to unburned fire-adapted plant communities in coastal and inland marshes

Challenges to attaining desired state of conservation conditions

- Long-term fire return interval shows too little fire applied to landscape since inception of park
- Two-decade fire return interval shows need for more fires during wet conditions
- Pine rocklands have not been burned for >6 years

The most common condition in EVER is “Fire to rare”, and this applies to approximately 56% of the land surface area (Table 4.14, 4.15). Almost 12% of fire adapted area in EVER exhibit long-term fire return times that are consistent with current fire management goals (Figure 4.29). Areas that burn too frequently are quite uncommon (< 1% of EVER). At least 28% of lands in ENP contain vegetation types that do not require fire management (cypress forests, coastal mangrove forests, and subtropical hardwood hammocks).

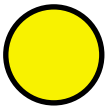
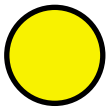
Table 4.14. Assessment of fire history in Everglades National Park.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Long Term fire return time		56% of EVER land needs more frequent fire to achieve natural resource goals. Wildfire/urban interface burns have become more frequent in last 10 years, and this has improved fire return times.	Pinelands should burn every 3–7 years, coastal prairies every 2–10 years, and sawgrass marsh or marl prairies every 3–12 years.
Fire Intensity in Shark River Slough		An uncontrolled, peat consuming, tree island destroying fire burned ~40,000 ac during May-June 2008. Dry season fires have become less frequent in Shark River Slough since the area affected by this type of fire peaked in the 1984–1995 period.	Low-medium intensity fires are desired. Fires that burn organic soils or tree crowns are too intense and should never occur.
Time since last fire (last 20 years)		~20% of fire adapted communities have been burned recently	All fire adapted communities should burn at desired intervals.
Fire in restoration areas		Fire frequency in HID areas is appropriate. Recent application of fire downstream of 1 mile bridge in the East Everglades addition lands has prepared the area for pending hydrologic restoration.	Areas should be burned 1–3 years prior to hydrologic restoration. Areas where soils are scraped should be burned once they can carry fire.

Table 4.15. Assessment of fire history among discreet physiographic regions.

Physiographic region	Goal-oriented performance	Time since last fire (last 20 years)	Long term fire return interval	Rationale
Region 1 – Ten Thousand Islands				Very little fire in last 2 decades, ~58% of region does not need fire.
Region 2 – Broad and Lostman’s River				More fire needed in ~85% of fire adapted habitats in the region.

Table 4.15 (continued). Assessment of fire history among discreet physiographic regions.

Physiographic region	Goal-oriented performance	Time since last fire (last 20 years)	Long term fire return interval	Rationale
Region 3 – Shark River Slough				Recent improvements due to Wildland/Urban interface burns.
Region 4 – Rocky Glades				More fire needed in ~85% of fire adapted habitats in the region, ~15% of region has desired long-term fire return interval.
Region 5 – Taylor Slough Headwaters				~45% of region has desired long-term fire return interval.
Region 6 – Western Coastal Swamps and Lagoons				~40% of region matches goals. Prescribed fire activity has increased recently.
Region 7 – Pinelands and Marl Prairies				Historically this has been most active prescribed fire area in EVER Activity has recently declined.
Region 8 – Taylor Slough				~30% of region matches goals for fire, small portions of area have been burned in last 10 years
Region 9 – Southeastern Marl Prairie				~40% of region matches goals for fire, very small areas burned in last 10 years
Region 10 – Whitewater Bay				Very small area requires fire. Most of small area recently burned after long period of no fire.
Region 11 – Cape Sable				~60% of region doesn't need fire, activity has increased in last 10 years
Region 12 – Eastern Coastal Swamps and Lagoons				~40% of region doesn't need fire, activity has increased in last 10 years

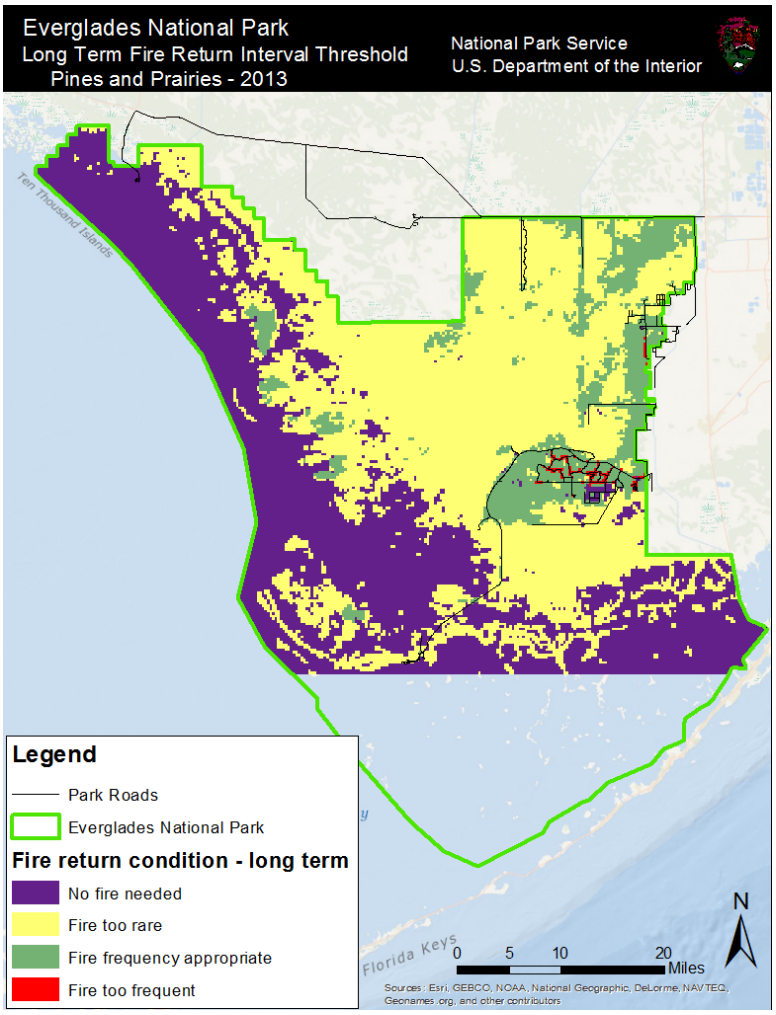


Figure 4.29. Long-term fire return interval relative to goals across EVER.

Highlights

- Wildland prescription fire program has improved long-term fire management status of thousands of acres of marshlands since 2005.
- Wildland prescribed fires have prepared northeast Shark River Slough for rehydration actions.
- Wildland-urban interface fires have effectively reduced risks/impacts of dry season arson/accidental wildfires that were common in the East Everglades Addition Lands prior to park establishment.
- Fire management is occurring in the hole-in-the-donut area, and has been shown to be useful in converting excess phosphorus that is present in scraped soils into a form that is less biologically available.

- Long-term fire return intervals are much longer than desired. Several decades of increased fire management activity will be needed to correct this enduring challenge.

Importance

Fire adapted plant species are prevalent in the Pinelands, short hydroperiod marshes, sawgrass marshes, and coastal prairies that occur in 72% (or 1101 square miles) of the land surface of Everglades National Park.

Fire is essential for managing Pine Rocklands in EVER, which are the last vestige of a globally imperiled habitat. Pine Rocklands contain many endemic plant species.

Fire management of marshes is an essential aspect of managing the transition from degraded to restored conditions in the most severely damaged portions of the Park.

The absence of fires for 12 years or more increases the risk of high intensity fires that burn soils and destroy adult trees (Photo 15).

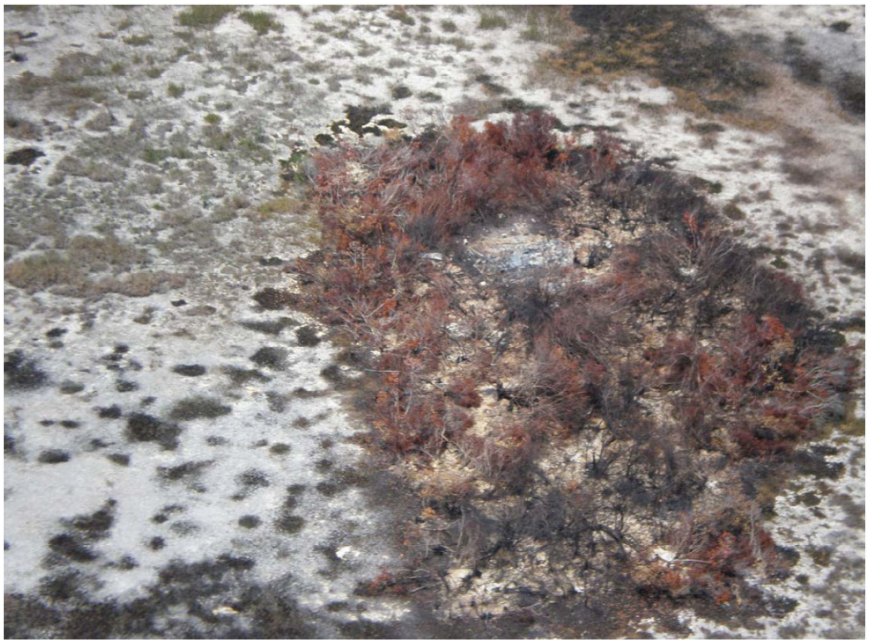


Photo 15. Aerial photo (June 2008) of burned out tree island within the Mustang Corner fire incident boundary. Reprinted with permission from Ruiz et al (2010).

Background and Importance

The role of fire in facilitating the development and maintenance of graminoid marshes, pine rocklands, and coastal prairies is well known. Risks of intense out of season fires are also well understood, and this type of fire was much more frequent in northeastern Shark Slough in 1952–1995 than it has been since 1995 through the present (Figure 4.30, section 4.6.2). Establishment of Tamiami Trail bridge, transfer of water to the eastern portion of Shark Slough, and continued prescribed fires should reduce this challenge in the future.

Fire management can also reduce the availability of the residual phosphorus in soils that were farmed before inclusion in EVER by converting up to half of phosphorus present in living plants into a form that is not biologically available: a geologically stable phosphate mineral (Hogue and Inglett 2012). Fire also promotes the development of desirable habitat heterogeneity at 100–10,000 m^2 (room-size to acre-size) spatial scales through the interaction of fire severity and subsequent hydrology (Sah et al. 2012).

Fire is useful for nurturing shifts in plant species composition of disturbed areas into a condition where they are no different from species composition of other locations that experience similar hydroperiods but were never used intensively by humans. Fires that consume aboveground plant biomass, but do not consume organic soils appear to be ideal, since the soil development process plays an important role in returning the site to the phosphorus limited condition that is predominate throughout Everglades marshes.

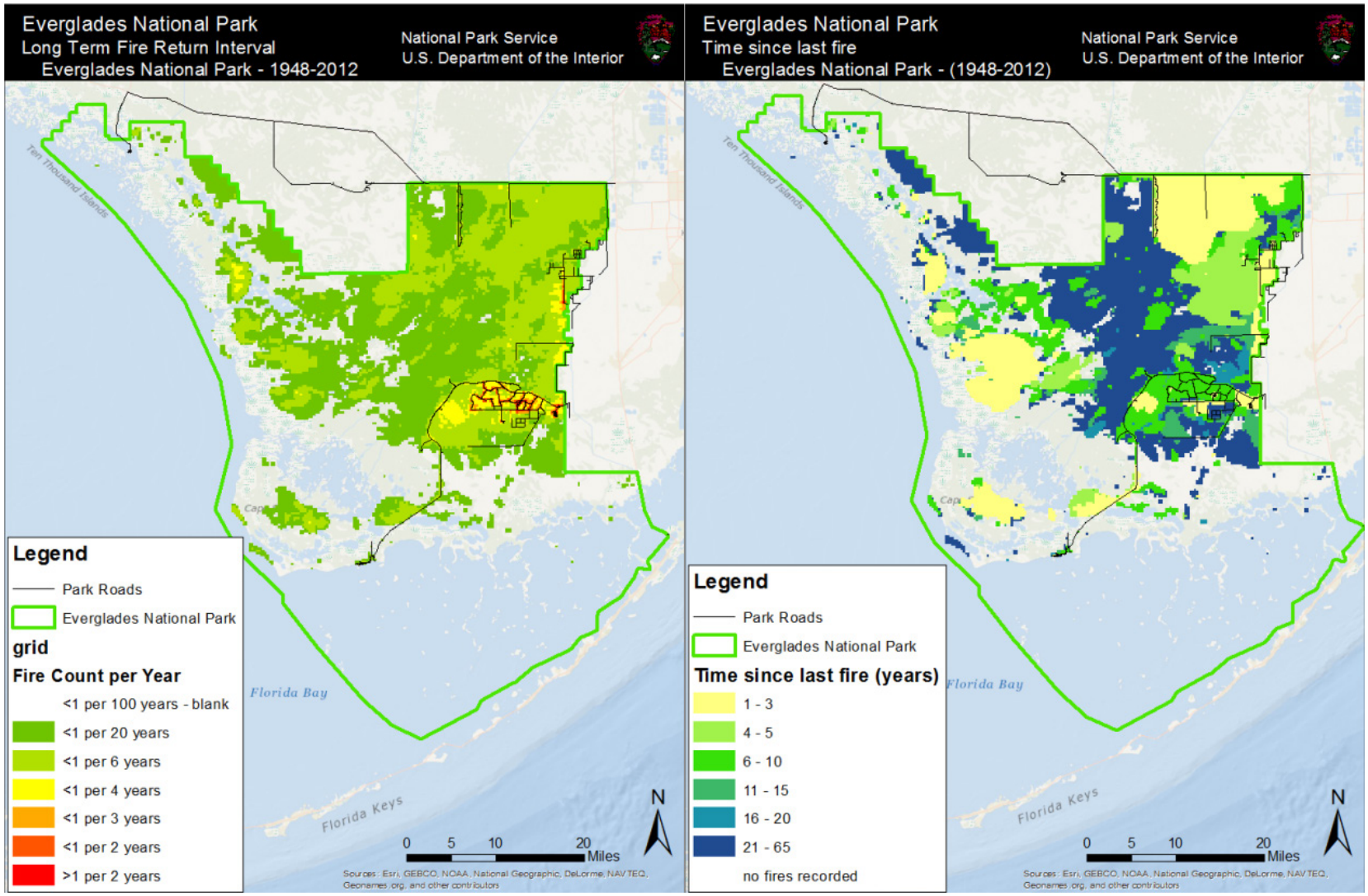


Figure 4.30. Long-term fire return interval (left) and time since last fire (right) in Everglades National Park.

The relative importance of early versus late growing season fires in controlling shrubs and broadleaf exotic plants is complex, and may be best addressed using demonstration projects where seasonal timing treatments are repeated within sites and shifts in plant functional types (i.e., shrubs, grasses, forbs, etc.) are observed over decades. Interviews with fire managers in EVER reveal that the current operating perspective is that fire frequency is more important than season in influencing proportionality of shrubs/grasses over decadal intervals. Research in fire-adapted ecosystems in the temperate United States suggest that seasonality is quite important (sensu Drewa et al. 2002), but the consequences of fire season on different species in different environmental contexts is widely variable (Drewa and Havstad 2001, Dacy and Fulbright 2009, Wilcox and Giuliano 2010) the variable patterns of seasonal moisture in southern Florida coupled with the absence of cold conditions may interact with the complex/fractured soils of the rocklands to reduce the importance of seasonality in shaping the species composition of understory communities (compared with temperate pinelands).

Fire intensity in Shark River Slough (as indicated by a count of dry season fires) indicates that the number and acreage of fires that are a high risk for consuming peat soils or burning tree canopies have declined since this fire type peaked between 1984–1995 (Figure 4.31). The risk of these fires continues, as indicated by the recent occurrence of a destructive fire (named the “Mustang Corner Fire”) that burned ~40,000 ac over a 1 month period during extreme drought conditions in 2008.

Fire return times are shortest near roads and least frequent (or not recorded) throughout the coastal marshes and in the long-hydroperiod wetlands in the interior of EVER (Figure 4.30). An assessment of the status of discreet physiographic regions reveals the evidence of increased fire management activity during the last two decades as well as the shifting of prescribed fire resources from applying fires to pine rocklands to applying fires to marshes along the wildland/urban interface, coastal marshes, and interior marshes that are far from roads.

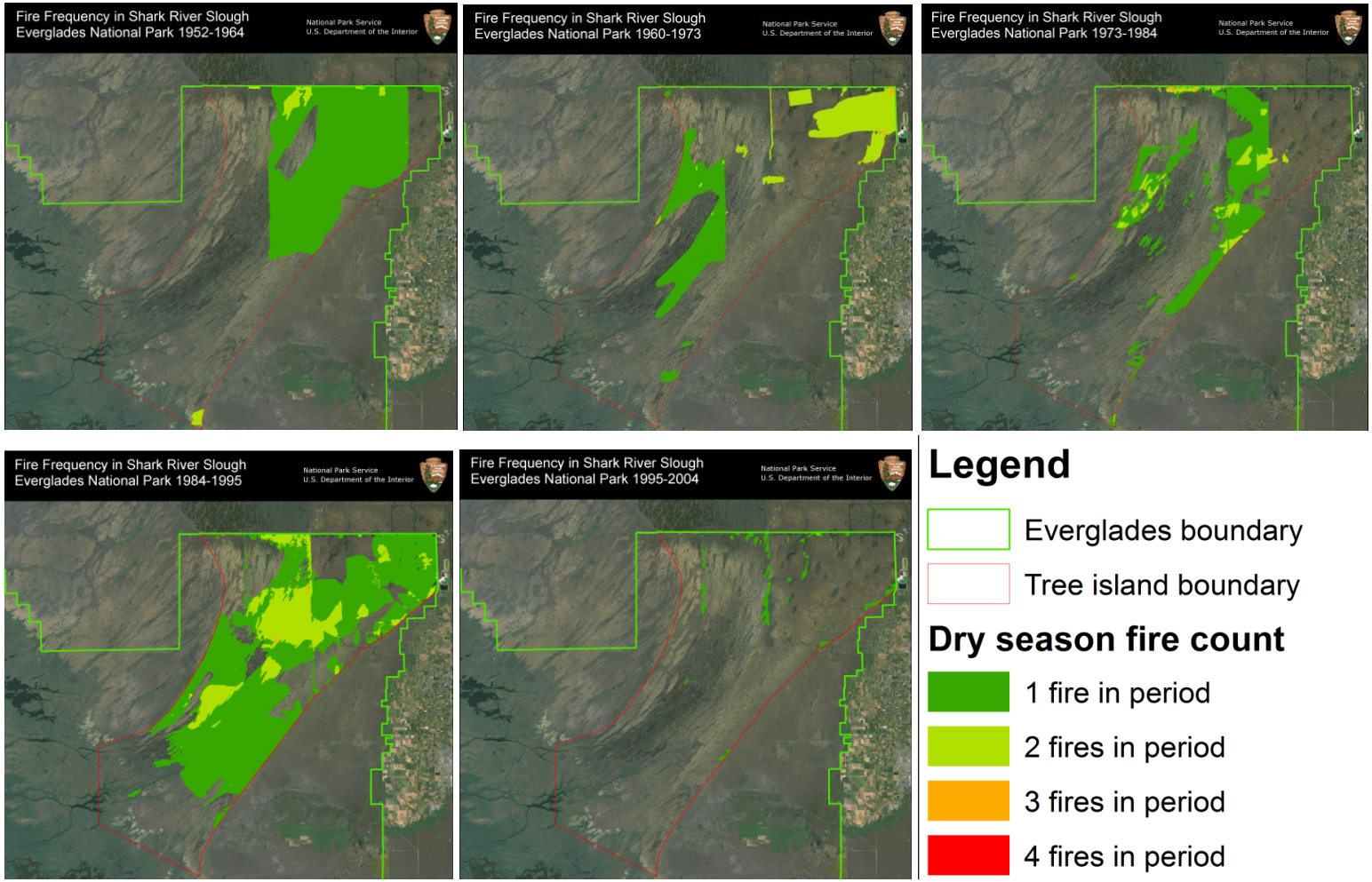


Figure 4.31. A count of dry season fires in Shark River Slough over five decadal intervals since 1952.

Desired State of Conservation

The Everglades ecosystem contains several plant communities that consist of mostly "fire adapted plant species" (defined as plant species that have traits that allow them to survive fires). These species are expected to thrive in areas where low-intensity fires occur frequently. Pinelands, short hydroperiod marl prairies, sawgrass marshes, and coastal prairies are the four major vegetation types that require frequent fire to maintain stable species composition over centuries, and which cover thousands of acres of EVER. EVER fire management has set a goal of burning pinelands every 3–7 years, coastal prairies every 2–10 years, and sawgrass marsh or marl prairie every 3–12 years (NPS 2013).

Fire management activities have historically been insufficient to meet biologically desirable goals. Addressing this challenge will help us avoid the likely consequence of lower frequency/higher intensity fires occurring throughout the park. Intense fires will reduce forest coverage and denude habitats, perhaps enhancing extirpation risks for critically endangered or threatened plants, insects, and animals.

The desired outcome for areas where significant shifts in hydrology are expected is an ecosystem that is well hydrated, experiences fewer days where extremely dry conditions prevail, and which experiences frequent fires that are less severe than what has been observed in the past six decades. This type of fire condition is expected to produce a mosaic of vegetation types within a landscape that exhibits a greater degree of heterogeneity than is present in areas that are considered degraded today (like the East Everglades Addition Lands). It is essential to note that the need for fire management is certain to continue, and that the occurrence of fire is an important aspect of driving transitions from degraded to restored conditions.

Description of Indicator Monitored

Tables 4.16 and 4.17 provide a complete description of the assessment metrics for the EVER fire program that are used in this report.

Table 4.16. Whole park fire management program metrics.

Measurement	Metric	Scale	Threshold
Long Term fire return time	Proportion of area where (# fires / # years in period of record) is within target range	All fire adapted communities (1,100 mi^2) over 1948–2012 time period	Good >80%; Caution = 30–80%; Bad = Less than 30%
Fire Intensity in Shark River Slough/Rocky Glades region	Number of peat consuming or canopy consuming fires in last decade	All fire adapted communities (1,100 mi^2) evaluated over decadal intervals 1948–2013	Good = 0; Bad > 0
Time since last fire	Proportion of fire adapted communities in park with time since last fire less than maximum desired return interval	All fire adapted communities (1,100 mi^2)	>80% = Good; 20–79% = Caution; <20% = Bad
Fire in restoration areas	Best Professional Judgment	All fire adapted communities (1,100 mi^2)	Best Professional Judgment

Table 4.17. Physiographic region fire management metrics.

Measurement	Metric	Spatial Scale	Thresholds
Goal-oriented performance	Proportion of physiographic region that matches long term fire return interval goals	All fire adapted communities (1,100 mi^2)	Good >80%; 30–79% = Caution; < 30% = Bad
Long term fire return interval	Proportion of fire adapted communities in each physiographic region with 2–8 year return interval	All fire adapted communities (1,100 mi^2)	>80% = Good; 30–79% = Caution; < 20% = Bad
Time since last fire	Proportion of fire adapted communities in each physiographic region with time since last fire less than maximum desired return interval	All fire adapted communities (1,100 mi^2)	>80% = Good; 20–79% = Caution; <20% = Bad

Supporting Processes and Management Implications

Major improvements in our understanding of the status and trends of fire management in EVER have occurred in the last decade. Vegetation map development, ecological monitoring of disturbed areas, tree island change analysis, soil disturbance mapping, and the development of an database depicting historical fire perimeters in EVER (courtesy of USGS – Smith et al. in review) have all contributed to the shared awareness of the type and degree of fire management challenges that are present in EVER (summarized in Figure 4.32).

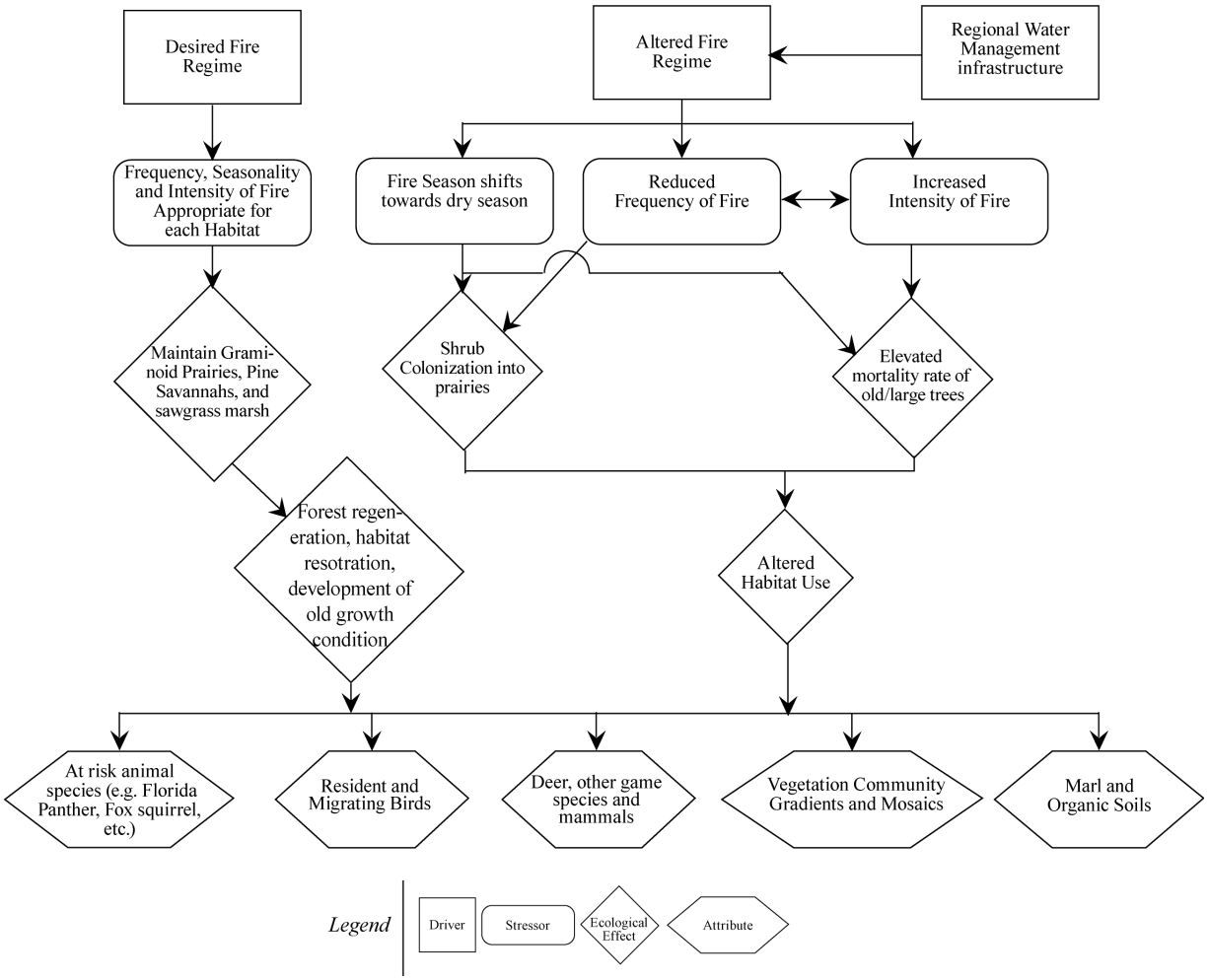


Figure 4.32. A conceptual diagram of the causes, dependencies, and consequences of desired versus altered fire regimes.

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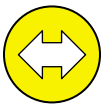
4.5. Soils

Peat soils predominated across the region prior to drainage of the ecosystem. Deep peat soils are expected to sustain a high biomass of Everglades crayfish by allowing this species to avoid the negative impacts of severe drought and exploit abundant food resources that occur following droughts (Dorn and Volin 2009). Marl soils (calcium carbonate muds) are often interlaced with peat soils due to the abundance of calcium carbonate in the geology of the region. Marl soil formation is associated with very low concentrations of phosphorus, and the formation of marl requires high light penetration to the surface of the water column during wet, hot, summer months. Coastal peat soils are essential buffers against a rising sea level, are home to burrowing crabs, and support high biomass coastal communities. Sustaining soil development processes is essential for maintaining a healthy ecosystem and is dependent upon effective hydrologic restoration and continuation of low nutrient conditions.

4.5.1. Status and Trend

Attribute: Soils

Overall Condition & Trend:



Rationale: Soils in EVER appear to have stabilized following significant loss of organic soils since 1946 (with loss prior to 1946 very likely). Improvement to soils will require significant progress with the Everglades Restoration Program.

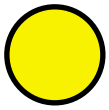
Desired State of Conservation: Accreting peat soils in ridge-slough-tree island landscape and coastal habitats. Marl soil formation in short-medium hydroperiod wetlands. Effective restoration of areas with poor land use history. A stable coastline where soil accretion is faster than sea-level rise.

4.5.2. Highlights

- Peat soil loss in Everglades National Park is centered in northeastern Shark Slough region (Table 4.18, Figures 4.33, 4.34).
- Peat soil loss is problematic throughout the historical Everglades ecosystem – particularly in state managed lands upstream of EVER.
- Long-duration hydroperiods are necessary to sustain peat soils. Elevated phosphorus concentrations in the water column occur when hydroperiods are too short and peat soils decompose.
- Continued success with maintaining marl soil formation processes is dependent upon maintaining low-nutrient status.

- Coastal peat soil formation stabilizes the coastline and coastal habitats when it outpaces the rate of sea-level rise.

Table 4.18. Soil indicators for Everglades National Park.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Freshwater Muck/peat soil		Peat soils have consistently declined over a six-decade period since establishment of EVER. Shifting water patterns due to Everglades restoration efforts may begin in 2014, triggering improvement.	Muck/peat soils should be gradually accreting.
Marl soils		Conditions that support marl formation exist and are stable across most of EVER.	Low nutrient status in marshes supports marl formation across the freshwater marshes of EVER.
Rock soil		Only a few hundred acres of rockland soils are disturbed, less than 5% of the total area of rockland soils. Restoration of Hole-in-the-donut site is addressing most of the disturbed rockland soils.	Intact pine rocklands soils
Coastal peat		Coastal peat soils accumulate 1–4mm per year (based on size of mangrove forest). Essentially equal to the 2.24 mm/yr. rate of sea-level rise observed in Key West, FL since 1913.	Accreting peat soils stabilize coastline for centuries consistent with recent (~5000 years before present) geologic history of the region.

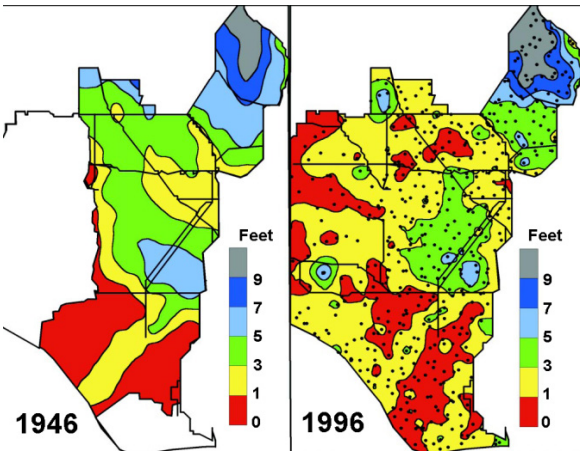


Figure 4.33. Soil thickness (feet) as reported by Davis in 1946 (left) and at 479 sites in 1995–1996.

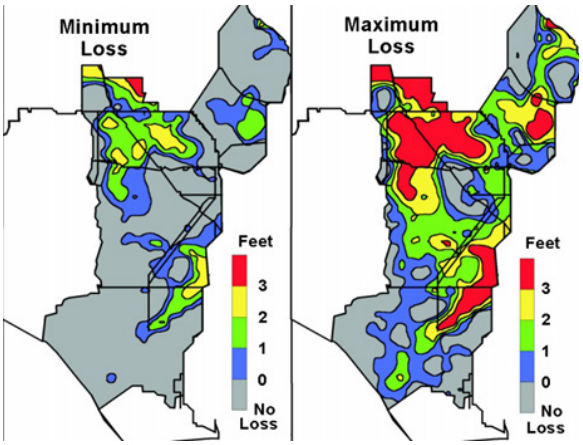


Figure 4.34. Soil loss estimate from 1946 to 1996 for the Everglades (EPA Remap 2000).

4.5.4. Background and Importance

Healthy soils interact with healthy plant communities to deliver high biomass food webs. Soils are produced through the interaction of vegetation that loads a soil with carbon, the decomposition of vegetated matter, geologic "parent" materials, and physical processes like flooding, erosion, and compaction. Mucks (or peats), marls (calcium muds), and rocklands (dried calcium carbonate rock), are the dominant soil types in EVER. Mucks, marls, and rocklands occupy areas in correspondence to duration of flooding. The dark brown/organic mucks are associated with sloughs and long hydroperiod marshes. Marls are associated with short-medium hydroperiod marshes and prairies, and rocklands are associated with rarely flooded pinelands.

Importance: Peat soils are essential habitat for Everglades crayfish. Marl soil formation is associated with very low phosphorus conditions that are typical of the ecosystem. Coastal peat soils are responsible for stabilizing the coastline and provide habitat for crabs and other organisms that live at the interface with the ocean. An inventory of soils in EVER has not occurred since the establishment of the park. The Environmental Protection Agency's REMAP program has produced the most extensive recent dataset of soil conditions across the Everglades ecosystem, and several processes funded through the Comprehensive Everglades Restoration Plan (CERP) have complemented this information. Scientists from the University of Florida (funded by CERP) have conducted soil coring and associated assessment of soil nutrient concentrations and bulk density across the Everglades Protection Area – which includes Everglades National Park and portions of Big Cypress National Preserve (RECOVER 2009).

Muck/peat soils are the most compromised soil types in the region. Farming in the East Everglades Addition, lands and dehydration of the same region – as a result of regional water management infrastructure – are responsible for the losses of soil. Peat soils in northeastern Shark Slough may stabilize in the coming 5–10 years now that seepage management is in place along the eastern boundary of EVER, the 1-mile bridge on the Tamiami Trail is installed, and a plan to gradually shift in operations of the canal that parallel's the roadway is being implemented. The processes that support the formation of marl soils continue to prevail across most of EVER. Elevated nutrient levels from canals can stimulate biomass production in marshes (often cattail), reducing light penetration,

and preventing the marls from forming (see Dierberg et al. 2002, Grace 2003, Pietro et al. 2006 for observations of calcium precipitation in Everglades marshes). The only location where nutrient levels are high enough to potentially impair marl soil development is a small area downstream of the S-332 structure that delivers water into Taylor Slough.

Coastal muds and muck/peat soils along the coast appear healthy as well. The coastal system changes more quickly than most areas, due to tidal interchanges and significant sediment deposition events associated with storm driven tidal surges (Smith et al. 2009). Currently, maximum coastal peat soil development rates are slightly more rapid than the rate of sea-level rise (in terms of long-term average rates in well-developed mangrove forests), but the intrusion of saltwater into coastal groundwater has been shown to drive rapid deterioration of sawgrass-derived peat soils in experimental settings (Chambers et al. 2014). For this reason, that status of coastal soils is identified as "warrants moderate concern", and risks of rapid deterioration are in the freshwater marsh just upstream of the coastal mangrove forests.

Rock soils occur in pinelands, and are generally stable. Only the hole-in-the-donut area (see section 4.6.1.1) contains rockland soils that are substantially impaired (these soils were crushed by rock-plows prior to the assimilation of private farmlands into the interior of EVER in the 1970's).

4.5.5. Metrics

Assessment of soils in EVER is centered on the question of whether soil formation processes are effectively supported in terrestrial and coastal wetlands. Pine rocklands are assessed by the extent to which they have been disturbed (Table 4.19).

Table 4.19. Metrics for assessment of soils in EVER.

Soil type	Metric	Scale	Threshold
Freshwater Muck/peat soil	Depth to bedrock	Areas with peat soils in 1946	Resource in Good Condition: ≥95% of areas are accreting Warrants Moderate Concern: 80–95% of areas are accreting Warrants Significant Concern: < 80% of areas are accreting
Marl soils	Potential for active marl development	Freshwater marshes	Resource in Good Condition: ≥95% of freshwater marsh suitable for marl formation Warrants Moderate Concern: 80–95% of freshwater marsh suitable for marl formation Warrants Significant Concern: < 80% of freshwater marsh suitable for marl formation
Rock soil	Spatial extent, proportion disturbed	Pinelands	Resource in Good Condition: ≥ 95% of rocklands undisturbed Warrants Moderate Concern: 80–95% of rocklands undisturbed Warrants Significant Concern: < 80% of rocklands undisturbed
Coastal peat	Net accretion	Coastal and estuarine areas	Resource in Good Condition: soil accretion more rapid than sea-level rise Warrants Moderate Concern: soil accretion equal to rate of sea-level rise Warrants Significant Concern: sea-level rise more rapid than rate of soil accretion

4.5.3. Status and Trends

Marl and rockland soils are stable. Organic soils (muck or peat) are in severe decline in northeastern Shark Slough, and generally declining since establishment of the park (Figures 4.33, 4.34). Organic soil decline is generally associated with a lack of water delivered to EVER from upstream basins. Peat soils consist of partially decomposed plant matter. Peat soils are vulnerable to increased rate of decomposition and loss of CO_2 to the atmosphere when exposed to the air, and dry peat soils are vulnerable to fires. Coastal soils are the most dynamic. Moderate concern is warranted for coastal soils given the possibility of accelerating sea-level rise caused by climate change. Coastal peat soils accrete due largely to accumulation of root matter (Whelan et al. 2005, Pearlstine et al. 2009, Smith et al. 2009). The health and size of coastal mangrove forests is a key determinant of coastal peat accumulation. Increased freshwater deliveries should enhance the size of coastal forests, by expanding the growing season, and reducing stresses associated with saltwater on plant roots. Larger trees cause more rapid rates of peat accumulation. The National Research Council recommends increasing freshwater deliveries to EVER as the best strategy for stabilizing the coastline, as this should enhance the natural resilience of coastal habitats (CISRERP 2008).

4.5.6. References

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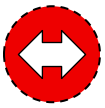
4.6. Inland and Coastal Biological Integrity

4.6.1. Terrestrial Invasive Exotic Plants

Status and Trend

Attribute: Terrestrial Invasive Exotic Plants

Overall Condition & Trend:



Rationale: There are over 55,000 acres infested with invasive exotic plant species in EVER. Management processes are increasing and a wide range of partnerships are being developed to address exotic plants. The main concern is whether the rate of expansion is greater than the rate of decline due to management.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

The EVER exotic plant program directs limited resources to the treatment of those exotic species where management actions have the greatest likelihood of achieving the desired state. Available funding, current treatment technologies, and the biology, distribution, and accessibility of the particular exotic species (amongst other considerations) influence how park management prioritizes which species are treated. Physical removal of Melaleuca and Australian pine are likely to result in desired biological conditions. The prioritization of resources explains why Melaleuca and Australian pine show the most positive forecasted trends (Table 4.20). A second tier of resource prioritization is required within the work on Melaleuca and Australian pine, where decisions must be made between maintaining vast areas of these two species at or near the desired state versus bringing additional areas of Melaleuca and Australian pine under control. Given the management priority of Melaleuca and Australian pine, the expected trend for all remaining exotic plant species, even those of high management concern, is that the total number of infested acres will continue to increase (Table 4.20).

Table 4.20. Summary of the status of the four invasive plant species of top management concern and the group of additional invasive plant species in Everglades National Park.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Melaleuca quinquenervia		Most park invasive plant management effort is directed at this species. Chemical and bio-control agents are effective. Number of infested acres has decreased during the past 10 years.	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.

Table 4.20 (continued). Summary of the status of the four invasive plant species of top management concern and the group of additional invasive plant species in Everglades National Park.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Casuarina equisetifolia		Casuarina is second in terms of the amount of effort dedicated to management. Chemical control is effective, but access to some remote infestations is difficult. No effective bio-control exists. Number of infested acres is decreasing.	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.
Lygodium microphyllum		Management activity is limited by remoteness but is effective on dense infestations. Hope exists for development of an effective bio-control.	Less than 5% cover per km^2 is present in currently infested areas and area of infestation is not expanding.
Schinus terebinthifolius		Management of this species is limited to specific areas of high priority. No effective control currently exists for use in remote areas. No effective bio-control exists. Overall, the area of infestation is increasing.	Less than 5% cover per km^2 is present in currently infested areas and area of infestation is not expanding.
Additional collective exotic plant species		Management efforts for these species are currently limited to areas of high concern such as those with high visitor use or areas with threatened and endangered species that may be impacted by the presence of exotic plants. Chemical controls and effective bio-controls differ by species. The overall area affected by the combination of these plants is increasing.	Less than 1% cover per km^2 is present in currently infested areas and area of infestation is not expanding.

Background and Importance

Approximately 1,100 plant species currently are recorded in EVER and, of these, approximately 250 are non-native (exotic) plants. Exotic plants have the capacity to drastically alter the natural environment (Doren et al. 2009, Mack et al. 2000). Consequently, several laws, general directives and polices, including but not limited to NPS Organic Act of 1916, NPS Management Polices 2006 (4.4.4.1–2) and the enabling legislation for EVER, require management of exotic plants.

Limited funding and time make it infeasible to treat all the exotic plants of management concern. Whiteaker and Doren (1989) prioritized the management of exotic plants in EVER based on five categories defined by distribution and potential to invade. Today, the four exotic plant species that are of highest management concern and affect the largest proportion of EVER by area are Melaleuca (*Melaleuca quinquenervia*), Australian pine (*Casuarina equisetifolia*), Old World climbing fern (*Lygodium microphyllum*), and Brazilian pepper (*Schinus terebinthifolius*). Surveys and mapping indicate that these four species are distributed across approximately 30% of the land mass of EVER. The remaining approximately 246 exotic plant species vary in the degree of their potential to invade

and their distribution pattern. The distribution and percent cover of these other species are difficult to estimate since monitoring of these species is limited.

Status of the Indicator in the Current Year and Trends over Time

The 2010 **D**igital **A**rea **S**ketch **M**apping (**DASM**) data are the most current data available for estimating the cover and density of the four priority exotic species described above (Figure 4.35). At the time of this report, a majority of the Melaleuca in EVER has been initially treated (treated once). However, more than 4,000 ac of Melaleuca still remain, of which 1,600 ac still need initial treatment. The 1,600 ac consist of dense (greater than 50% cover) to very dense (greater than 75% cover) Melaleuca in the northeastern part of EVER (Shark River Slough and Rocky Glades regions). The majority of Australian pines within EVER have received initial treatment and are gone; however, about 800 ac of low (0.1–25%) to moderate (26–50% cover) Australian pine infestation remain in the southeastern part of EVER and are still in need of initial treatment.

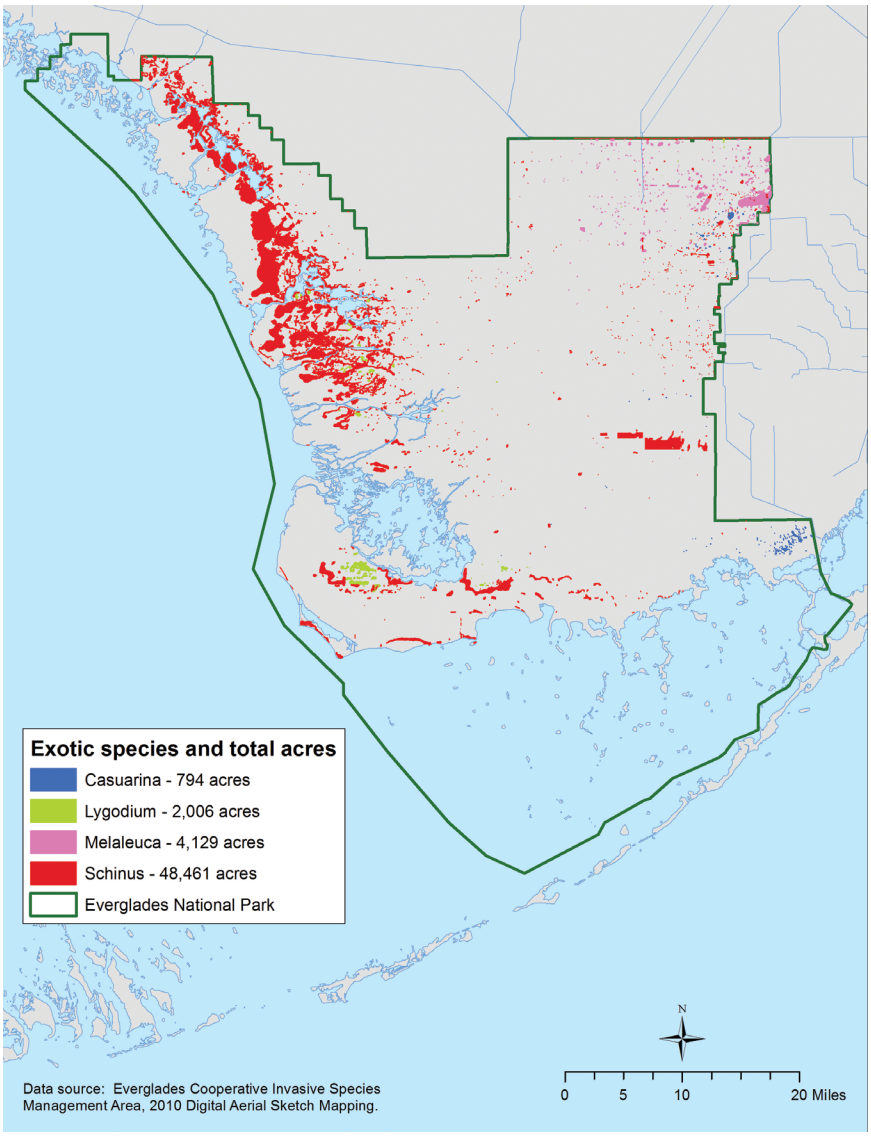


Figure 4.35. The 2010 distribution of the four invasive exotic plant species monitored with the Digital Area Sketch Mapping (DASM) technique for Everglades National Park.

Old World climbing fern was first reported in EVER in 1999, growing in the remote, sparsely wooded coastal marshes along the western part of EVER. At the time Old World climbing fern was reported, it was estimated to cover less than 300 ac. Due to a combination of the plants' biology, inaccessibility of infested sites, limited treatment options, and limitations on funding, Old World climbing fern is expanding its range. Today, Old World climbing fern has established in approximately 2,000 ac of the coastal marshes at densities ranging from >5 to 75% cover and, to a lesser extent, has invaded other habitats across EVER. Old World climbing fern is a major challenge in the nearby Arthur R. Marshall Loxahatchee National Wildlife Refuge, and there is great concern about the future spread of this climbing fern in EVER.

Brazilian pepper is the most widespread invasive plant in EVER. Brazilian pepper is estimated to cover more than 48,000 ac, and is expanding in range. Brazilian pepper is particularly abundant along the fringes of the mangroves at densities ranging from >5 to 75%. In some instances, individual stands of Brazilian pepper cover 4,000 to 6,000 ac. Due to a combination of the plants' biology, inaccessibility of infested sites, and limitations on funding, a cost-effective strategy for systematically removing Brazilian pepper from the park—without reducing treatment of Melaleuca, Australian pine, or Old World climbing fern—has not been identified. Rather, treatment of this plant is done sporadically as a part of broader exotics projects and in discreet areas that have been identified as resource management priorities, such as areas of high visitor use or areas where exotic vegetation could have negative impacts on threatened and endangered species.

The other 246 exotic plant species currently within EVER have varying invasion potentials and distributions. According to the Florida Exotic Pest Plant Council's (FLEPPC) 2011 list of invasive plant species, 36 of the 246 exotic species in EVER are considered capable of altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives. Furthermore, new exotic plant species have established immediately outside EVER boundaries and some have characteristics that indicate they would pose a threat to EVER's natural environment. Insufficient resources limits EVER's ability to contain those species that are restricted in distribution but pose a potential threat to natural areas and to prevent new exotic species from entering EVER.

Desired State of Conservation

Many of the descriptions of invasive exotic plant management in NPS documents lack measurable goals and provide only general language about control being feasible. The basic intention is to limit the distribution and abundance of any exotic species to the maximum extent practicable with available resources (NPS 2006). In this report, quantifiable objectives for the desired state of the four exotic plants of highest management priority (Melaleuca, Australian pine, Old World climbing fern, and Brazilian pepper) in EVER are described. Quantifiable objectives are also described for the remaining exotic plants found within EVER.

The desired management state for Melaleuca and Australian pine in EVER is defined as less than 1% cover per km^2 in the areas now or historically containing these species, and prevention of the expansion of these species to new areas. If greater than 1% cover per km^2 or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to the control of Melaleuca and Australian pine.

The desired management state for Old World climbing fern and Brazilian pepper is set as less than 5% cover per km^2 in areas currently containing these species, and prevention of the expansion of these species to new areas. If greater than 5% cover per km^2 or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to control of Old World climbing fern.

The desired management state for the remaining 246 exotic plant species that are present in EVER is defined as less than 1% cover per species per km^2 in areas currently containing these species, and

prevention of the expansion of these species to new areas. The desired management state would also include early detection and control of newly detected species. If greater than 1% cover per km^2 or a greater than 5% increase in infestation area is detected within a 2-year period, then greater resources should be dedicated to the control of these species.

Description of Indicator Monitored

A number of monitoring efforts are in place to track the status of exotic plant species in EVER and surrounding areas. Currently Melaleuca, Australian pine, Old World climbing fern, and Brazilian pepper are monitored using the Digital Aerial Sketch Mapping (DASM) method (Figure 4.35). This method consists of conducting systematic aerial survey transects in small aircraft flying at low altitude, with observers visually identifying, estimating percent cover, and mapping species occurrence across the landscape (Rodgers et al. 2014). The South Florida Water Management District, NPS, and U.S. Fish and Wildlife Service conduct this survey every 2 years.

In addition to the interagency DASM monitoring project, the NPS also has independent monitoring projects. The Corridors of Invasiveness project is conducted by the NPS' South Florida/Caribbean Network. The monitoring goal of the Corridors of Invasiveness project is to detect newly emerging invasive plant species in or near the NPS lands of south Florida, including Everglades National Park, Biscayne National Park, and Big Cypress National Preserve. Areas susceptible to new infestations are surveyed once every five years in a rotation among the parks. The NPS Exotic Plant Management Team (EPMT) also conducts monitoring on NPS lands to quantify the efficacy of treatment. This monitoring effort has established permanent plots within areas of known invasive exotic infestation and monitors the plots before and after the plants are "treated" (or all exotics are removed). Chance observations are also recorded and reported to reliable sources through EDDMapS (Early Detection and Distribution Mapping System), an on-line invasive species distribution mapping system.

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4.6.1.1. Everglades National Park's In-Lieu-Fee (ILF) Wetland Restoration Mitigation Project: Hole-in-the-Doughnut (HID)

Status and Trend

Attribute: HID In-Lieu-Fee Wetland Restoration Mitigation Project

Overall Condition & Trend:



Rationale: 4895 acres of rock crushed soils removed and:

- Hydrology restored
- Herbaceous dominated wetlands restored
- Exotic species below 1% cover threshold in all areas where soil has been removed

NPS Biological restoration criteria

- Plant species composition trending towards reference communities
- Residual phosphorus gradually decreasing through natural soil formation processes

Importance

Restoring wetlands heavily infested with exotics in the heart of the Everglades national park is an example of an ideal mitigation project (Figure 4.36 reprinted courtesy of Smith et al. 2011; Photo 16).



Photo 16. Restored marsh in the HID. This area was ~80% cover of Brazilian pepper prior to soil scraping.

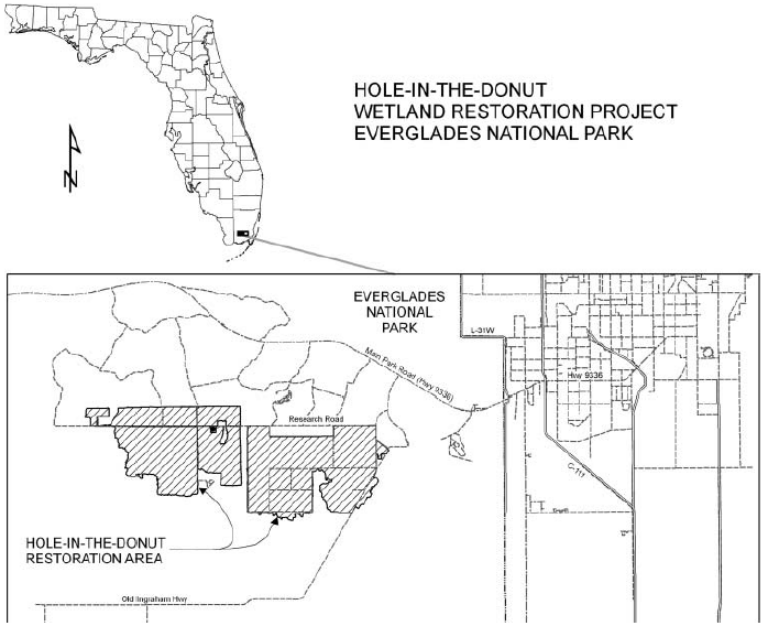


Figure 4.36. The location of the HID restoration site along the southern portion of Long Pine Key.

Highlights

- To date, ~4,895 of the 6,300 ac of the HID have been restored to herbaceous dominated prairie (Figure 4.37).

- Hydrology has been restored to 4,895 ac of the HID (Figure 4.38).
- Native wetland plants colonize, perpetuate themselves, and dominate the restored sites.
- No exotic plant species occupies more than 1% of the restored areas.
- Both Prescribed Fire and natural wetland soil formation processes are either diluting or converting excess soil phosphorus into forms that are less biologically available.

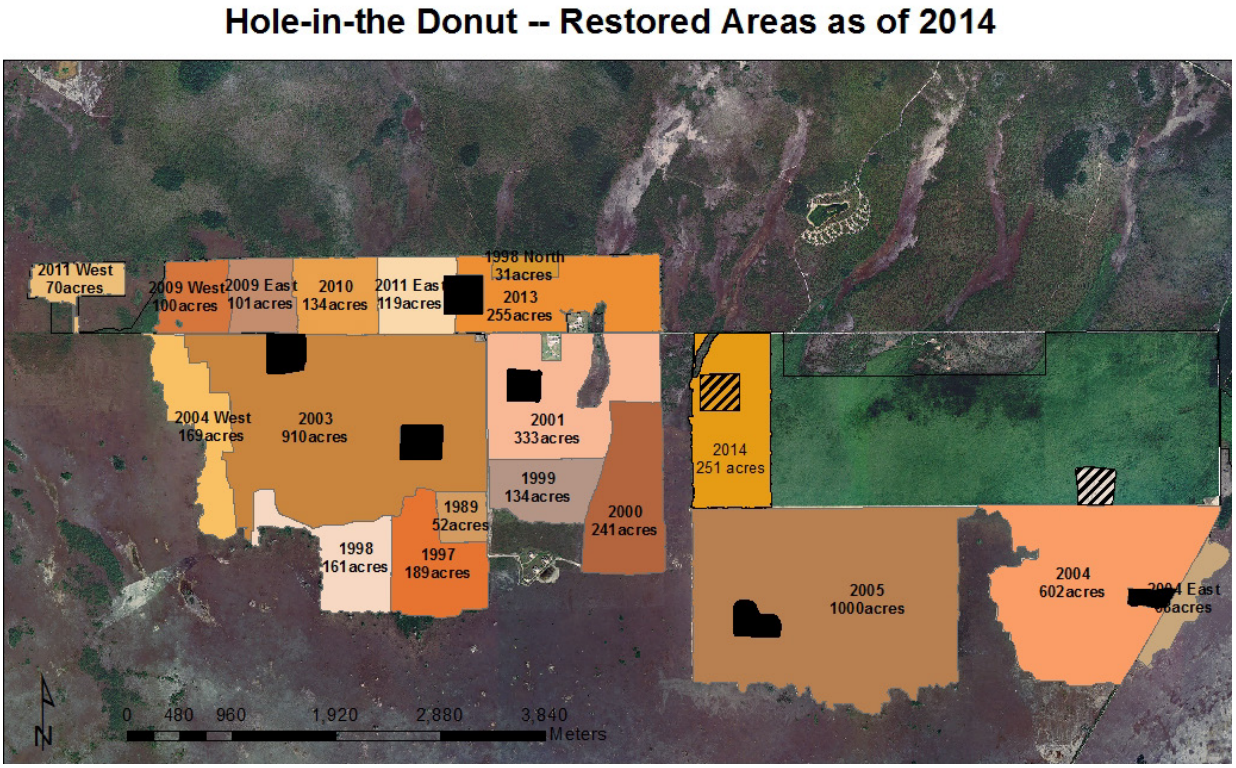


Figure 4.37. Restored areas in the Hole-in-the-Donut. The year that the site had soil removed and the acreage of the site are indicated for each area. Black and stripped areas are locations where crushed soils are piled.

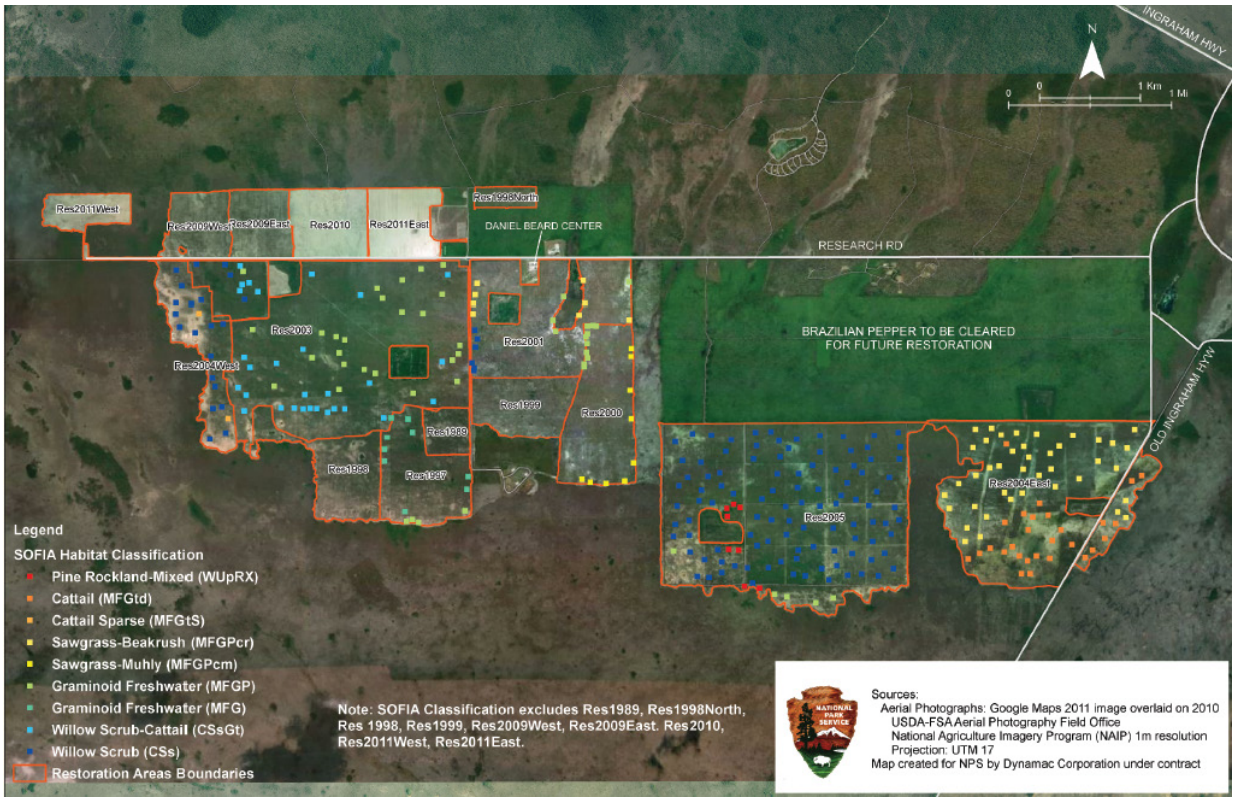


Figure 4.38. Plant community types observed in the HID restoration site.

Background, Supporting Processes, and Management Implications

The area known as the Hole-in-the-Doughnut (HID) began to serve as a permitted "In Lieu Fee" (ILF) wetland mitigation project in the mid-1990's (USACOE Permit #1993-01691); FDEP Permit #132416479). The HID ILF is one option for off-site mitigation to individuals (permittees) with unavoidable wetland losses due to development in Miami-Dade County. The cost of mitigation at the HID ILF covers the restoration, monitoring and maintenance of the project site. The HID was used for agriculture until the 1970's. Carbonate rock was crushed (rock plowing) on 6,300 ac, to create soil suitable for farming. Once farming ceased, Brazilian Pepper became the dominant plant species. Focusing mitigation resources in this area supports the Everglades National Park's goal to ensure that high quality habitats are available to support native wildlife, as well as threatened or endangered species. The HID presents a unique opportunity for an ILF mitigation project; since the area being mitigated is in public ownership and part of a World Heritage Site. Restoring this highly disturbed area supports the condition of surrounding habitats that are being actively preserved and managed, as well as directly offsetting the impacts to similar wetlands as they are developed in Miami-Dade County. Enhancing disturbed locations such as the HID that are surrounded by large, actively preserved landscapes is important for reducing establishment pressure from exotic plants and animals.

The HID In-Lieu-Fee mitigation project is successfully restoring previously farmed areas in Everglades National Park. Exotic species are known to denude ecological functions in general (Doren et al. 2009). Brazilian Pepper invaded the areas in the HID where limestone rock was crushed

creating soils suitable for farming (Loope and Dunevitz 1981, Ewel et al. 1982, Krauss 1987). The farmed soils prevented re-establishment of the native plant communities (e.g., sawgrass marsh, muhly prairie) that are expected given the elevation and hydroperiods (i.e., number of days per year that water is above ground surface) observed on these sites (Smith et al. 2011). There are three aspects of the farmed soils that interact to prevent the normal habitat development processes from occurring: 1) Elevated level of nutrients; 2) Reduced hydroperiod (caused by increased elevation); 3) Increased aeration of plant rooting zone. The restoration method of scraping sites to bare rock physically removes Brazilian Pepper, crushed rock soils, and a significant fraction of residual fertilizers or pesticides.

The change to the site caused by clearing vegetation and scraping soils allow natural wetland soil formation processes to occur. These processes have the added benefit of either diluting (through organic soil accumulation) or binding (through inorganic calcium cycling that forms rock) residual phosphorus. Soil removal initiates the shift from nitrogen to phosphorus limitation that is predicted to occur over a 15-year period (Inglett et al. 2011, Smith et al. 2011). The normal condition for Everglades' soils is phosphorus limitation (Hagerthey et al. 2008). The re-establishment of periphyton contributes to the restoration of soil forming processes (marl formation – a calcium rich soil) and the binding of Phosphorous with Calcium (Dierberg et al. 2002, Pietro et al. 2006).

Prescribed fire can also reduce the availability of the small fraction of residual phosphorus that remains by converting up to half of phosphorus present in living plants into a form that is not biologically available - a geologically stable phosphate mineral – when fires burn above a 400˚ C temperature threshold (Hogue and Inglett 2012). Fire also promotes the development of desirable habitat heterogeneity at 100–10,000 m^2 (room-size to acre-size) spatial scales through the interaction of fire intensity and subsequent hydrology (Sah et al. 2012).

The function of fire in the HID landscape was lost until the areas were restored to a native herbaceous dominated plant community. The unmitigated areas dominated by Schinus do not carry fire. Prescribed fires have been successfully applied to the HID as a management tool following scraping, and monitoring of cumulative fire history continues (Figure 4.39). Fire is useful for nurturing shifts in plant species composition of scraped areas into a condition where they are no different from areas in other locations that experience similar hydroperiods but were never used for agriculture. Fires that consume aboveground plant biomass, but do not consume organic soils appear to be ideal, since the soil development process plays an important role in returning the site to the phosphorus limited condition that is predominant throughout the marshes of the Everglades.

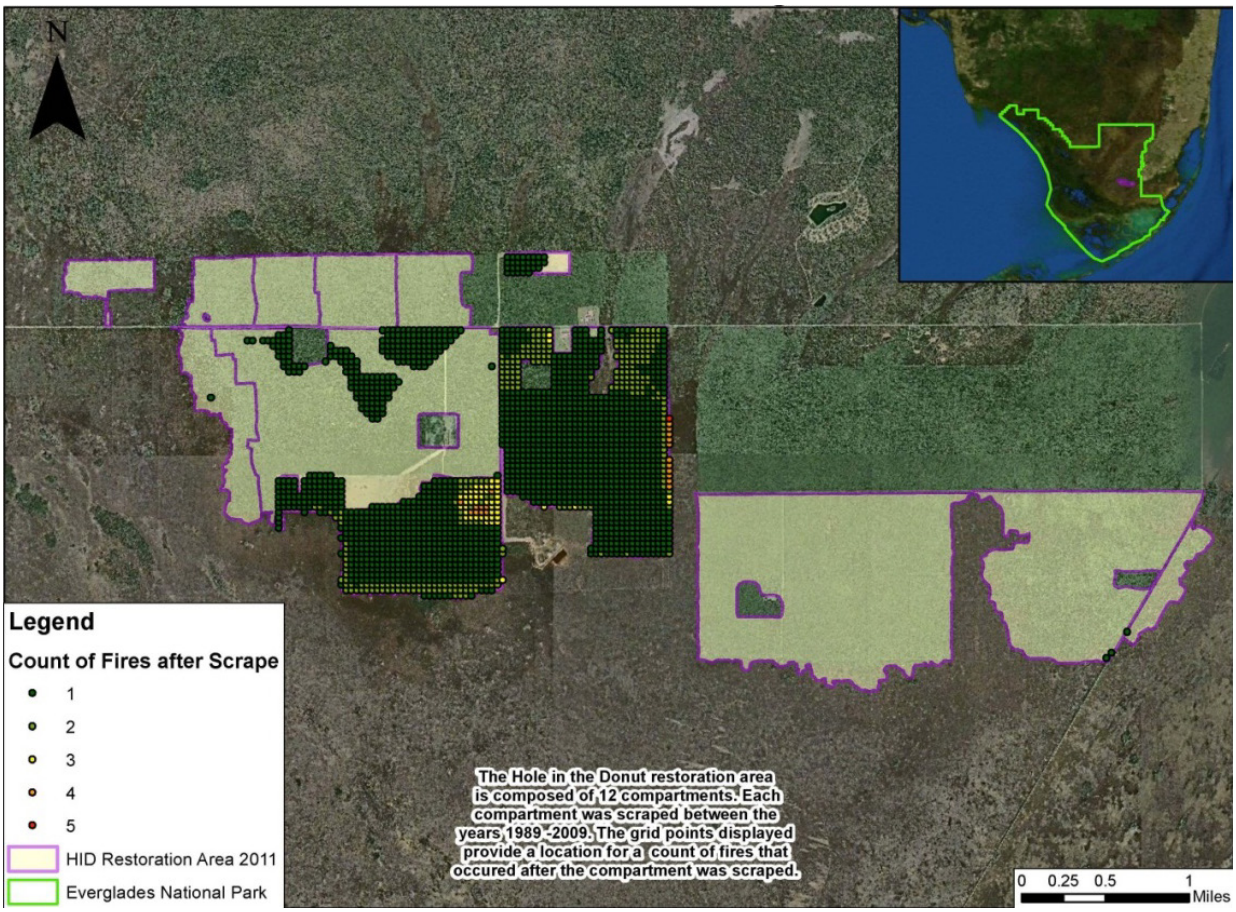


Figure 4.39. The cumulative number of fires occurring among the scraped areas in the HID before 1/1/2012. After 5–10 years of initial biomass accumulation following scraping, a site is ready to experience fires every 3–12 years.

The prospect of continued success in the HID seems likely. The research and monitoring conducted to date indicate that removal of crushed soils and the Brazilian pepper overstory interact with the application of prescribed fires to enhance the physical structure of the environment. Once the physical environment has been enhanced, naturally occurring ecological processes can operate. The development of peat soils in areas with deep water, and marl soils in shallower wetlands continue to enhance soil conditions by diluting residual nutrients. As soil development proceeds, plants establish and self-organize into discreet communities based on the interaction of water patterns, nutrient concentrations, and fire events. These processes appear to be functioning stably across the 4,000+ acres of restored areas. A conceptual model of these processes (Figure 4.40) can be used to quickly communicate the logic of the HID restoration program so that the success of this long-term habitat restoration project can be replicated elsewhere.

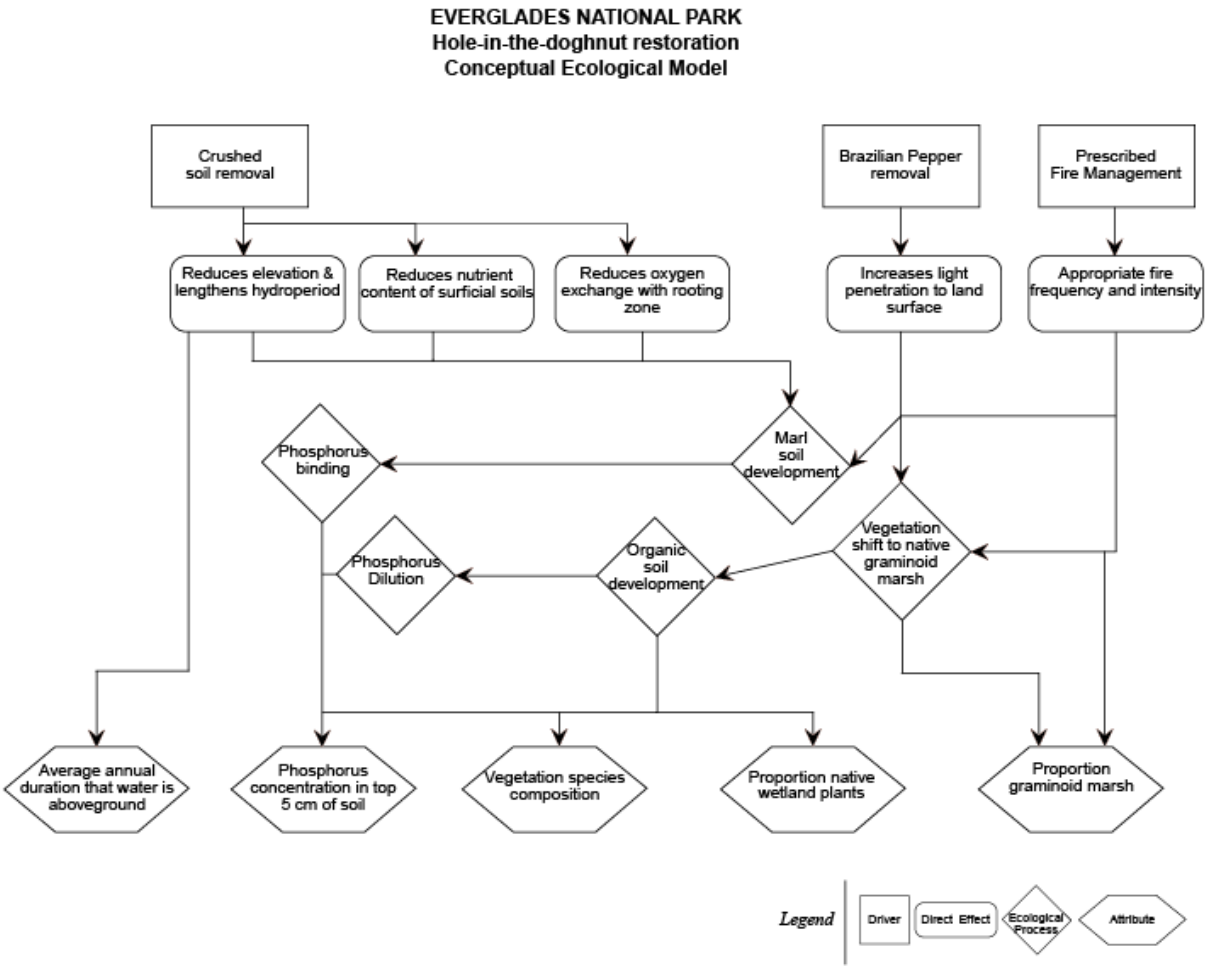


Figure 4.40. A conceptual diagram of the relationships between management actions and the ecological processes that influence vegetation response in the Hole-in-the-doughnut in-lieu-fee wetland mitigation site.

Description of Indicator Monitored

Assessment of the HID ILF is based upon two tiers of indicators. Tier one indicators are found in the HID ILF restoration permits. Tier two indicators are scientifically based goals that are not identified in the permit requirements. NPS managers developed tier two indicators from relevant science conducted in the Everglades ecosystem, and use these indicators to increase awareness of the outcome of the mitigation actions. Tier one indicators include the proportion of cleared area, the proportion of native wetland plants, restoration of appropriate hydroperiods in scraped areas, and the proportion of restored areas that is herbaceous habitat (Table 4.21). Tier two indicators include the percent similarity of plant species composition in sampled areas to reference communities, and natural wetland soil processes (Table 4.22). Three assessment measures are key abiotic (non-living) aspects that affect the success of the mitigation effort (soil removed, hydrology restored and acceptable wetland soil forming functions), and three assessment measures are biotic (living) aspects of the site (proportion native wetland plants, graminoid prairie, and vegetation composition) which are directly affected by the three previous indicators.

Table 4.21. HID metrics associated with permits (Tier 1).

Measurement	Metric	Scale	Threshold
Soil removed	Proportion of area cleared	entire HID site (6,300 ac)	Warrants significant concern = crushed rock soils not removed; warrants concern = crushed rock soils removed; Good = Crushed rock soils removed and vegetation recolonized
Proportion native wetland plants	Percent of native plants observed in monitored sites	Individual scraped areas (~200–2000 ac)	> 99% = Good; 95–99% = warrants concern; <95% = Warrants significant concern
Hydrology restored	% similarity of observed and predicted water depths	Individual scraped areas (~200–2000 ac)	90–100% similarity = Good; 51–89% similarity = warrants concern; <50% similarity = Warrants significant concern
Herbaceous Prairie	Percent Herbaceous prairie	Individual scraped areas (~200–2000 ac)	90–100% Herbaceous prairie = Good; 70–90% Herbaceous prairie = warrants concern; < 70% herbaceous prairie = Warrants significant concern.

Table 4.22. HID metrics associated with NPS ecological goals (Tier 2).

Measurement	Metric	Scale	Threshold
Vegetation composition	Percent similarity to reference community composition	Individual Scraped patches (~200–2,000 ac)	Warrants significant concern = vegetation composition exotic; warrants concern = Graminoid native vegetation trending towards reference composition; Good= Vegetation composition matches ecologically intact areas outside of project footprint
Residual Phosphorus concentration	Concentration of phosphorus in top 5 cm of mineral soil	Individual scraped patches (~200–2,000 ac)	Warrants significant concern = concentration of P elevated above reference marsh (0.25 mg/kg soil); good = concentration of P below 0.25 mg/kg soil

Status and Trends

The status of the HID is that the area continues to warrant concern (yellow), but the mitigation measures are clearly working, and the site is obviously improved since mitigation efforts began in the early 1990's.

Currently, 70% of the HID has had contaminated, crushed soils removed. The areas where soil has been removed are predominately herbaceous wet prairies, with a high proportion of native plant species across a range of hydroperiods (Table 4.23, 4.24, Figures 4.36, 4.37, and 4.41). A more careful inspection of the monitoring information indicates that the species composition is increasingly similar to native communities over time, and that the soil nutrient concentrations are declining. The continued decline of soil nutrient concentrations are inferred from our understanding of soil development processes, and a small project conducted by Inglett et al. (2011).

Table 4.23. HID Condition Assessment permit related (Tier 1) metrics.

Criteria	Condition & Trend	Rationale	Reference Condition
Proportion of area with acceptable soils		70% of the HID has acceptable soil conditions. Significant progress continues.	Continuous marl soils, no crushed soils present
Proportion native wetland plants		Self-sustaining native wetland plant community is present on all restored sites. Exotic species abundance is less than 1% permit threshold in monitored plots.	Native wetland plant community.
Hydrology restored		Hydrology is effectively restored across sites where agricultural soils were removed.	Standing water aboveground for at least two weeks per year. Up to 50 weeks standing water aboveground acceptable in low elevation areas.
Herbaceous Prairie		All restored sites >90% coverage of graminoid prairie.	Wetland plant community dominated by grasses, sedges, rushes or slender emergent wetland plant species.

Table 4.24. NPS ecological goal metrics (Tier 2).

Criteria	Condition & Trend	Rationale	Reference Condition
Vegetation species composition		Graminoid native vegetation trending towards reference composition at all scraped sites.	Marl Prairie, sawgrass marsh, Rhynchospora marsh, or slough vegetation communities
Residual Phosphorus Concentration		Improving trend inferred from limited measures and well understood nutrient removal processes (fire and soil development reduces P availability.)	Phosphorous limited vegetation, with less than 0.25 g phosphorus per kg of soil in open marsh

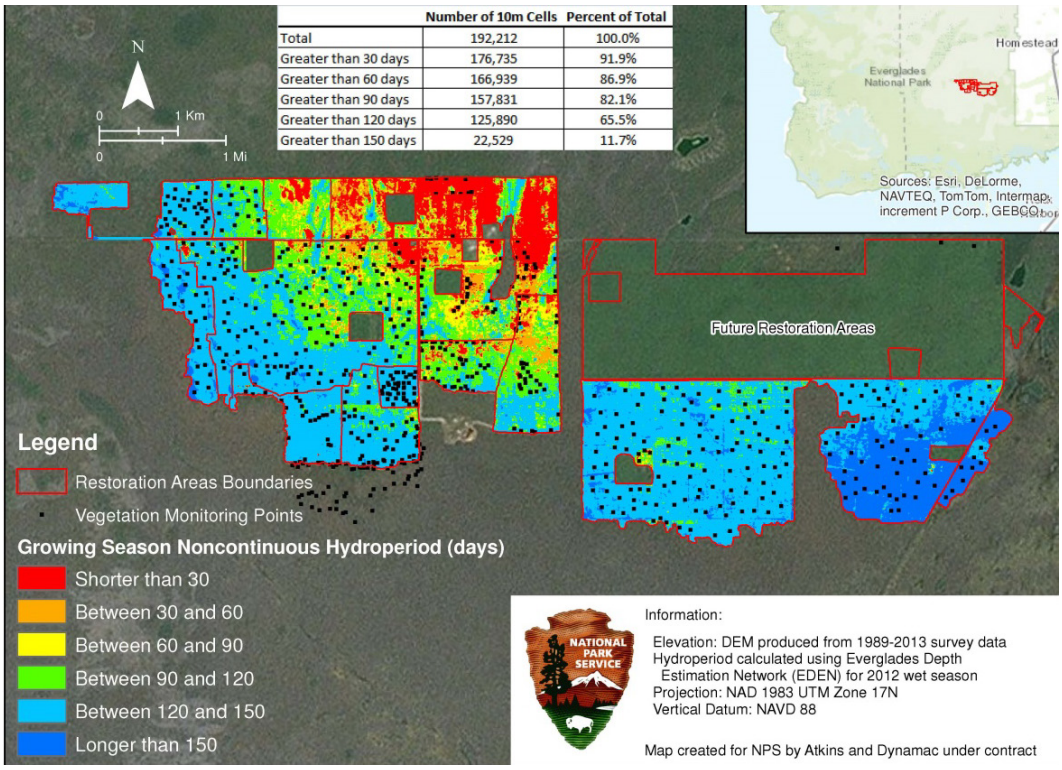


Figure 4.41. Predicted hydrologic conditions on restored sites, determined by the relationship between observed elevations and waters levels observed at long-term water depth monitoring stations.

The monitoring of HID sites confirms that removing crushed rock soil eliminates exotics, restores hydrology, and enables colonization of native species. Prescribed fire enhances habitats, and supports the development of a muhlenbergia-sawgrass dominated graminoid prairie that is similar to the types of marshes that are predominate across other areas in EVER that experience similar hydrology.

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4.6.1.2. Exotic Fish in Freshwater Marshes

Status and Trend

Attribute: Exotic Fish

Overall Condition & Trend:



Rationale: The rate of introduction of new exotic fish species is increasing. Less than 2% of fish monitored in Shark River Slough and Taylor Slough are exotic species. Exotic species are being observed in more locations in recent surveys, suggesting that they are spreading.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

The rate of new introductions has increased since 2000. This is a significant concern and a negative trend (Table 4.25). Seventeen species of exotic fishes have been observed in EVER, which represents a significant change in the composition of freshwater fishes. The Cichlidae (none of which are native to Florida) are now the largest family of freshwater fishes found in EVER, with 10 species present in the park. Increases in the number of exotic introductions appeared to follow changes in water management that altered the connectivity of canals to EVER marshes (Kline et al. 2013). Incorporating invasive species control into the adaptive management process of hydrologic restoration may help reduce the spread of exotic fishes into natural areas and limit further degradation of the native food web.

In the slough habitats, exotic fishes tended to be <2% of the total catch, but across the greater freshwater area, exotic fishes were >2% of the total catch between 2004 and 2009, a significant concern (Figure 4.42 for general spatial reference). However, since the 2010 cold weather event, the relative abundance of exotics dropped below 2%, but exotics were caught in more locations in 2012 than in 2011, suggesting caution is warranted, with an undesirable trend toward a higher relative abundance (Table 4.25). The vulnerability of exotic fish from tropical climates to periodic cold winter temperatures may be a key to their management. Schofield et al (2009) suggest restoring or modifying unnatural deep-water habitats such as canals, borrow ponds, and ditches to allow natural winter cooling, which could help control exotic fish populations.

Table 4.25. Invasive exotic fish (freshwater).

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Rate of new introductions of exotic fish		Since 2000, eight new exotic fish species have been observed in EVER, an increase in the rate of introductions.	Rate of new introductions of exotic fishes is decreasing over time.
Relative abundance of exotic fishes in Shark River Slough		Exotic species are present, but relative abundance continues to be less than 2% threshold in monitored sites.	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.
Relative abundance of exotic fishes in Taylor Slough		Exotic species are present, but relative abundance continues to be less than 2% threshold in monitored sites.	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.
Relative abundance of exotic fishes in EVER-wide annual sample		Exotic species are present, but relative abundance has been less than the 2% threshold at monitored sites since the January 2010 cold weather event. However, exotic species were collected at more sites in October 2011 than in 2010, suggesting an undesirable trend.	Freshwater fish assemblage is dominated by native species and contains less than a 2% relative abundance of exotic individuals.

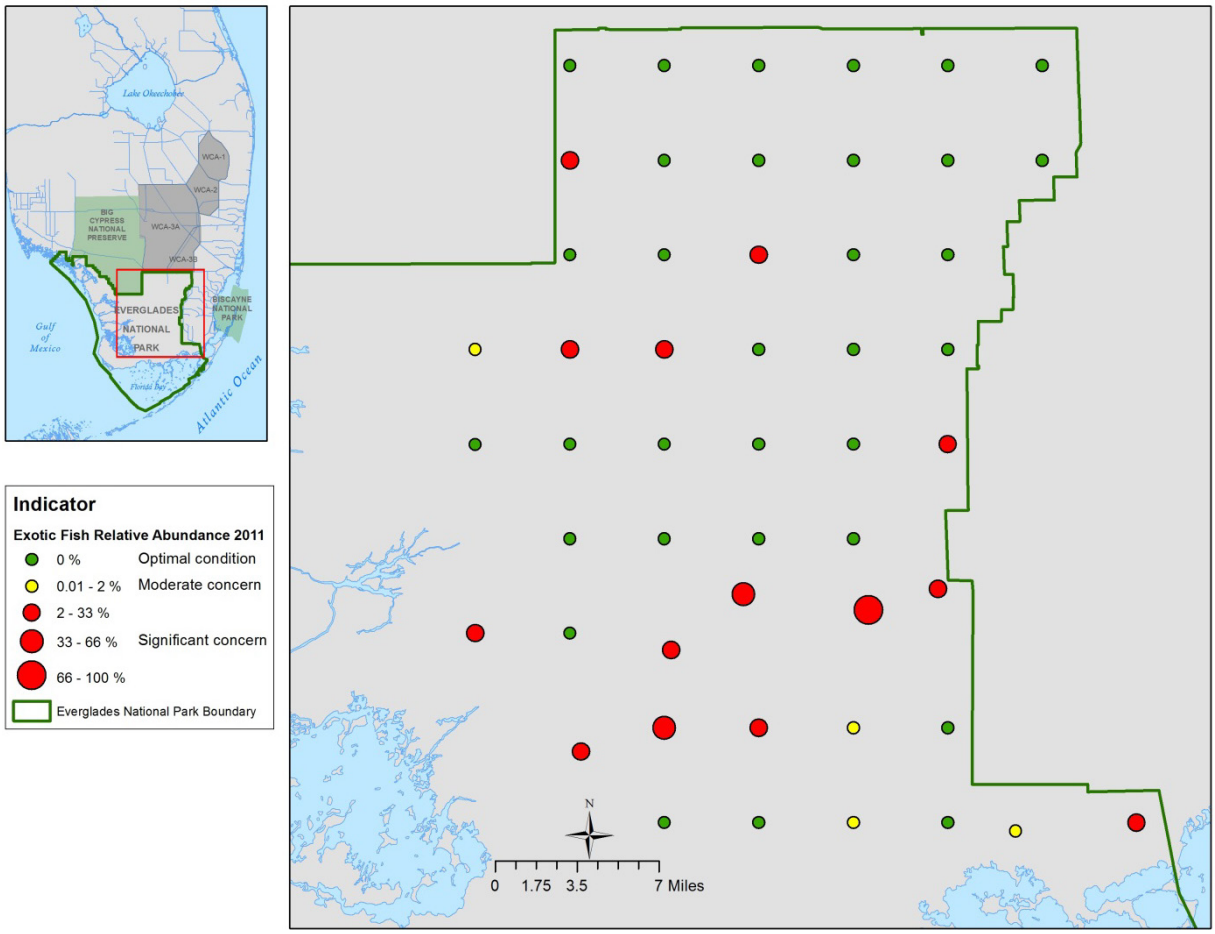


Figure 4.42. Map of the relative abundance of exotic fish at 50 sites sampled in October 2011.

Background and Importance

The invasion of exotic fishes and aquatic invertebrates continues to be a challenge facing natural resource managers in south Florida (Photo 17). Everglades National Park (EVER) is mandated to preserve the flora and fauna in a natural state (1934 Everglades Establishment Act) and to "maintain natural abundance, diversity, and ecological integrity of native plants and animals" (1989 Everglades National Park Protection and Expansion Act). The establishment of exotic species in the park ecosystem conflicts directly with these mandates.



Photo 17. Exotic fish in bucket. Clockwise from one o'clock: brown hoplo, African jewelfish, Mayan cichlid, black acara, jaguar guapote, and black acara again. Photo by Jeff Kline, EVER.

The landscape of present day south Florida is crisscrossed by large and small drainage canals, and contains deep-water habitats "rock pits" that were uncommon prior to development (Gunderson and Loftus 1993). As of 2007, 34 exotic freshwater fish species have established reproducing populations within Florida (Shafland et al. 2008). When released by pet owners or escaped from aquaculture facilities, exotic fishes find refuge in deep water canals from the seasonal drying and cool winter temperatures that normally cause species of tropical origin, vulnerable to cold temperatures, to die (Shafland and Pestrak 1982). After surviving a cold snap, exotic fish to emerge and spread over large areas (Courtenay and Robins 1973, Courtenay and Miley 1975, Loftus and Kushlan 1987, Loftus 1988). The first non-native fishes were found in EVER in the late 1960's to early 1970's (Loftus 1988). By 2000, nine non-native species had been observed in EVER and several species were known from the canal system near EVER but not yet found within park boundaries (Loftus 2000). As of 2012, 17 non-native fishes have been found in EVER and 14 of these appear to have established reproductive populations (Kline et al. 2013). These exotic species represent a significant addition to

the naturally species-poor native fish assemblage found in the freshwaters of EVER (32 species; Loftus 2000). Periodic increases in the number of new exotic species observed in the park appear to correspond with changes in the connectivity of EVER marshes with canals. Enhanced connectivity occurred when operations and design of the water management system was modified (Kline et al. 2013). Preventing future introductions may be the most effective means to manage exotic fishes because effective control or elimination of exotic fishes is difficult and may be impractical within the extensive wetlands of the Everglades (Loftus 1988).

Desired State of Conservation

The rate of new introductions and relative abundance of exotic fish are relevant indicators by which to assess the desired state of conservation of EVER. Few technologies are feasible to control or eliminate exotic fishes in open wetlands (Loftus 1988). Therefore, a decrease in the rate of new introductions is a desired state of conservation of EVER. A freshwater fish assemblage composed entirely of native species is the desired state of conservation. A relative abundance of exotic fish >2% indicates a condition warranting significant concern, between 0% and 2% indicates a marginally degraded but potentially ecologically sustainable condition, and 0% indicates the optimal condition. These criteria were developed by Dr. Joel Trexler, Florida International University, for Shark River and Taylor sloughs in the Freshwater Fish and Macroinvertebrate section of the System-wide Ecological Indicators for Everglades Restoration (SEIER) reports (Doren et al. 2008).

Description of Indicator Monitored

Monitoring efforts are in place to detect new exotic species and track their distribution within EVER marshes. All fish monitoring projects within EVER offer the potential to collect exotic species, and visual observations verified by EVER staff can provide important records of new exotic species occurring in the park. Previous studies provide a baseline condition against which to assess the current exotic species condition. Loftus (1988) documented the early history of invasions by exotic fishes into EVER. Trexler et al. (2000) summarized the relative abundance of exotic fishes from monitoring efforts in EVER from before 2000. Kline et al. (2013) revisited the history of invasions into EVER associated with major water management changes, presented a summary of freshwater monitoring efforts after 2000, and provided accounts of exotic species introduced after 2000. The history of introductions reported by these studies was used to calculate a rate of new introductions of exotic fishes to EVER (number of new species per year) starting in the time period 1947–1949 and continuing on a decadal basis (e.g., 1950–1959, 1960–1969, etc.) to 2010–2012. The decadal time scale was used to reduce the influence that subjectively selected time scales could have on the calculation of rate of new species introductions.

Everglades National Park's long-term monitoring effort has used a one m^2 throw trap to quantitatively sample the small-fish (<80 mm standard length) assemblage in northern Shark River Slough (Figure 4.43) since the 1978 water year (ending April 1978). These data are used to assess the relative abundance of exotic fish within wet prairie and slough habitats based on water years (e.g., the 2000 water year is May 1999 to April 2000). The relative abundance of exotic fish is also assessed with throw traps at three sites in southern Shark River Slough and three sites in Taylor Slough (Figure 4.43) under a cooperative agreement between EVER and Dr. Joel Trexler (Florida

International University), combined with data collected in northern Shark River Slough, and reported in the SEIER reports (Doren et al. 2008).

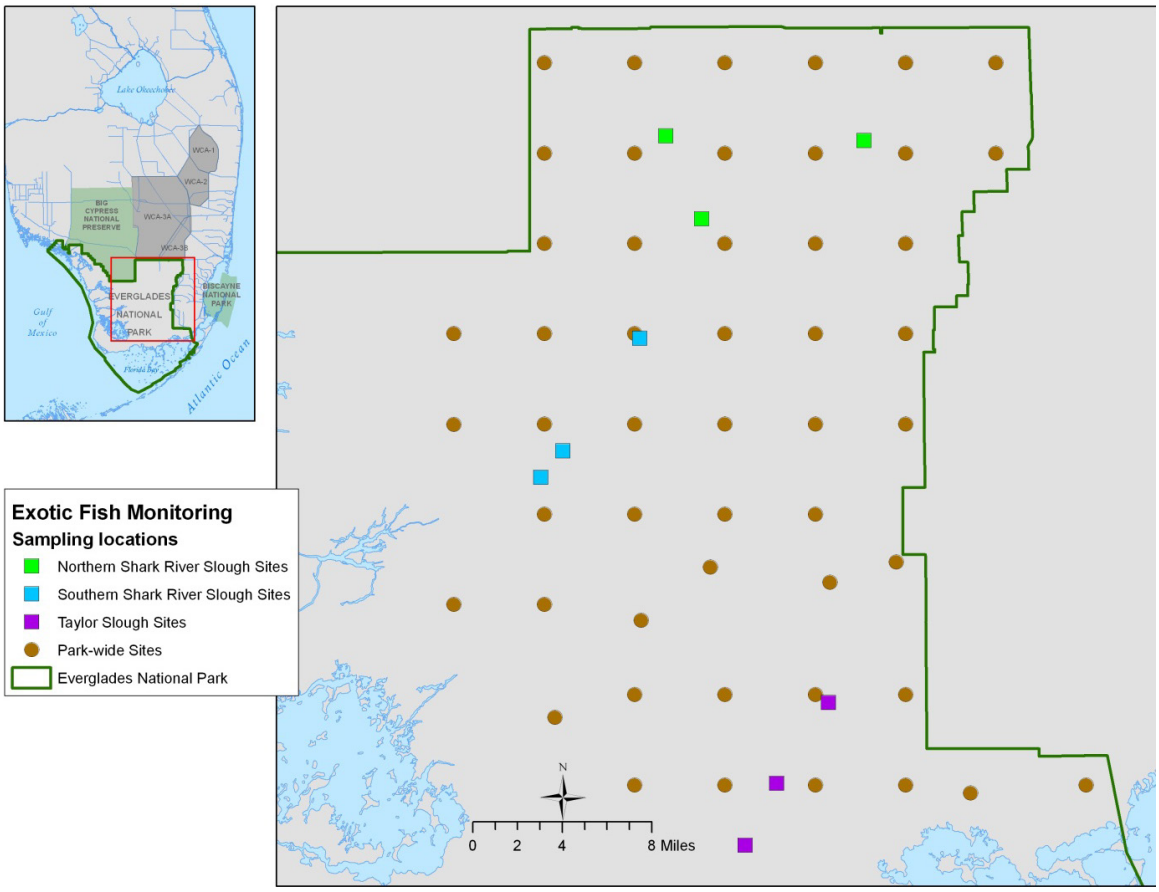


Figure 4.43. Map of monitoring locations for exotic fish indicators.

A park-wide sample has been conducted annually each October from 2004 to 2011. EVER staff collect the samples with the goal of tracking the spread of exotic species throughout the freshwater marshes. Samples are collected from 50 sites throughout the freshwater area of EVER including slough, rocky glades, marl prairie, and mangrove fringe habitats (Figures 4.42 and 4.43). Six minnow traps are set at each site for 24 hours. This method is known to collect a wide variety of species, including exotic species, and generally characterizes the small-fish assemblage at a site. This project also estimates the frequency of occurrence of exotic fishes (percentage of sites where at least one fish of any exotic species was collected), which can be used as an indication of spatial distribution of non-native fishes.

Status of the Indicator in the Current Year and Trends over Time

When EVER was established in 1947, there were no known exotic fishes inside park waters. The exact dates the first exotic fishes (black acara, *Cichlasoma bimaculatum*, and walking catfish, *Clarias batrachus*) were found in EVER is unknown but is presumed to be from the late 1960's to early 1970's (Loftus 1988; Figure 4.44). Between the late 1960's and 1979, three exotic species were

observed in EVER. Between 1980 and 1992, six new exotic fishes were observed in EVER bringing the total to nine (Figure 4.44). No new species were observed between 1993 and 1999. Between 2000 and 2012, eight additional exotic fishes were observed in EVER (Figure 4.44). When time series information is summarized by decade, we estimate one new species per decade in the 1960's, two new species per decade in the 1970's, and five species per decade in the 1980's. The increase in the 1980's occurred shortly after the construction and operation of the South Dade Conveyance System, when water managers began routing additional water to the eastern side of EVER from canals (Kline et al. 2013, Kotun and Renshaw 2013). In the 1990's, only one new species was observed (0.1 species/yr.) during a time when water management was relatively consistent after an increase in pump station capacity in 1992 (Kline et al. 2013, Kotun and Renshaw 2013). In the 2000's, there was an increase in the rate of new exotic species to 0.7 species/yr. coincident with major water management changes, including the Interim Structural and Operational Plan and the Interim Operational Plans (ISOP/IOP), which routed additional water to the eastern side of EVER, raised canal water levels, and increased connectivity of canals to EVER marshes (Kline et al. 2013, Kotun and Renshaw 2013). This increase in species and the increased rate of introductions since 2000 represents a degradation of the aquatic fauna assemblage in EVER, though no new species were collected after 2010. At present, 17 species of exotic fish have been observed in EVER, and of these, 10 species are in the family Cichlidae.

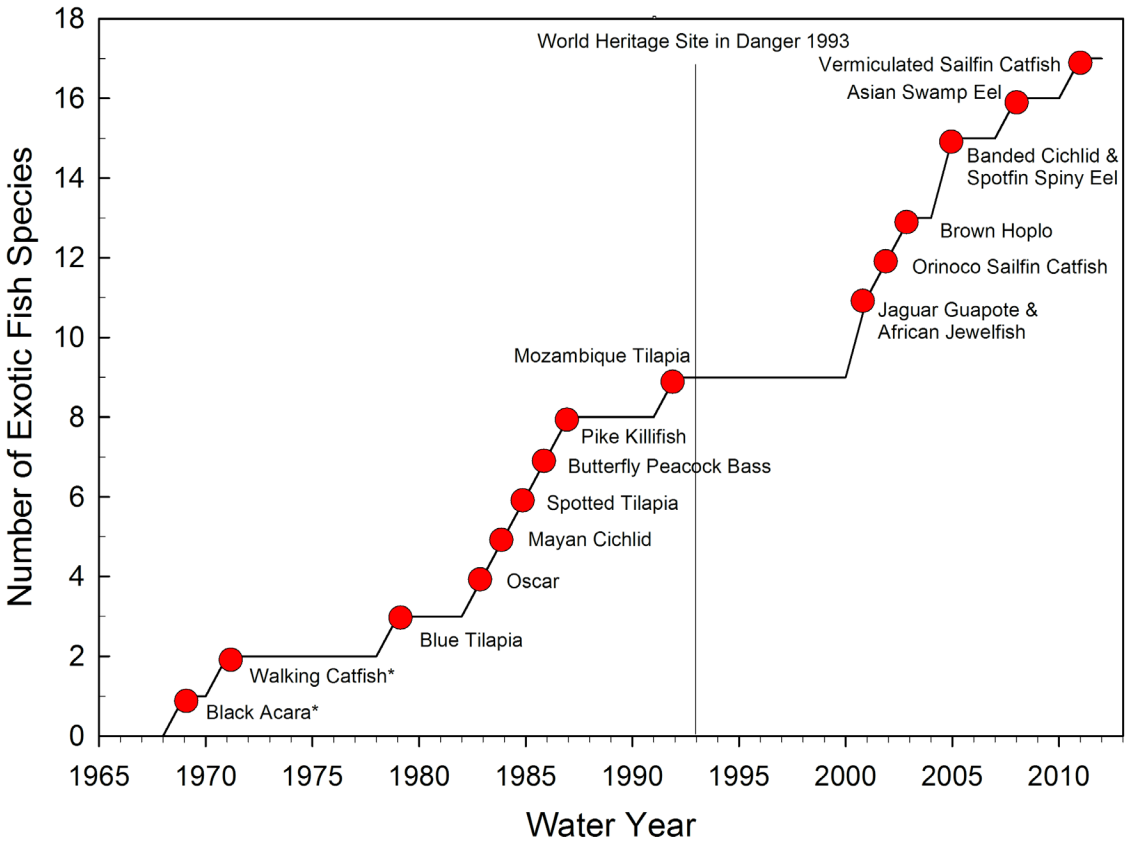


Figure 4.44. Timelines of the introductions of exotic fish species into EVER. * denotes an approximated date.

No exotic fishes were collected at the long-term monitoring sites within northern Shark River Slough from the start of the project in 1978 through the 1984 water year. The first exotic fish (a black acara) was collected in the 1985 water year, but no other individuals were collected until 1991 (Figure 4.45B). In the 1993 water year, the relative abundance of exotic fish peaked at 2.5% of the total catch. Since then, the relative abundance of exotic fish was consistently less than 2% and no exotic fishes were collected in the 2011 water year (Figure 4.45A). The cumulative number of exotic species reached three species by 1993 and then increased to four species in 1995. No new species were collected until the 2004 water year. Between 2004 and 2008, four additional exotic species were collected. The relative abundance of exotic fish species in both Shark River and Taylor sloughs was <2% in 2012, similar to that reported in the 2009 SEIER. However, exotic species were present at the throw-trap sites in the slough habitats indicating a moderately degraded, but stable status.

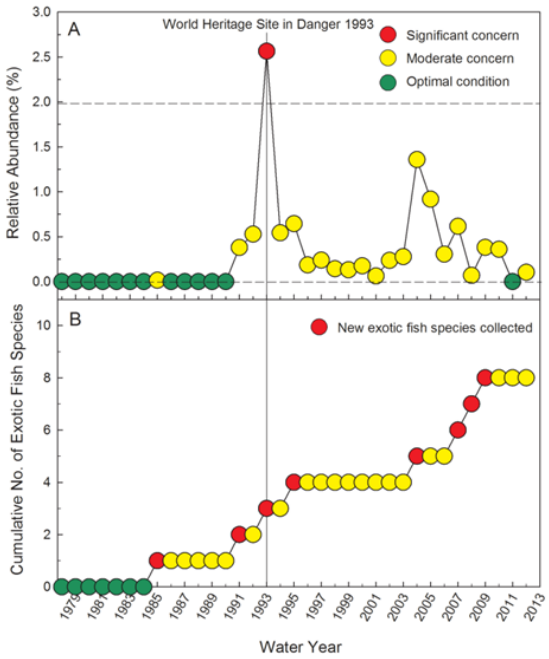


Figure 4.45. The A) relative abundance and B) cumulative number of exotic fish species collected with throw traps in northern Shark River Slough from 1978 to May 2012.

The number of exotic fish and the proportion of fish biomass that were exotic were highest in the park wide samples collected from 2004 to 2009; however, catches were lower in 2010 and 2011. Between 2004 and 2009, an average of 2 to 8 exotic fish were caught per site (Figure 4.46A) and the relative abundance of exotic fish was between 8 and 18% of the total catch, warranting a negative condition (Figure 4.46B). At least one exotic fish was collected at 56–78% (28–39 sites) of the 50 sites between 2004 and 2009 (Figure 4.46C). The relative abundance and frequency of occurrence of exotic fish dropped following a cold weather event in January 2010 (Figure 4.46B and C). In 2010 and 2011, the mean catch dropped below an average of one exotic fish per site and the relative abundance of exotic fish dropped below 2%, warranting a cautious condition and positive trend assessment (Figure 4.46B). In 2010, exotic fish were only collected at 13 sites (26%). In 2011, exotic

fish were collected at 18 of 50 sites (36%; Figure 4.46C) and were at a relative abundance >2% at 14 sites (Figure 4.42), an indication the exotic fish populations were expanding.

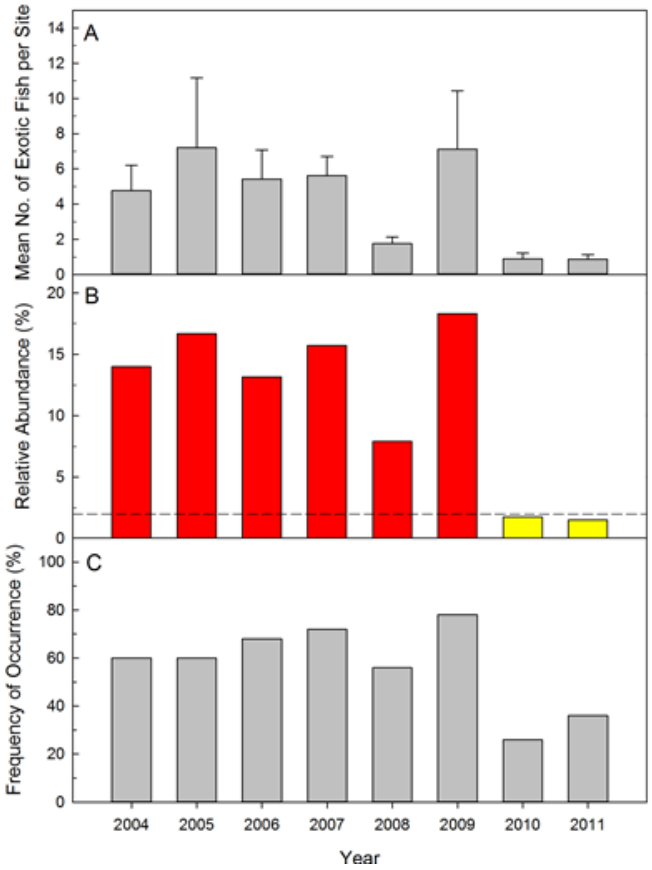


Figure 4.46. The A) mean number per site, B) relative abundance (%), and C) frequency of occurrence of exotic fish at 50 sites sampled in October of each year during 2004–2011. Columns summarize all sampled sites throughout the freshwater marshes of EVER. A relative abundance of >2% is the threshold for significant concern (red) and >0 and <2% indicates a moderate concern rating (yellow).

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4.6.1.3. Invasive exotic herpetofauna

Status and Trend

Attribute: Exotic herpetofauna

Overall Condition & Trend:



Rationale: The rate of introduction of new exotic herpetofauna species is increasing. Burmese pythons are widespread and reproducing in the wild (Photo 18). Eradication of exotics outside of EVER is effective in small areas, but challenges remain with recognizing and addressing the full range of infested locations. Tegu populations are growing outside of EVER, and are being detected inside EVER more frequently.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.



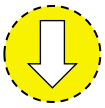
Photo 18. Burmese pythons are now regularly encountered along roads and levees throughout the Everglades landscape. Photo by Michiko Squires, University of Florida.

Highlights

Invasive species issues have sometimes taken a back seat to landscape-scale Everglades restoration efforts. This has perhaps partially contributed the current condition and trends detailed above and summarized in Table 4.26 below.

More recently, however, the South Florida Ecosystem Restoration Task Force (SFERT)—representing senior policy advisors from federal, state, local, and tribal interests—has increasingly prioritized action against harmful nonnative species. In cooperation with the ECISMA, the SFERT began drafting a strategic action framework in 2013 that, when fully developed, aims to orchestrate existing efforts against invasive species and could provide opportunities to better meet the desired state of conservation described herein.

Table 4.26. Summary of the herpetofauna indicators in EVER.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Rate of new herpetofaunal introductions in and around EVER		Florida has more established exotic herpetofauna than any other place in the world (Krysko et al. 2011). EVER is at high risk for additional invasions of exotic herpetofauna.	Minimize and eliminate new invasive herpetofaunal introductions to EVER.
Containment and control of established populations: Burmese python		Burmese pythons are now widespread and are having negative impacts on native species.	Burmese python population in the park is contained and decreasing.
Response efforts to known invasive species adjacent to EVER: North African python		Response to a small and contained population of North African pythons adjacent to EVER demonstrated that removals can be effective for small areas. Full eradication may not be possible.	Known invasive species adjacent to EVER are eliminated prior to establishment in the park.
Response to recent introductions to the park: Argentine tegu		Tegus have recently moved into EVER but reproduction has not yet been detected. Trapping is possible but resources (staff and funding) are inadequate. The extent of spatial distribution of tegus inside the park is uncertain.	Recent introductions to the park are effectively addressed and populations of incipient invasive species are eliminated.

Background and Importance

The prolonged invasion of south Florida by myriad nonnative reptile and amphibian species is well documented. The region enjoys a subtropical climate, is a major gateway of global trade in live animals, and supports a heavily populated, culturally diverse metropolis of high relative wealth—all circumstances that aid the introduction, establishment, and spread of invasive species (Chiron et al. 2010, Pyšek et al. 2010, Engeman et al. 2011). Once established, these species rarely prove manageable. Rather, their ability to persist and flourish presents the potential to negatively impact

native wildlife populations, change ecosystem structure and function, become a nuisance to human communities, and/or alter the historic character of the invaded area.

Recent studies reveal that the invasion of Florida by herpetological species is particularly severe. As of 2011, 56 reptile and amphibian species were established in the state, a number unmatched anywhere in the world (Krysko et al. 2011). The vast majority of these species are found in southern Florida, persisting around and—in some cases—within the Everglades ecosystem (Meshaka 2011). For more than a century, repeated inventories of reptiles and amphibians have documented an accelerated rate of new introductions (King and Krakauer 1966, Wilson and Porras 1983, Meshaka et al. 2004, Meshaka 2011). Nonnative invaders now account for more than one-fourth of the herpetological species presently found in Florida (Meshaka and Ashton 2005).



Photo 19. Ongoing evening surveys provide one method for monitoring the status of invasive herpetofauna. Photo by Michiko Squires, University of Florida.

Given limited resources, competing management priorities, and a paucity of effective control tools, it is impractical to attempt management of all nonnative reptile and amphibian species currently established in and around Everglades National Park (EVER). National Park Service policies stipulate that species that present the greatest potential for impact and/or the greatest promise for control are afforded top priority (NPS 2006). In accordance, three species of considerable concern have been

targeted for management: the northern African python (*Python sebae*), the Argentine tegu (*Tupinambis merianae*), and the Burmese python (*Python molurus bivittatus*; Photo 19).

The northern African python appears to be established over a relatively small area of central Miami-Dade County that immediately borders the northeastern corner of EVER. The Argentine tegu—an omnivorous, terrestrial lizard of considerable size—is well established in southern Miami-Dade County, and multiple individuals have been intercepted along the EVER border. At present, there is no evidence to suggest that northern African pythons or Argentine tegus are reproducing within the park proper. The Burmese python, however, is presently well established across a very large swath of south Florida, including all terrestrial ecosystems of EVER.

Collectively, these three species all show potential to spread beyond their current range (tegus are a temperate species), negatively impact native wildlife through competition and direct predation, and adapt to new environments. Each of these species, however, exists within a distinct state of invasion relative to the park and—consequently—each serves as a benchmark for the park's larger efforts against nonnative herpetofauna.

Desired State of Conservation

The desired state of conservation for this indicator is a notable decline in the number of nonnative herpetofaunal species found in the greater Everglades ecosystem, a decrease in the spatial extent of their occurrence, and a reduction of impacts on park resources from their presence.

Efforts to manage invasive herpetofauna are hampered by the continued introduction of new reptile and amphibian species. Each new arrival demands attention that diminishes the availability of the finite resources at the park's disposal. Thus a necessary precursor to attaining our desired state of conservation for established species is to substantially slow the rate of additional introductions with the eventual goal of eliminating new arrivals altogether.

Prevention is the park's most effective and least costly management option, and remains the preferred conservation scenario. Eradication—through the application of early detection and rapid response protocols—is desired where new introductions do occur, particularly when they threaten resources within EVER. Management goals for well-established species that are unlikely to be eradicated in the next decade are to contain the non-native species within a known geographic area and begin to reduce of the size of the observed population.

In summary, the following four goals define our desired state of conservation:

Goal 1: The rate of new herpetofaunal introductions in and around EVER decreases over time.

Goal 2: Known invasive species populations in lands adjacent to EVER are detected and eliminated prior to establishment in the park.

Goal 3: Recent introductions to the park are effectively addressed and populations of incipient invasive species are eliminated.

Goal 4: Established populations are contained, decreases in the health/abundance of established populations are achieved, and the ecological effects of these species on resources within EVER are reduced.

Description of Indicator Monitored

A series of herpetological inventories has been published for EVER, providing historical snapshots of the reptile and amphibian assemblage in the park (Dalrymple 1988, Meshaka et al. 2000, Rice et al. 2004). Coupled with periodic inventories regularly published for the larger region, these studies also provide a measure of the rate of new introductions experienced over time.

Several ongoing early detection, monitoring, and suppression efforts help inform the status of nonnative reptile and amphibian species in south Florida. Much of this work is performed under the auspices of the multi-agency Everglades Cooperative Invasive Species Management Area (ECISMA), a coalition of partners and cooperators that address invasive species issues across jurisdictions within the region. The ECISMA was first organized through a Memorandum of Understanding in 2008, to which EVER was a formal signatory.

ECIMSA partners continually aggregate and verify observations of nonnative species through telephone, online, and mobile reporting avenues. Rapid response efforts are regularly organized through the ECISMA to assess new arrivals of management concern and attempt the eradication of incipient populations. These include ongoing surveys to assess the status of northern African pythons and ongoing efforts to trap and remove Argentine tegus.

ECISMA partners also work collaboratively on several long-term monitoring and containment efforts. The Everglades Invasive Reptile and Amphibian Monitoring Program (EIRAMP)—spearheaded by the University of Florida—utilizes systematic, periodic surveys along standardized routes to help document the presence and distribution of invasive species within the region. Working on behalf of federal and state authorities, both authorized agents and individual permit holders help detect and remove invasive reptiles within their respective jurisdictional boundaries. ECISMA partners also solicit involvement from the public through online and in-person training opportunities that encourage and facilitate the reporting and/or removal of invasive reptiles.

Finally, EVER and other partner agencies fund and/or facilitate key research projects that help document the occurrence, life history, impact, and potential for control of exotic invasive amphibian and reptile species. The results of these various efforts have informed our current assessment and will inform subsequent assessments of relevant status and trends.

Status of the Indicator in the Current Year and Trends over Time

The status of invasive exotic herpetofauna is described in the context of four natural resource goals.

Goal 1: The rate of new herpetofaunal introductions in and around EVER decreases over time.

At present, it appears the rate of new introductions in Florida continues to escalate, particularly in the Everglades region (Photo 20). This is evidenced not only by the establishment of new taxa (Krysko et al. 2013, Rochford et al. 2013), but also by the discovery of new satellite populations of species previously established elsewhere in the state (Florida Fish and Wildlife Conservation Commission

2014). If this trend continues unabated, it will become increasingly difficult to prevent new species from colonizing EVER and to manage those species already present.



Photo 20. The Oustalet's chameleon (*Furcifer oustaleti*) has recently become established in close proximity to the eastern boundary of ENP. Photo by Emma Hanslowe.

Nearly 84% of Florida's nonnative herpetofauna has been introduced through the pet trade (Krysko et al. 2011). Although trade is regulated for a handful of exotic reptiles and amphibians through state and federal statute, the vast majority of herpetological species remain available for import and personal ownership. Given the known shortcomings of present authorities, there is little promise that regulation will curb the influx of new introductions in the near future.

Goal 2: Known invasive species adjacent to EVER are detected and eliminated prior to establishment in the park.

In 2010, researchers offered compelling evidence that the northern African python was established in Florida, following several years of encounters within a limited geographic range in central Miami-Dade County (Reed et al. 2010). These recoveries included individuals of various size classes, gravid females, and exceptionally large specimens (Reed et al. 2011a, b). Although this population presently exists within close proximity of the northeastern boundary of EVER, best available evidence suggests the species has not yet made incursions into the park.

Coordinated, multi-agency surveys for the northern African python have occurred annually since 2009. Surveys are conducted on select days during winter months, when weather conditions are most amenable for detection and capture. Occasional searches conducted by state-permitted hunters augment detection efforts throughout the year, as do opportunistic road patrols by ECISMA partners. An ongoing public information campaign also encourages residents of nearby communities to report all sightings of large constrictors.

Five northern African pythons were removed from the area during 2013, and more than 30 have been seen or captured in the area to date. Population estimates remain elusive, due largely to presumably poor rates of detectability and the inherent difficulties of surveying a largely inaccessible landscape.

Still, the species does not appear to have spread beyond a roughly 10-km^2 area of infestation over the past decade.

Given their limited distribution and relatively low rate of occurrence, there is considerable optimism that northern African pythons can be eradicated. This hope is further buoyed by the high level of interagency cooperation involved in the effort. At least one recent case study suggests that an aggressive, multi-agency approach can lead to the successful eradication of an established invasive reptile. However, this typically requires prolonged support and engagement from all partners. The invaded range of the northern African python encompasses a patchwork of differing jurisdictions. It is important to note that not all landowners presently permit survey and removal on their lands—a reality that could compromise the efficacy of future efforts.

Goal 3: Recent introductions to the park are effectively addressed and populations of incipient invasive species are eliminated

A seemingly robust population of Argentine tegus continues to thrive in southern Miami-Dade County in close proximity to the eastern boundary of EVER (Pernas et al. 2012; Photo 21). An omnivorous species, the Argentine tegu can ingest a wide variety of live prey, consume eggs of nesting birds and reptiles, and possibly compete with native species for available resources. Similar impacts have been observed from other areas where this species has become an invasive pest (Enge 2007).



Photo 21. Argentine tegus are routinely trapped along the eastern boundary of EVER. NPS photo by Emma Hanslowe.

Two complementary programs currently exist to address the Argentine tegu. In 2013, ECISMA partners established an extensive trap line within—and along the periphery of—the core area of infestation in an effort to contain the existing population and monitor for spread. That same year, the U.S. Geological Survey (USGS) established a second network of traps along the eastern boundary of EVER nearest the area of infestation, attempting to intercept individuals moving westward toward the park along known dispersal corridors. Both networks—which include both live animal traps and

motion-activated cameras—are tended through late October, after which tegus enter a prolonged period of dormancy until the following February. Telemetry work has also been conducted to better understand patterns of nesting and dormancy in south Florida, and several private trappers have been working under state permit to aid in the removal of tegus.

Collectively, all efforts resulted in the removal of 182 tegus of various size classes in 2013 (Eckles 2013). Of these, 11 were intercepted by the USGS along the eastern boundary of EVER. Because trapping and interdiction efforts against Argentine tegus are relatively new, little can be inferred at present regarding the relative size and health of the target population. Nonetheless, results from the initial years of effort indicate that the population is firmly established and that individuals are utilizing dispersal corridors to invade new locations. The ability to continue containment and interdiction programs against tegus remains questionable, as these programs are labor intensive and generally lack necessary funding and personnel.

Goal 4: Established populations are contained, decreases in the health/abundance of established populations are achieved, and the effects of these species on resources within EVER are reduced

The Burmese python is now well established in the Everglades region. Because they share many characteristics with northern African pythons (Photo 22), assessing the relative size and health of the population is similarly difficult for Burmese pythons. Nonetheless, observations and captures confirm that pythons are likely present throughout all terrestrial habitats of EVER and now range considerably farther north and west of park boundaries (Florida Fish and Wildlife Conservation Commission 2014).



Photo 22. Despite its size, the cryptic habits and coloration of the northern African python make detection difficult. NPS photo by Lori Oberhofer.

Recent studies on the ecology of the Burmese python in Florida shed some light on the cost of establishment. Direct predation on a wide variety of native, warm-blooded wildlife is well documented (Snow et al. 2007, Dove et al. 2011). For some taxa, the results have been severe. The presence of Burmese pythons has been linked to a precipitous decline in the number of small and medium-sized mammals observed in the park (Dorcas et al. 2012). Among this group, foxes and marsh rabbits seem particularly impacted, as sightings in the park have become exceedingly rare.

Current control techniques provide virtually no hope for eradication of Burmese pythons (Reed and Rodda 2009). Applied experience also reveals that these techniques offer limited value in suppressing the current population across the vast wilderness of EVER. Furthermore, recent research continues to identify the Burmese python as a surprisingly adaptable species whose influence, perhaps, has not yet been fully felt (Mazzotti et al. 2007, Dove et al. 2012, Hart et al. 2012).

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4.6.2. Ridge, slough, and tree island (RSTI) patterned landscape

Status and Trend

Attribute: Ridge, slough, tree island landscape

Overall Condition & Trend:



Rationale: The status of the ridge, slough, and tree island patterned landscape in EVER warrants significant concern. The RSTI landscape in the north half of Shark Slough and Rocky Glades are seriously impaired. The RSTI landscape in Broad/Lostman's River is stable in most areas. Southern Shark Slough and Coastal Swamps/Lagoons are relatively stable. White water lilies are not abundant in any portion of the park due to insufficient water volume deliveries, and sawgrass marshes have expanded into areas that were formerly sloughs. Soil loss risk is high in this region where peat soils should predominate. Exotic plants are more prevalent in areas of severe impairment to the landscape. Habitat quality for birds and mammals is likely to be significantly diminished in the compromised portions of the Ridge-slough-tree island landscape.

Highlights

- Ridge, slough, and tree island patterned landscapes (Photo 23) are a defining feature of the main overland drainage in Everglades National Park
- Mean tree island neighborhood areas for tree islands larger than one acre were 51% smaller in 1952 compared to 2004 (Figure 4.47). Small animals must search nearly double the area to find forested habitat that is larger than one acre.
- Tree island loss is concentrated in East Everglades Addition lands, the southern edge of Shark River Slough, and the Rocky glades region
- White water lily is no longer abundant throughout the Everglades ecosystem, as it was prior to regional drainage (LoGalbo et al. 2012 and references therein).

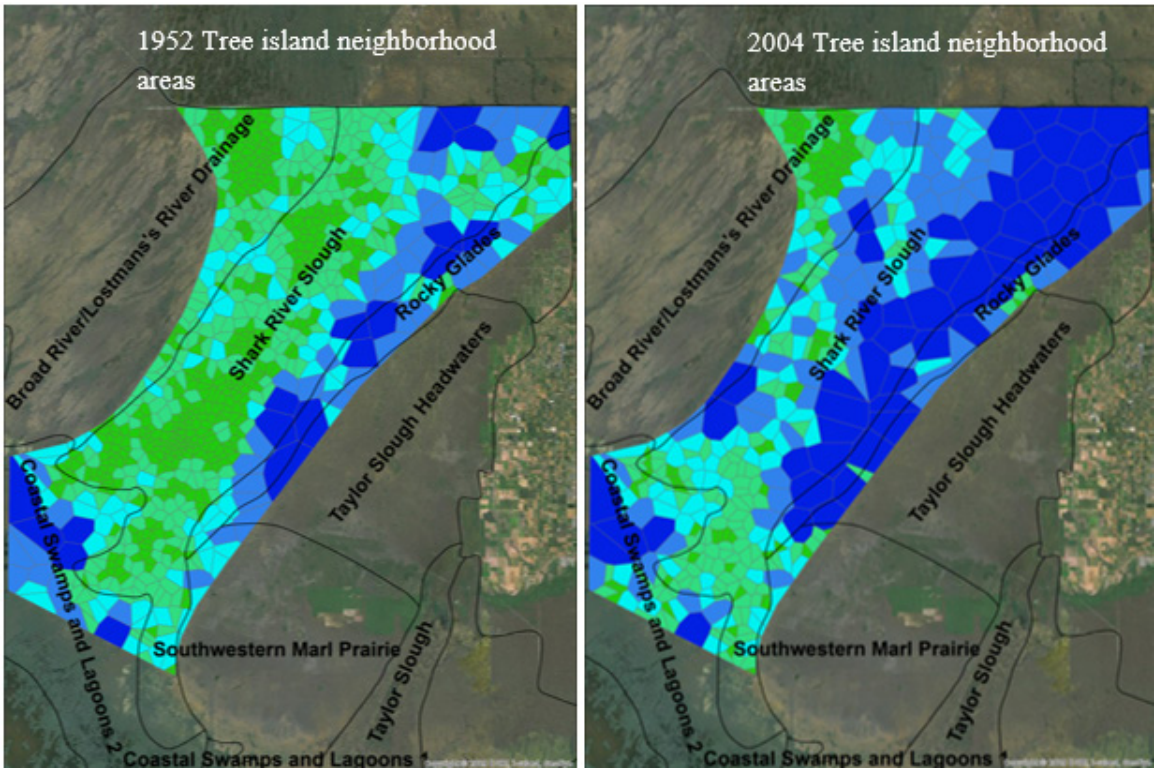


Figure 4.47. Tree island neighborhood areas in 1952 and 2004. Tree island losses over the five-decade period are widespread, with the eastern half of Shark River Slough and the Rocky Glades areas demonstrating the largest proportional losses. The size of polygons reflect distance between to the nearest neighboring tree islands. The 1952 picture shows a higher number of tree islands and shorter distances between islands than the 2004 picture, a very small number of locations accumulated tree islands during this period.

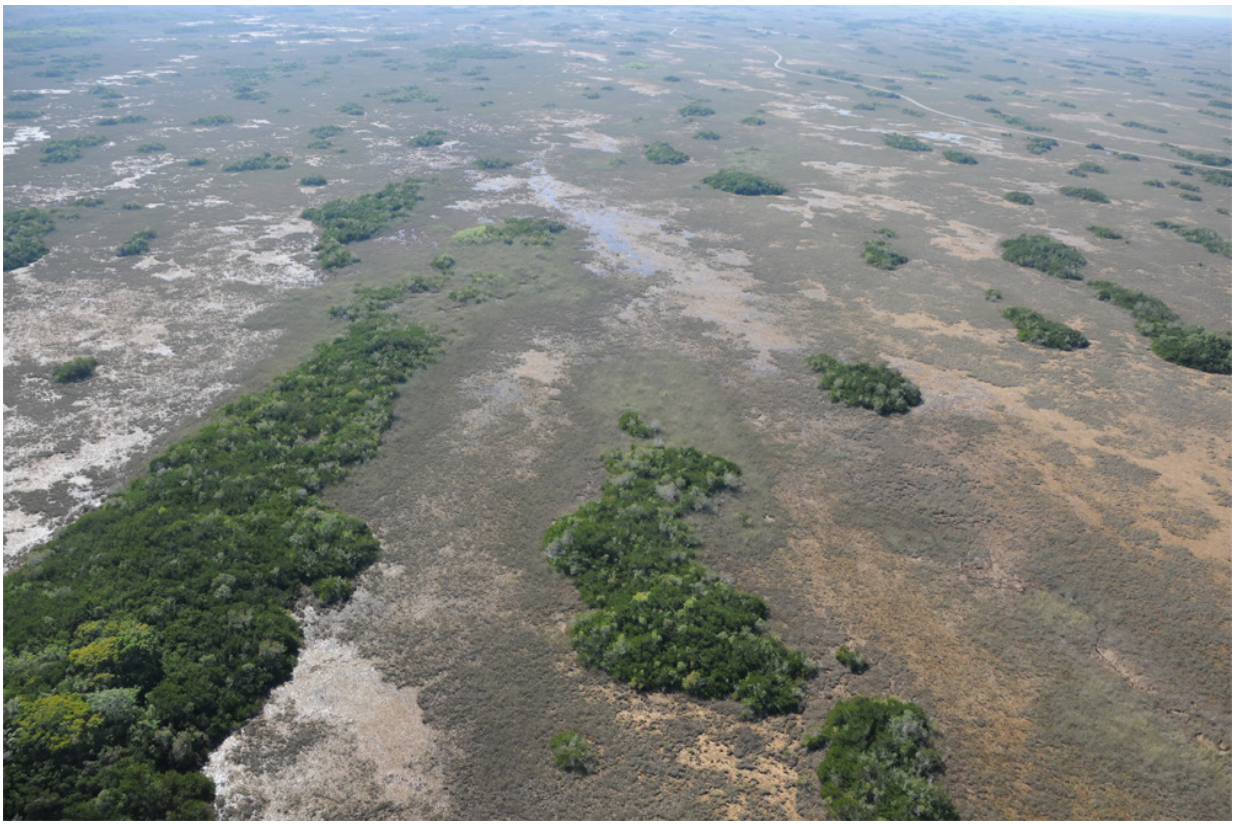


Photo 23. The ridge, slough, and tree island patterned landscape in Everglades National Park, 2013. Photo provided by Joaquin Alonso.

Background and Importance

Tree islands are disproportionately important habitat for birds and mammals. Loss of tree islands is indicative of lack of water and correlated with peat soil loss.

The ridge, slough, and tree island (RSTI) landscape in EVER is centered in the Shark River Slough region and covers 26–28% of EVER land area (or roughly 400 of the 1530 square miles of the park lands). Historical evidence suggests that the patterned landscape extended into the Rocky Glades, Broad/Lostman's River, and Western Coastal Swamps and Lagoons regions (McVoy 2011). Taylor Slough also contains some areas of the RSTI patterned landscape. A significant amount of research, model development, and landscape-scale design tests have been focused on this landscape type. The indicator metrics used here are based largely on this body of research that is effectively summarized by Latham et al. (2010).

Tree islands are the dominant forest type in the RSTI landscape. The tree islands are often teardrop shaped and oriented in parallel with the prevailing direction of water flow. A cross-section of a healthy RSTI landscape shows a regular, repeating pattern of sloughs, ridges, and tree islands that are spaced 100–150 intervals (Watts et al. 2010). Tree islands cover less than 10% of the RSTI landscape, but are disproportionately important for the ecological functions that occur across the landscape. Tree islands are biodiversity hotpots for birds (Gawlik and Rocque 1998). Tree islands

concentrate scarce phosphorus through a large variety of different mechanisms (those mechanisms complied by Latham and Coronado 2010, are: evapotranspirational pumping of surface and groundwater - McCarthy and Ellery 1994, Rietkerk et al. 2004a, Ross et al. 2006; higher dry fallout deposition on trees - Weathers et al. 2001, Krah et al. 2004; increased deposition of animal bones and feces under trees - Lund 1957, Burton et al. 1979, Frederick and Powell 1994, Tomassen et al. 2005, Coultas et al. 2008; and the dissolution of phosphorus from limestone by the acidification of the rhizosphere by tree roots - Wetzel et al. 2005).

The RSTI landscape emerges from an expansive peat/muck soil system where water is abundant and nutrients (like nitrogen and phosphorus) are scarce. Effective protection of the ridge, slough and tree island habitats requires a stable peat soil system. Protecting peat soils will require alterations to the design and operation of regional water management infrastructure (Duever 2005, Ogden 2005). Two different processes are responsible for peat soil loss, and both are linked to lack of water. Rapid consumption of peat soils during intense fire events can destroy centuries of accumulated peat in a single event. Gradual loss of peat soils through oxidation can occur when hydroperiods are shortened, and the rate of decay of peat accelerates due to the presence of more oxygen in soils that are exposed to the atmosphere (compared to soils that are covered in water). This process has been described as “microbial” oxidation of soils, which can result in the loss of a decade or more of accumulated peat soil in a single year; 0.6 in of peat loss per year is the observed long term average in the Everglades Agricultural Area (Shih et al. 1998), while maximum peat accumulation rates in the Everglades are between 0.04–0.1 in per year (Larsen et al. 2007).

It is the combination of slow processes of nutrient redistribution combined with periodic flushing events, which redistribute floating carbon that sustain a healthy RSTI landscape. High water volume can flow through the channelized sloughs during brief, high rainfall events that occur in the late wet season (August through November). Birds and small mammals are important dispersers of seeds into tree islands, and the loss of large numbers of tree islands is likely to impact populations of these two species groups.

The status of the RSTI landscape in EVER warrants significant concern and the trend is declining. Interpretations of aerial imagery indicate that tree islands larger than one acre are 60% less frequent since 1940 (Figure 4.48). White water lilies were historically the dominant species in long hydroperiod sloughs, and are quite rare in EVER now. Sawgrass dominated ridges have expanded to cover lost tree islands and sloughs. Risk of soil loss due to dehydration and subsequent decomposition is unacceptably high in northeastern Shark River Slough and the Rocky Glades region. The risk of soil loss due to fire has declined since the 1980’s, due to integration of the East Everglades into the park in 1989, an enhanced wildland fire program, and greater awareness of risks of fires during dry conditions among managers and the general public. Table 4.27 summarizes the park-wide indicator metrics for the RSTI patterned landscape.

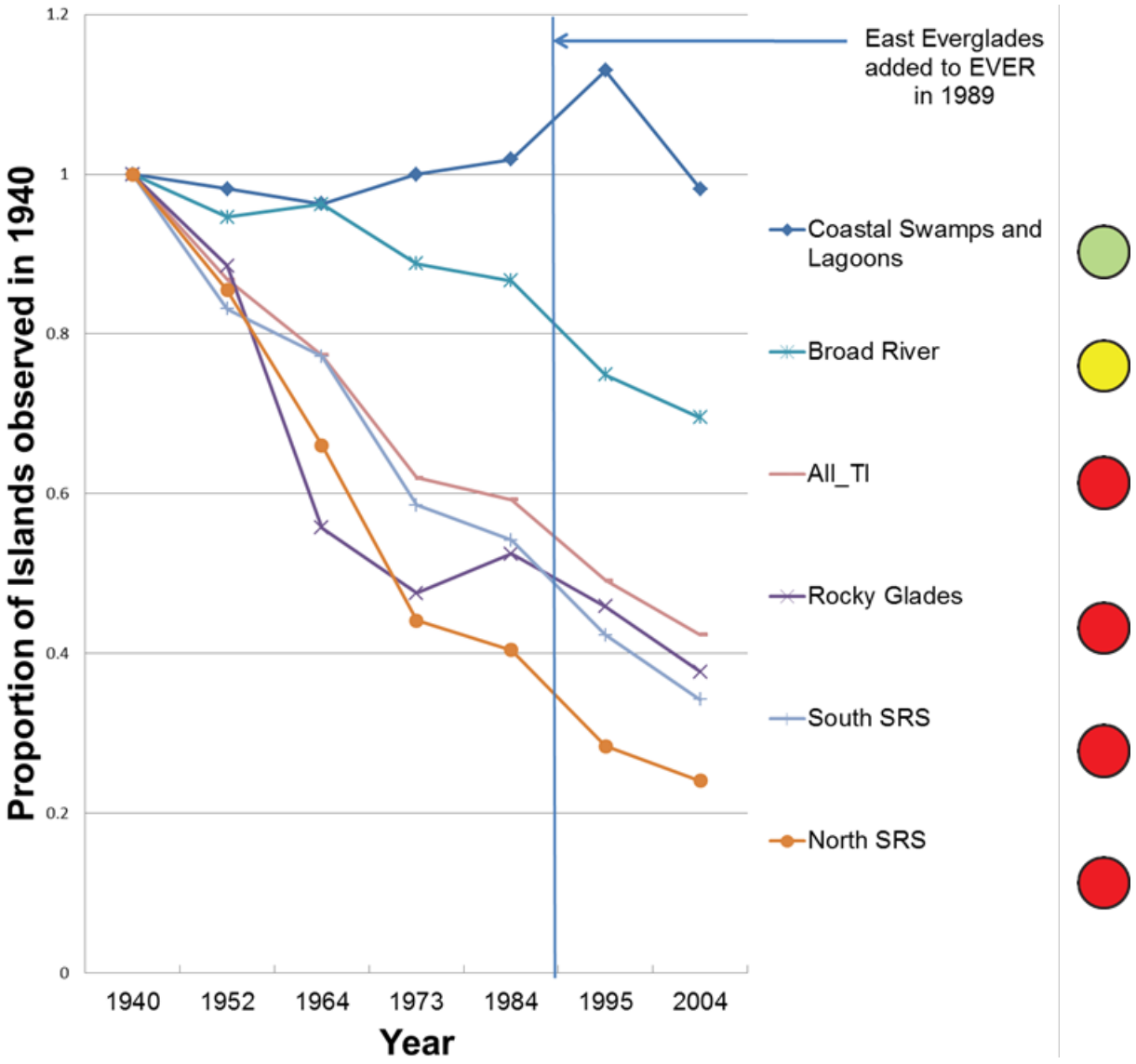
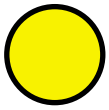


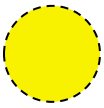
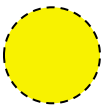
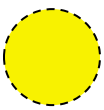
Figure 4.48. Proportional decline in the number of tree islands larger than one acre in the different regions of Everglades National Park.

Table 4.27. Status and trend of ridge, slough, and tree island patterned landscape warrants concern and is declining.

Indicators of Condition	Condition & Trend*	Rationale	Reference Condition
Tree island neighborhood area		Tree islands have declined ~10% per decade (both area and number of Tree Islands) consistently since the 1940's.	Tree islands should be stable components on the landscape for century long timescales.
Exotic plant presence		Northeastern Shark River Slough is heavily infested with exotic species. Treatment activities over the last two decades are improving the condition of this region.	Exotic plant species were much less frequent at the time EVER was established. The goal for most species is less than 1% cover per km^2. Goals for Lygodium and Schinus are less than 5% cover per km^2
Soil dehydration risk		Soil dehydration risk is unacceptably high in northeastern Shark Slough.	Aggrading peat/muck soils are desired in RSTI landscape. 8–10 months per year of water aboveground is required for peat/muck soils to develop.
Soil fire risk		An uncontrolled, peat consuming, tree island destroying fire burned ~40,000 ac during May-June 2008. Dry season fires have become less frequent in Shark River Slough since the area affected by this type of fire peaked in the 1984–1995 period.	No fires that consume peat soils or burn the canopy of trees should occur.

The conditions of the RSTI landscape among the regions of EVER are quite different (Table 4.28, Figure 4.48). The spatial pattern of tree island decline is quite similar to the spatial pattern of soil loss (see section 4.5). The status and trends of the RSTI habitat in Taylor Slough have not been measured, so our assessment in these areas is based on best professional judgment. Exotic plants, soil dehydration, and soil fire risks are different among regions as well. Extensive treatment of exotic plants has occurred along the eastern boundary of EVER. Soil dehydration and fire risks are worst in the northeastern corner of Shark River Slough and the Rocky Glades regions. The few tree islands that occur in the (Western) Coastal Swamps and Lagoons region are essentially unchanged since the 1940's, and the RSTI landscape that occurs in the Broad/Lostman's river region is the least degraded (and best hydrated) of the regions.

Table 4.28. RSTI landscape assessment for individual regions of EVER. Large differences exist between regions. Rocky glades is worst, northern Shark River Slough is next worst. Western Coastal Swamps and Lagoons is most stable, with Broad/Lostman's river and Taylor slough the next best.

Physiographic Region	Tree island neighbor-hood area	Exotic plant presence	Soil de-hydration risk	Soil fire risk	Rationale
Region 2 – Broad and Lostman's River					~30% of tree islands lost since 1940's. Region is a bit overhydrated due to regional water management infrastructure. Exotics are relatively sparse in this region.
Region 3 – Shark River Slough - north					~78% of tree island lost since 1940's. Soil fire risk, and soil dehydration is quite severe here. Melaleuca is primary exotic, and extensive management is occurring over last decade. Risk of soil fires decreasing due to wildland fire program.
Region 3 – Shark River Slough - South					~65% of tree islands lost since 1940's. Soil dehydration and fire risk is historically low. Exotic plants are sparse.
Region 4 – Rocky Glades					Rocky glades are chronically dehydrated, mustang corner fire started here, historical fires have done extensive damage. Exotic plants are extensive with most intensive exotics management effort in park focused on this region.
Region 6 – Western Coastal Swamps and Lagoons					Most stable region for tree islands since 1940's (no loss). Lygodium spreading in region, although little evidence of RSTI infestation.
Region 8 – Taylor Slough					Tree island change unmeasured. Significant hydrologic restoration has progressed since 1990's.
Region 9 – Southeastern Marl Prairie					Landscape scale tree island change unmeasured. Significant hydrologic restoration has progressed since 2000's.
Region 12 – Eastern Coastal Swamps and Lagoons					Landscape scale tree island change unmeasured. Significant hydrologic restoration has progressed since 1990's.

Metrics and supporting analyses

Given our clear understanding of the processes that form and sustain the RSTI landscape, we can reduce the assessment of status of this landscape type to a few key metrics: tree island neighborhood size, soil dehydration risk, and soil fire risk (Table 4.29). Each of these assessment metrics are supported by long term monitoring programs. Tree islands are monitored with aerial photography at roughly decadal intervals. Aerial photographs are interpreted by people with ESRI ArcMap software. More precise monitoring of tree island physical structure and species composition occurs in the context of the CERP landscape monitoring design. Water levels across the marsh are estimated daily across the region by a network of water depth/flow stations. The USGS synthesizes this information and provides it publicly online. Soil dehydration risk and soil fire risk both utilize water level information as well. Soil dehydration risk simply sums the cumulative drought intensity of each location where water stages are estimated for a defined period. Soil fire risk identifies water conditions during fire events and provides a summary of the cumulative risk of soil loss across all fire events that occur within a defined time period.

Table 4.29. Ridge, slough, and tree island landscape (RSTI) indicators for Everglades National Park are evaluated at a landscape scale and for individual regions of EVER where the RSTI landscape occurs.

Measurement	Metric	Scale	Threshold
Tree island neighborhood area	neighborhood area	RTSI landscape	Good Condition: 6–110 Ha Moderate Concern: 110–224 Ha Significant Concern: ≥ 225 Ha
Exotic plant presence	Proportion of 1km cells above “controlled” criteria	RTSI landscape	Good Condition: < 1% of 1km areas “controlled” Moderate Concern: 1–5% of 1km areas “controlled” Significant Concern: > 5% of 1km areas “controlled”
Soil dehydration risk	Best professional judgment	RTSI landscape	Best professional judgment
Soil fire risk	Fire risk index	RTSI landscape	Good Condition: no areas with decadal soil risk index > 4* Moderate Concern: up to 5% of area with decadal soil risk index > 4* Significant Concern: > 5% of area with decadal soil risk index > 4*

* Soil fire risk identifies how far below the soil surface water levels were during each fire event and provides a summary of the cumulative risk of soil loss across all fire events that occur within a defined time period.

Supporting analyses

Each of the tree island assessment metrics was created as a part of an analysis of an individual subject. Summary maps, data tables, and/or graphs for each metric are presented here.

1. Tree island neighborhood area: Figure 4.48 depicts the long-term trend of tree island loss. Figure 4.49 shows the spatial patterns of tree island loss (or gain) at each decade of the analysis. Figure 4.50 depicts tree island decadal losses. Gains of tree islands occurred in a

small number of locations in each decade, but were much smaller than the losses of tree islands. The small number of tree islands that were gained in each decadal interval have been documented, but are not shown in this report due to space constraints. The graphs depict the size prior to loss (X-axis) vs. loss area (Y-axis). Proportion of area lost indicated by size/color of circle. Black lines cross each graph at 25 ac tree island that lost 15 ac of size in all graphs. Results indicate that fewer tree islands registered loss in the first two decades, but larger islands were lost during this time. This result suggests that current landscape has smaller tree islands that are less stable features of the landscape that was present six decades ago.

2. Exotic plant presence: Figure 4.51 shows the presence of exotic plant species using a 1 km summary grid. Each cell is colored based on the status relative to the goal for exotic coverage. Overlaid on this map are the physiographic regions, and it is clear that exotic plants are unevenly distributed across regions of the park.

3. Soil dehydration risk: Figure 4.52 identifies the areas of northeastern Shark River Slough and Rocky Glades regions that have water aboveground far less frequently than Broad/Lostman's River and southern Shark River Slough.

4. Soil fire risk: Figure 4.53 shows the overall count of dry season/large-scale (larger than 2,000 hectares) fires from 1948–2012. Figure 4.54 shows the count of dry season/large-scale fires on roughly decadal intervals. The intervals are defined by aerial imagery collection dates and the fire counts were used to detect whether a relationship exists between the spatial pattern of dry season fire count and tree island loss patterns.

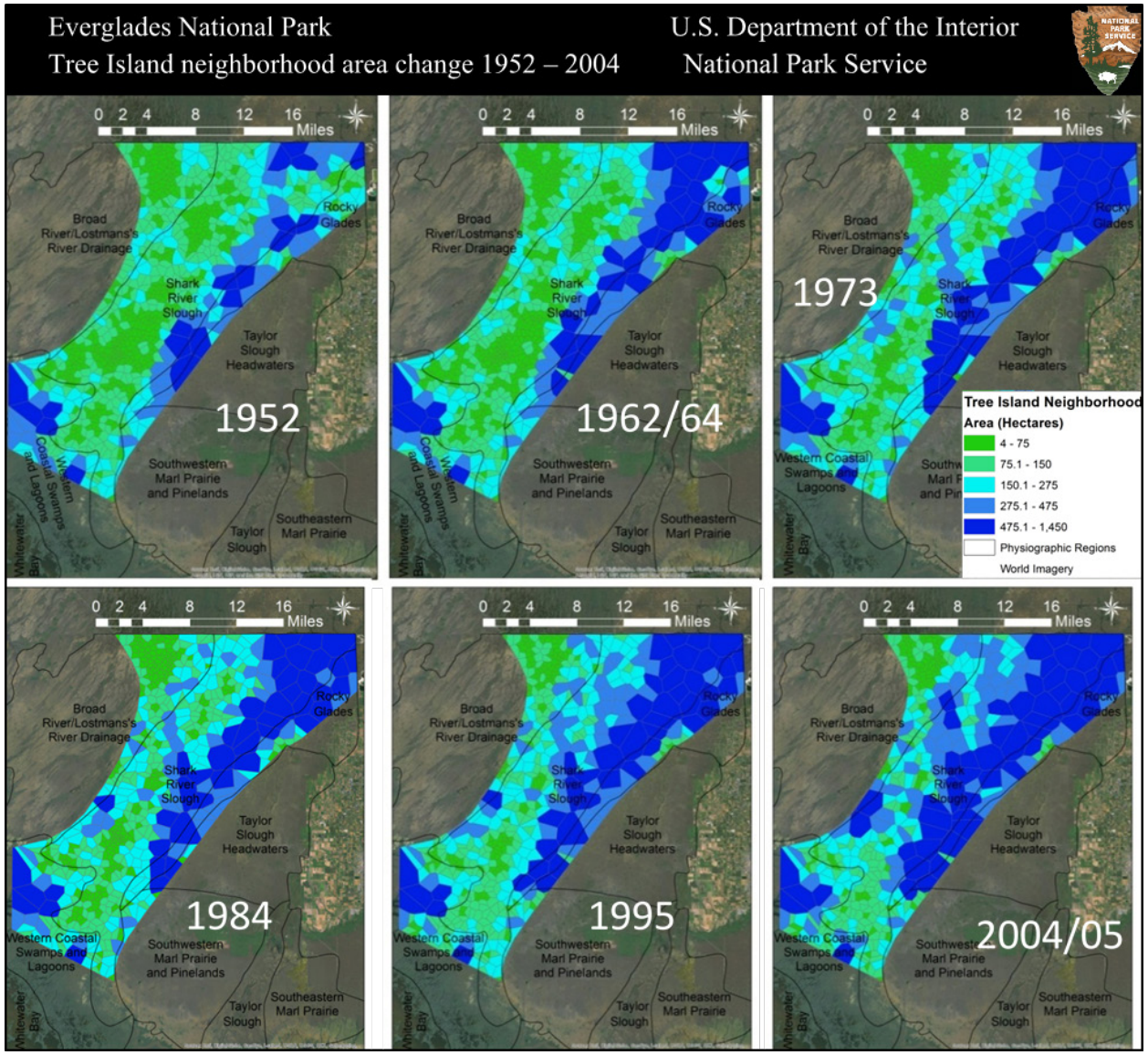


Figure 4.49. Map summary of tree island neighborhood areas from 1952 through 2005.

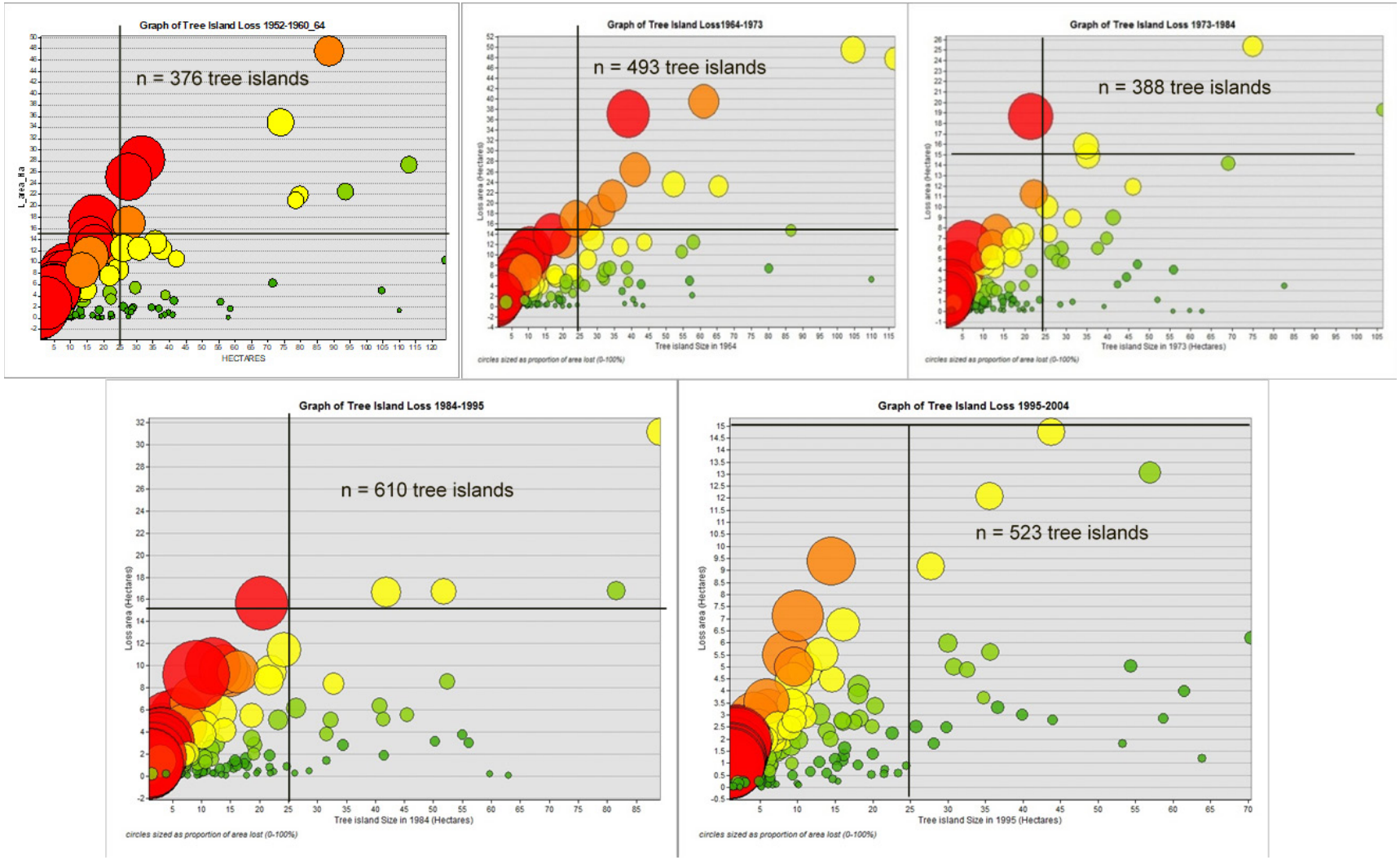


Figure 4.50. Reductions in tree island sizes on decadal intervals between 1952 through 2004. The graphs depict the size prior to loss (x-axis) vs. loss area (Y-axis). Proportion of area lost indicated by size/color of circle. Black lines cross at 25-ac tree island that lost 15 ac of size in all graphs.

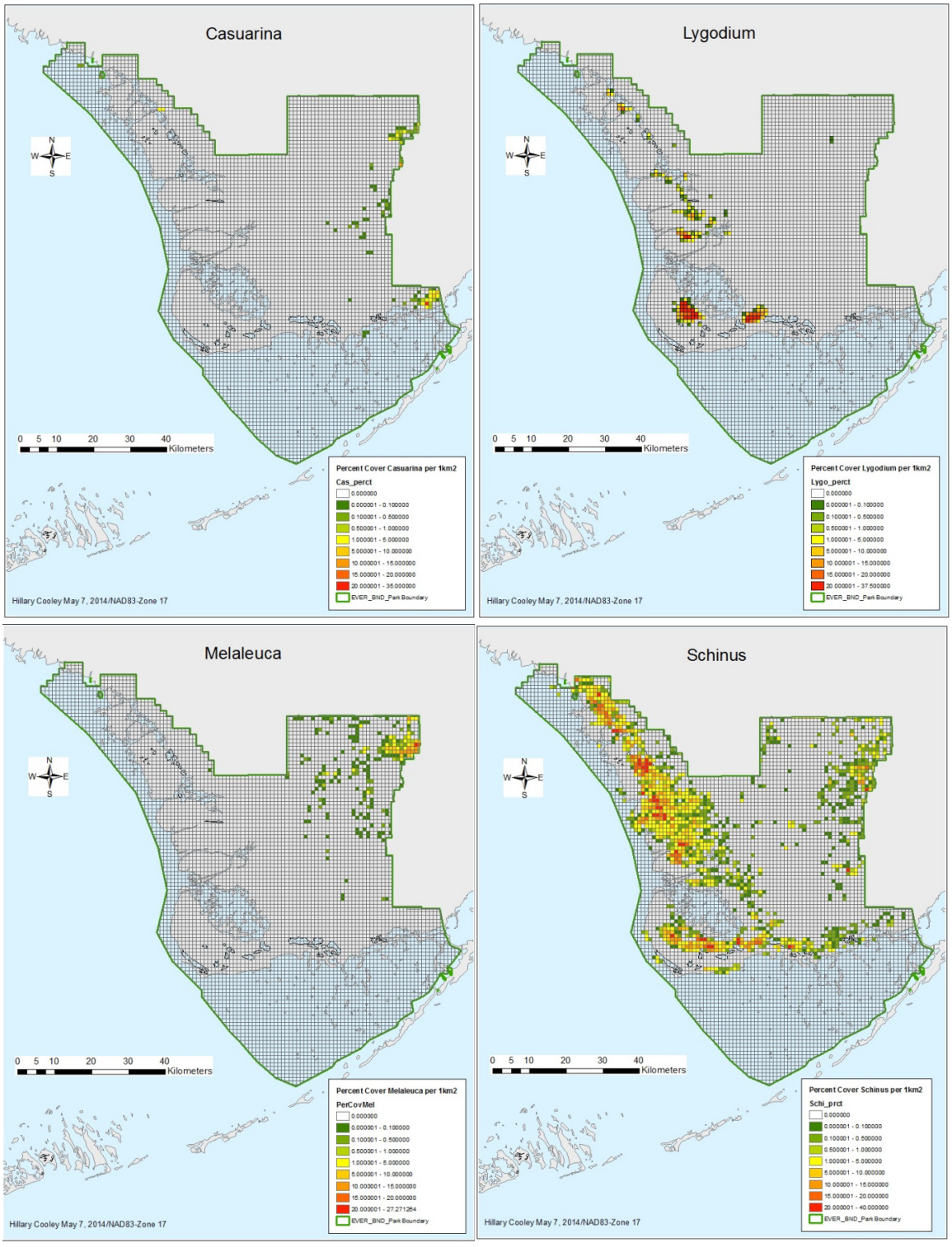


Figure 4.51. Top four exotic plant species coverage relative to goals. No color = no exotics detected, green = below target threshold, yellow = just above target threshold, orange/red = clearly above target threshold.

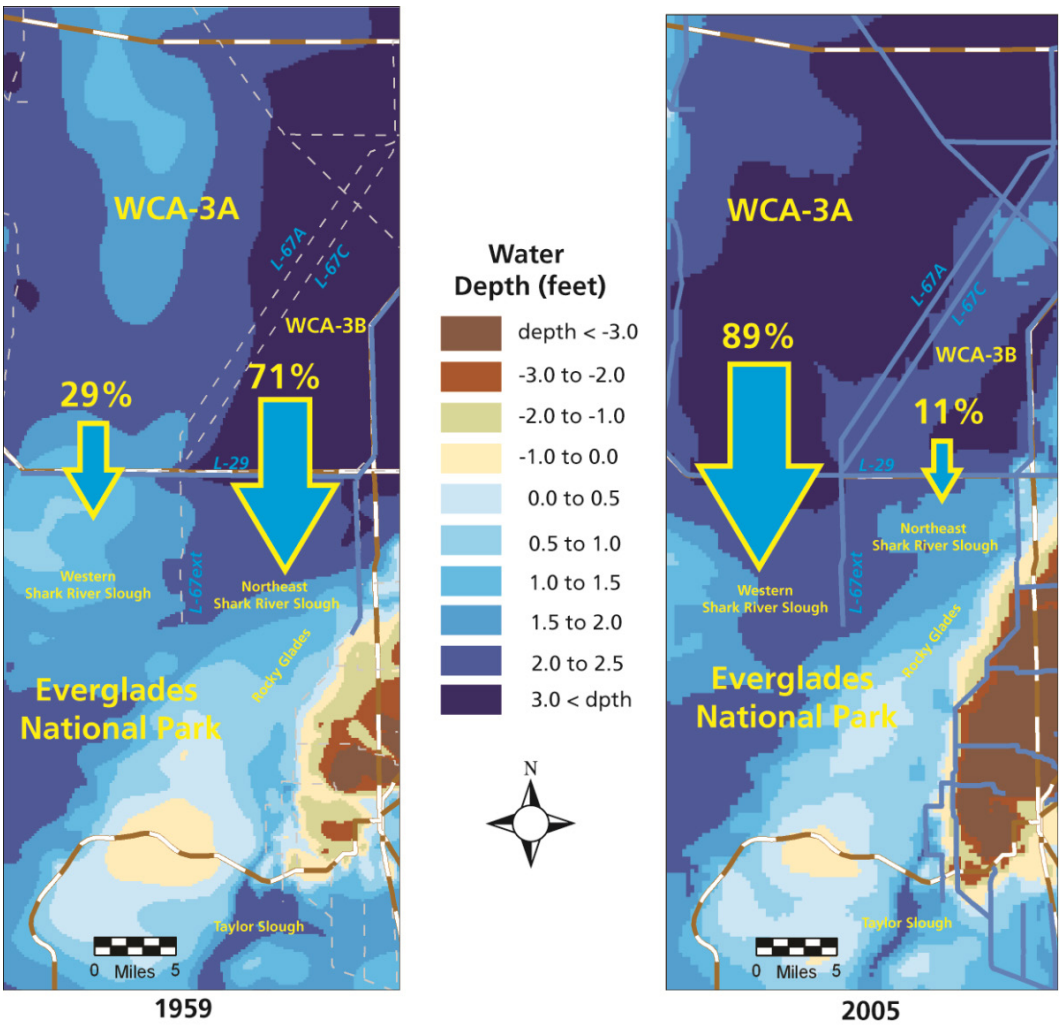


Figure 4.52. Water depths and flow distributions for two wet years (1959 and 2005) when more than 1 million acre-feet of water was discharged to Shark River Slough, Everglades National Park. These two years correspond to the period prior to compartmentalization (1959) and post-compartmentalized Water Conservation Area (WCA) 3 (2005). Prior to compartmentalization, the higher water depths and flow volumes were more confined to the eastern flow-way through Northeast Shark River Slough. Today, as depicted in 2005, the deeper water and greater flows are more confined to Water Conservation Area 3A and Western Shark River Slough.

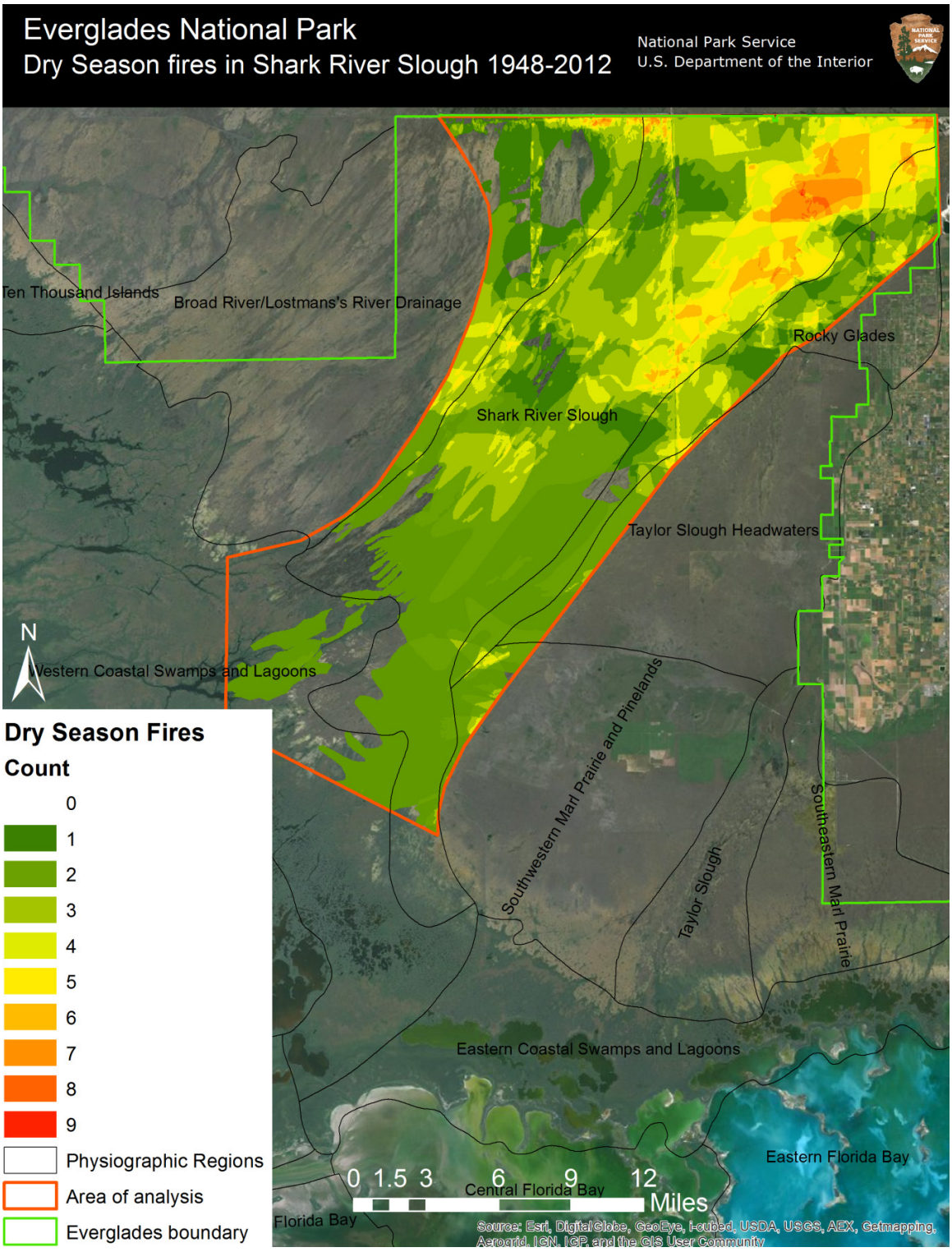


Figure 4.53. A count of dry season fires in Shark River Slough over six decades (since 1948).

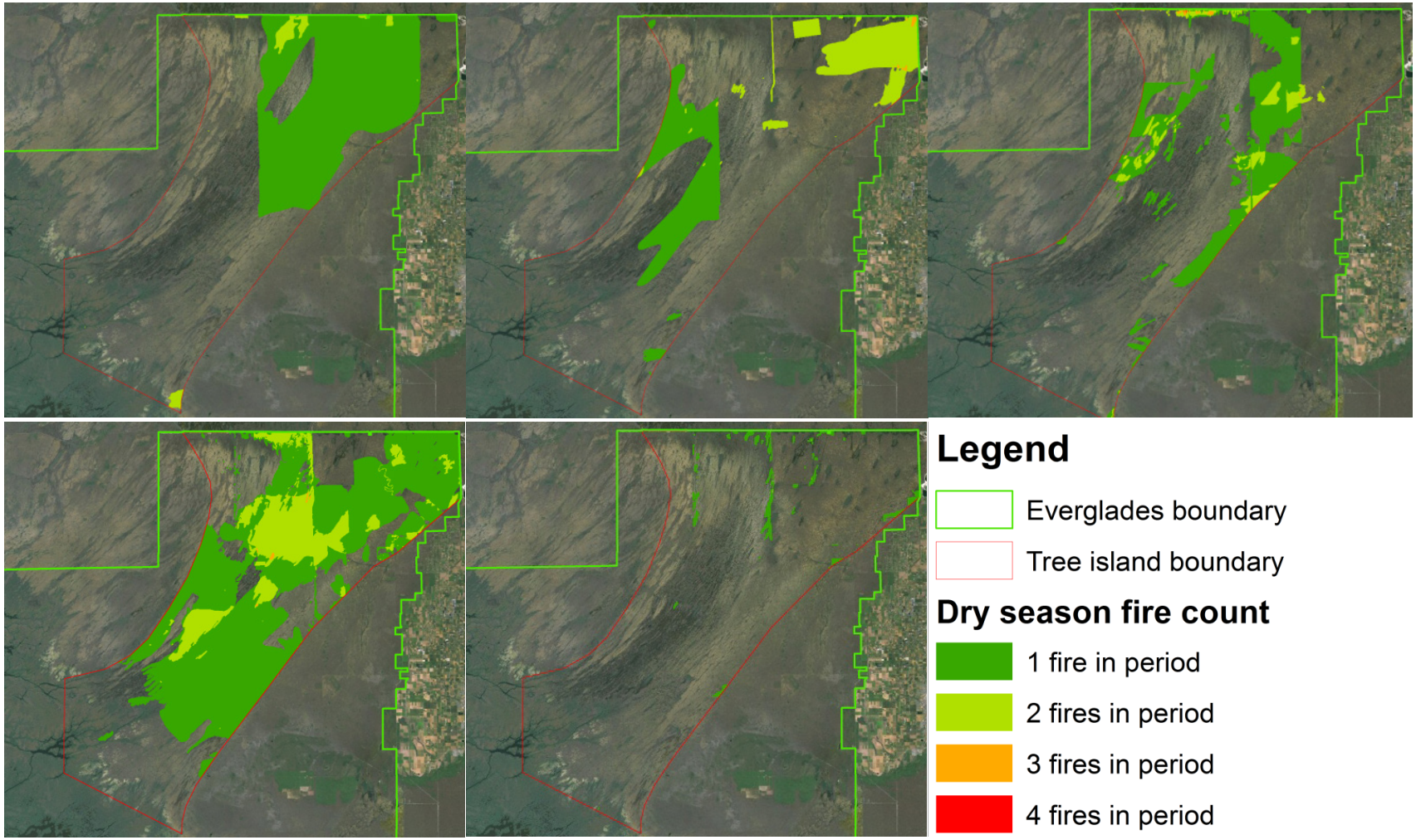


Figure 4.54. A count of dry season fires in Shark River Slough over five decadal intervals since 1952.

Acknowledgements
Ted Schall (USACE) did a tremendous amount of work organizing the historical imagery, processing the images into shapefiles that depict change in tree island abundance over time, and verifying the accuracy of the process. This section of the NRCA would not have been possible without his sincere effort, and those efforts are greatly appreciated.

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4.6.3. Wading Birds

Status and Trend

Attribute: Wading Birds

Overall Condition & Trend:



Rationale: The total numbers of pairs of nesting birds in the region are increasing, ibis are doing well. Nesting locations remain too far inland from the coast, and woodstorks remain too scarce with erratic nesting timing as a result of water management infrastructure and operations.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

While the condition and trend of some aspects of wading bird populations have shown considerable improvement over time, there remains reason for continued concern. The timing of wood stork nest initiation and the ratio of ibis to woodstork nests is poor. The total number of birds is increasing (mostly due to the success of ibis), but birds are still nesting too far inland (Table 4.30).

Table 4.30. Wading bird indicator metrics as identified by the Comprehensive Everglades Restoration Plan (RECOVER 2004, 2006a, 2006b), Frederick et al. (2008), and Brandt et al. (2012) for the recovery of wading bird populations in south Florida.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Total number of pairs of nesting birds in south Florida.		Absolute size of breeding populations of ibises, storks, and long-legged wading birds declined sharply from the 1930's to the 1970's. Since the mid-1980's, nesting numbers in EVER are trending up. Numbers fluctuate greatly from year to year.	Maintain or increase current total numbers of nesting birds in EVER mainland colonies to a level consistent with a restored Everglades ecosystem.
Month of wood stork nest initiation		Nest success continues to be highly erratic due both to extreme natural and managed seasonal hydrologic fluctuation. Trend is improving slightly, but storks continue to fail because of late nest initiation.	Month of wood stork nest initiation should be November or December.

Table 4.30 (continued). Wading bird indicator metrics as identified by the Comprehensive Everglades Restoration Plan (RECOVER 2004, 2006a, 2006b), Frederick et al. (2008), and Brandt et al. (2012) for the recovery of wading bird populations in south Florida.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Proportion of nests located in EVER headwaters		Recent trends are positive, especially for storks, but distant from the 70% target.	At least 70% of all wading bird nests should be located in the headwaters ecotone of the mangrove estuary of Florida Bay and the Gulf of Mexico (EVER).
Mean interval between exceptional white ibis (*Eudocimus albus*) nesting years		The trend is positive and consistent in recent years. This interval now consistently exceeds the target for restoration and has shown dramatic improvement in the last decade.	Mean interval between exceptional white ibis nesting years (≥13,000 nesting pairs) should be 1–2 years.
Ratio of wood stork and white ibis nests to great egret nests		Current ratio (2:1) is well below the 30:1 ratio that is considered representative of healthy nesting conditions. Ratio appears to have stabilized and has not moved much in the last 10 years (range ~1.5:1 to 4:1).	Ratio of the combination of wood stork and white ibis nests to great egret nests should be 30:1, which is characteristic of the community composition of pre-drainage conditions.

Background and Importance

Wading birds are a defining and visible component of the Everglades ecosystem. The decline of wading bird populations was cited as one of the primary reasons for the need to create Everglades National Park (EVER). Wading birds feed in wetland habitat, and are leading indicators of the health of food webs in the wetlands they occupy. Since the establishment of EVER in 1947, human development and urbanization of south Florida have put great stress on the area's water resources. Control features such as levies and canals have been constructed to divert and manage water for urban and agricultural development. Many wildlife species have been affected by the resultant changes in the natural hydrologic pattern throughout the Greater Everglades, including EVER, but perhaps the most visible change has been a drastic decrease in the historically large numbers of breeding wading birds.

During a visit to south Florida in the 1830's, the well-known naturalist and artist John James Audubon wrote, "We observed great flocks of wading birds flying overhead toward their evening roosts … They appeared in such numbers to actually block out the light from the sun for some time." It is estimated that there has been a 70 percent reduction in total number of nesting wading birds between the historical (e.g., pre-drainage) Everglades system and the Everglades as it exists today. Breeding bird records from the 1930's show that as many as 245,000 birds once nested in the Greater Everglades (Ogden 1994).

A decline in numbers of nesting birds is not the only change that has taken place over the years. Shifts have been observed in the timing of nest initiation, species composition of colonies, and abandonment of traditional nesting colony locations. A number of key species, most notably the

endangered wood stork (*Mycteria Americana*; Photo 24), have experienced a change in the timing of nesting initiation. Nesting now begins several months later in the dry season than in pre-drainage times. With nesting occurring later in the year, the arrival of the wet season rainfall can disperse prey before birds have finished nesting, leading to poor foraging conditions and starvation of chicks that are not yet fledged.



Photo 24. Fledgling wood stork chicks, Paurotis Pond, EVER. Photo by Lori Oberhofer, EVER.

Since wading birds are relatively easy to monitor across the landscape and much is known about their habitat requirements and historical nesting patterns, they are excellent indicators of environmental conditions in the Everglades. Wading birds breeding in the Everglades require easily available and abundant aquatic prey. Aquatic prey, in turn, are dependent on a variety of environmental factors including the quantity, distribution, and timing of water flows. To date, many of the proposed restoration projects, planned to reestablish a more natural timing and pattern of hydrology to the area, have not yet been fully implemented. Monitoring of nesting wading birds is planned in conjunction with restoration efforts. Everglades National Park will only be removed from the list of World Heritage Sites in Danger once healthy wading bird populations are re-established.

Desired State of Conservation

The desired state of conservation for wading birds (Photo 25) includes are based on work by Frederick et al. (2009) and goals for the recovery of wading bird populations in south Florida that are set as a part of the Comprehensive Everglades Restoration Plan (CERP; RECOVER 2004, 2006a, 2006b):

- The total number of pairs of nesting wading birds in south Florida should increase and stabilize around a minimum of 4,000 pairs of great egrets, 10,000 to 20,000 combined pairs of snowy egrets and tricolored herons, 10,000 to 25,000 pairs of white ibises, and 1,500 to 3,000 pairs of wood storks.
- Timing of nest initiation should change toward the earlier initiation dates that occurred in pre-drainage times.
- The proportion of wading bird nests that occur in the coastal/headwaters ecotone areas of EVER should increase until 70% of the combined nests within the Greater Everglades to be located in EVER.
- The frequency of occurrence of exceptional nesting events by white ibis (*Eudocimus albus*), in the Greater Everglades should increase.
- Species composition of nesting colonies should shift from those mostly composed of sight feeding species (egrets and herons) to those that are tactile-foragers (white ibis and wood storks).



Photo 25. Wading bird colony, Broad River, ENP. Photo by Lori Oberhofer, ENP.

Description of Indicator Monitored

Information about wading bird nesting effort, timing of nesting, and location and number of colonies is collected by EVER biologists during monthly colony nesting surveys. Colony surveys have been conducted consistently since the early 1990's. Prior to this time, aerial surveys and ground monitoring of accessible colonies occurred on a less regular schedule.

EVER biologists conduct aerial surveys of known colony sites beginning in October and continuing until nesting is finished (usually in May or June). A systematic survey throughout EVER for wading bird nesting is conducted once during the nesting season, when colonies are most active, in order to detect new and/or smaller transient colonies that might be missed during the monthly site checks. In areas outside of EVER, both aerial and ground surveys are conducted by biologists working for federal, state, university, and non-governmental organizations. Together, they provide coverage of wading bird colonies found in the Water Conservation Areas, including Arthur R. Marshall Loxahatchee National Wildlife Refuge, as well as other sites within south Florida.

Status of the Indicator in the Current Year and Trends over Time

Numbers of nesting wading birds declined sharply between the historical pre-drainage years of the 1930's and the post-drainage years of the 1970's (Ogden 1994, Crozier and Gawlik 2003). The performance measures set forth by CERP (RECOVER 2004, 2006a, 2006b) seek to increase and maintain a minimum of 4,000 pairs of great egrets, 10,000 to 20,000 combined pairs of snowy egrets and tricolored herons, 10,000 to 25,000 pairs of white ibises, and 1,500 to 3,000 pairs of wood storks. Some of these population targets have currently been met and trends are positive for all species with the exception of snowy egrets and tricolored herons (Figure 4.55).

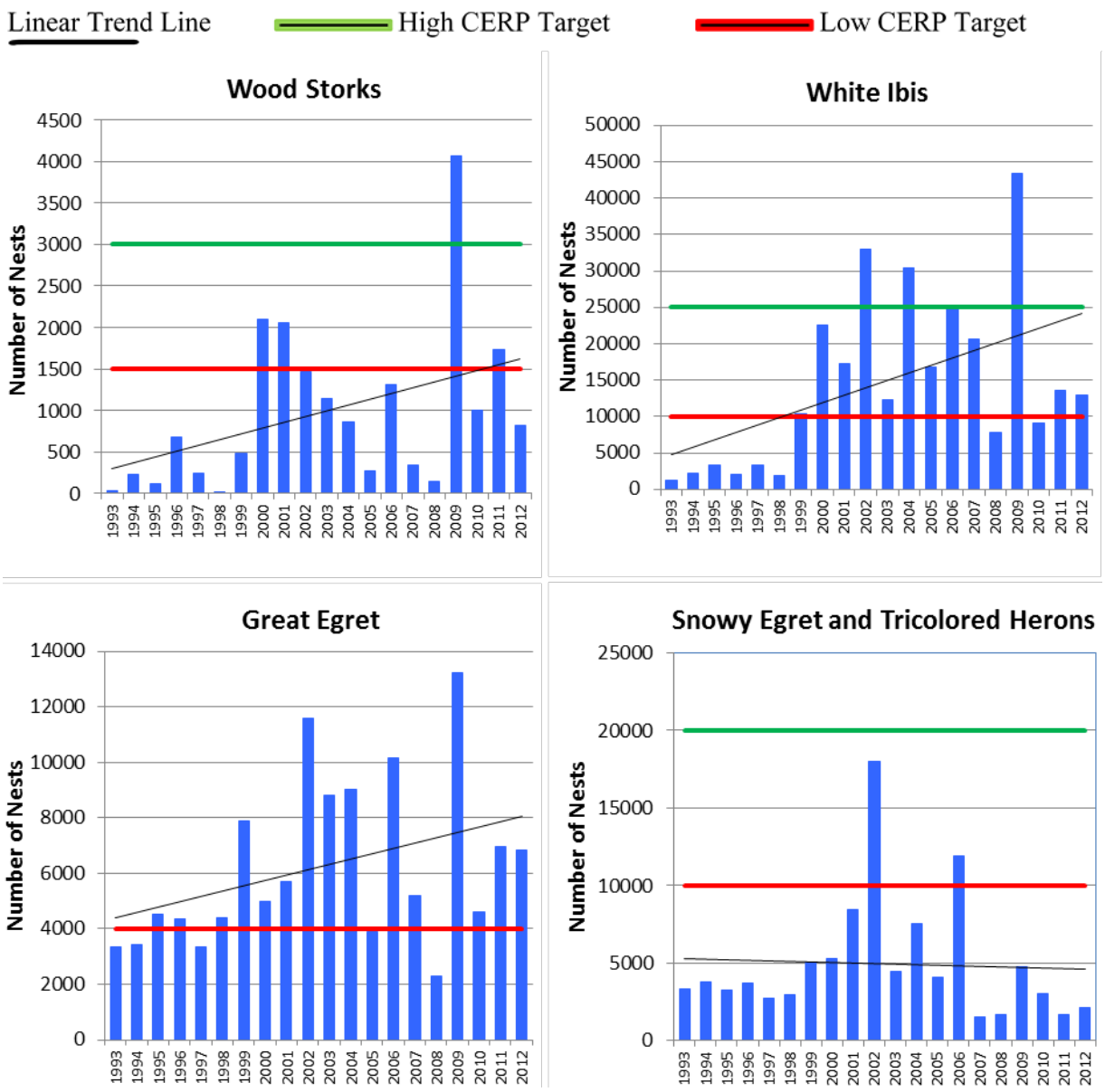


Figure 4.55. Number of nesting (a) wood storks, (b) white ibises, (c) great egrets, and (d) snowy egrets and tricolored herons in relation to CERP target populations, 1993–2012 (Frederick et al. 2008).

A return to the natural timing of wood stork nesting beginning in December/January is needed to ensure nesting success for wood storks. Wood stork chicks require 105 to 130 days to fledge from nests. The loss of early dry season foraging habitats has reduced numbers of prey fish enough to inhibit early wood stork nesting. If storks continue to initiate nesting late, then chicks have a much greater chance of still being in nests when summer rains begin in late May or June. When water levels rise, prey concentrations and density decline and chicks starve. This indicator has not improved over time as storks continue to initiate nesting in February or March at all colonies within the park.

The majority of nesting birds throughout south Florida are still nesting in the Water Conservation Areas and other areas to the north of EVER. Since 2009, more birds have chosen to form colonies in historic nesting sites near the coastal/headwaters ecotone areas inside the park (Figure 4.56 for locations, Figure 4.55 for trend). These sites include the headwaters regions of the Shark, Broad, and Lostman's rivers, Alligator and Cabbage bay areas, and southern mainland areas north of Florida Bay. If hydrologic conditions continue to improve, we should expect to see greater numbers of birds nesting in these areas as well as a return to other former (but currently empty) nesting areas such as Gator Lake, Mud Lake, East River, and Lane River. The goal for nesting spatial patterns has never been met in the last 20 years (Figure 4.57).

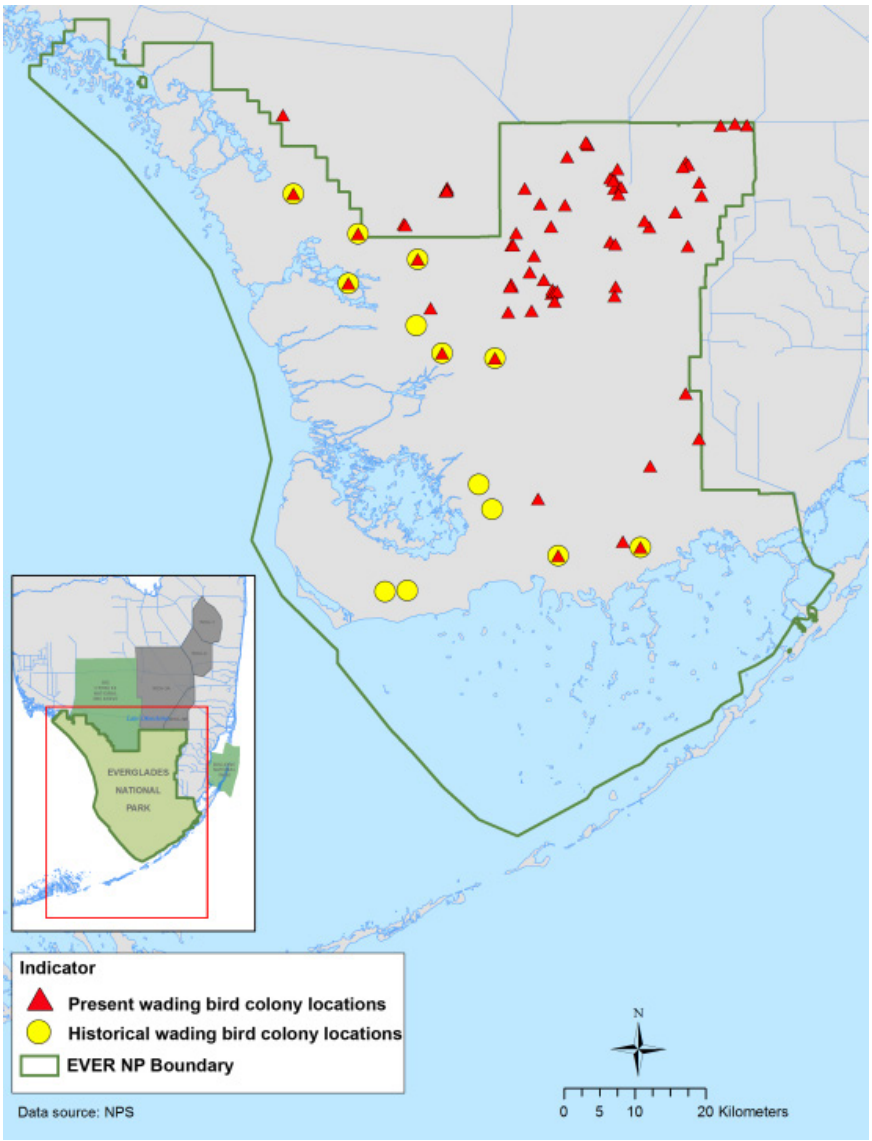


Figure 4.56. Location of present and historical wading bird colonies.

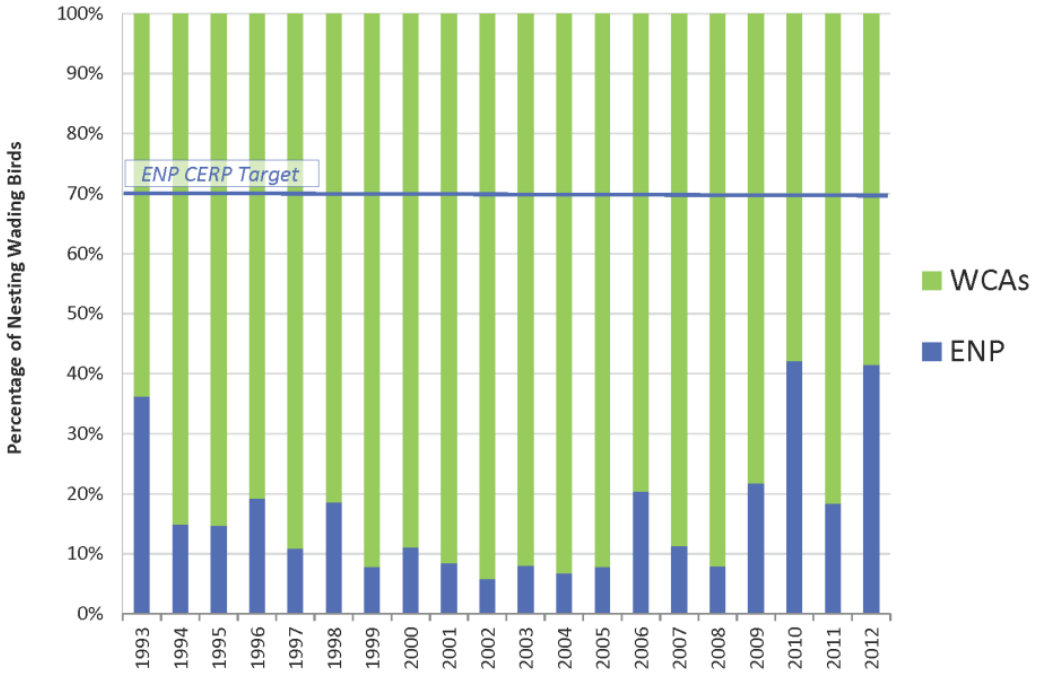


Figure 4.57. Proportion of wading birds nesting in estuarine/freshwater ecotone (ENP) and in Water Conservation Areas 1, 2, and 3 (areas north of ENP).

Prior to drainage of the Everglades ecosystem, large white ibis nesting events occurred approximately every 1or 2 years (Frederick et al. 2008). The number of nests and interval of very large nesting events recorded in recent years have met the target (Figure 4.58).

Egrets and herons feed by sight and do not require as high a prey density as tactile feeders such as ibis and storks. The change in composition of colonies from historic levels of tactile feeders to mostly sight-feeding birds suggests a decrease in prey density within the Everglades habitat (Gawlik 2002). The historic ratio of wood stork and white ibis nests (two tactile feeding species) to great egret nests (sight feeding species) is estimated to be 30:1. Current conditions do not approach this ratio, and observed ratios indicate that the habitat is becoming less favorable to tactile feeders. This ratio of tactile-feeding: sight-feeding birds has appeared to stabilize at 2:1, well below the desired target of 30:1 (Brandt et al. 2012; Table 4.30).

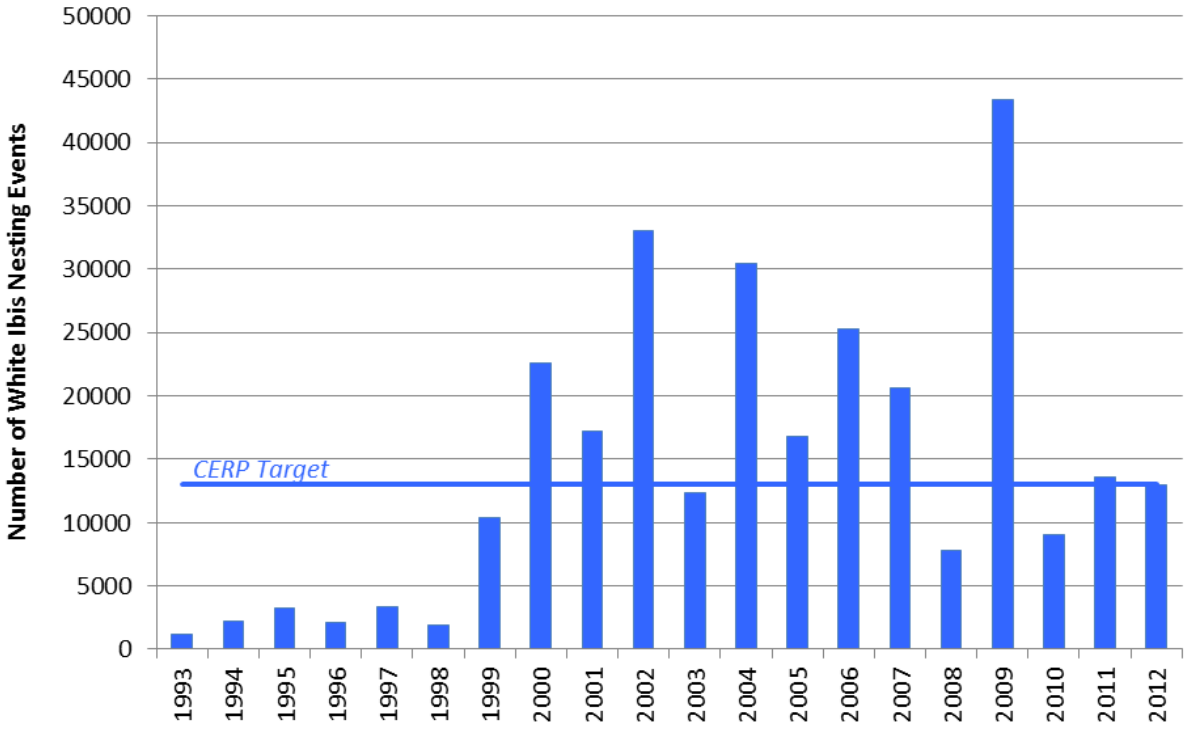


Figure 4.58. The number of white ibis nesting events in relation to the CERP target, 1993–2012.

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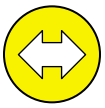
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4.6.4. American Alligator

Status and Trend

Attribute: American Alligator

Overall Condition & Trend:



Rationale: Alligator populations in EVER have improved since 1985, and while nesting numbers have increased, nesting success remains erratic, and population numbers appear to have stabilized below the numbers expected in a restored ecosystem. Confidence in this indicator is medium, since monitoring is no longer funded through the Comprehensive Everglades Restoration Plan.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

American alligator nesting, distribution, and abundance are improving, but the rate of population increase has declined. Alligators were critically endangered in 1985. Since then, populations have grown, nesting effort is increasing, but nesting success remains erratic and the number of nests per region (density) remains too low (regions identified in Figure 4.59, results summarize in Table 4.31).

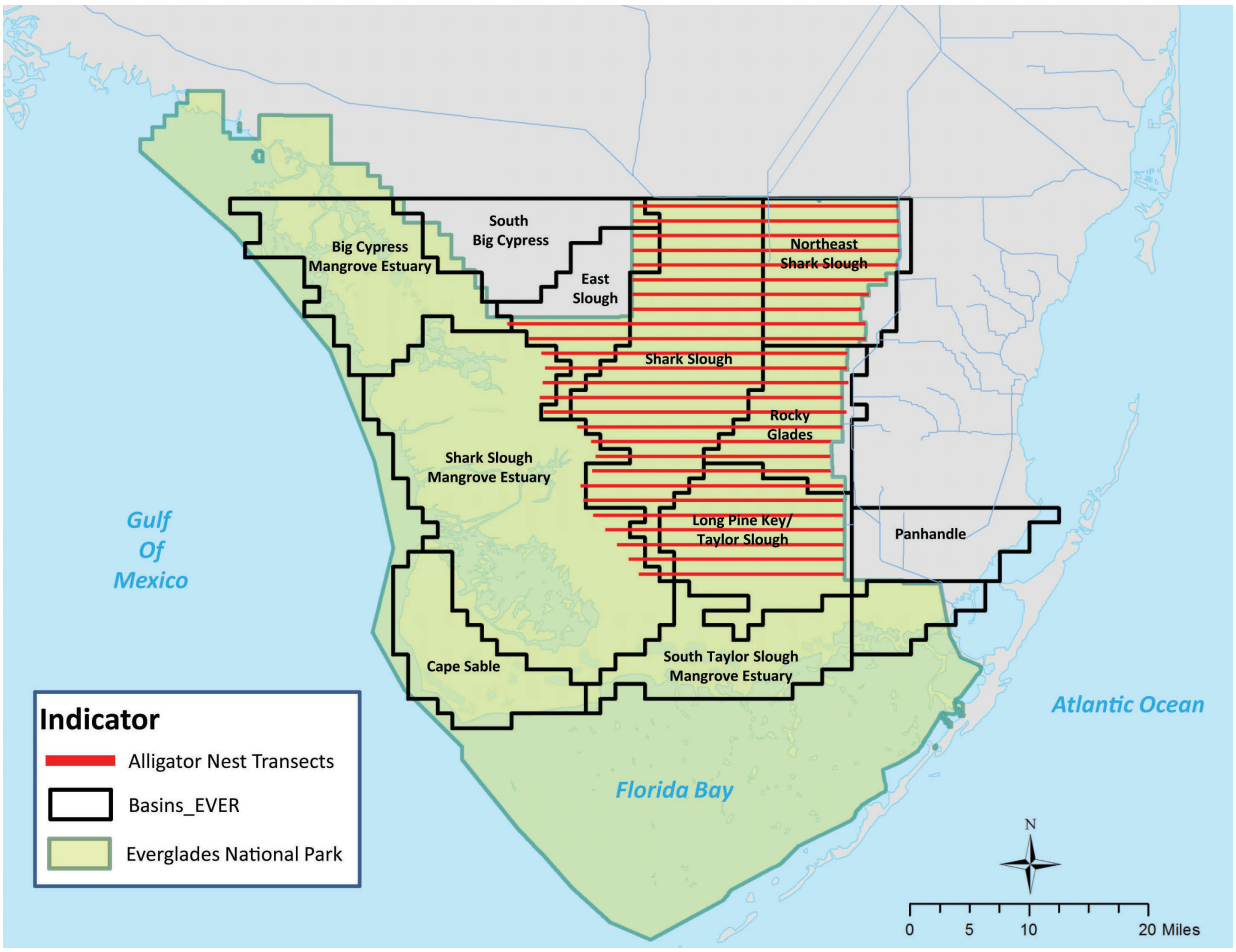
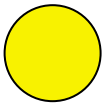
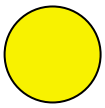


Figure 4.59. Location of alligator reproduction monitoring transects and associated hydrologic basins.

Table 4.31. American Alligator Status/Trend Summary.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Nesting effort		Nesting effort has increased significantly since 1985; recent trends show more stability during poor to moderate conditions and record numbers during favorable conditions.	Increasing trend in nesting effort throughout all freshwater marshes, particularly peripheral marshes historically believed to support the majority of nesting effort. The target is nesting effort consistent with a restored Everglades ecosystem.
Nesting success		Nest success continues to be highly erratic due both to extreme natural and managed seasonal hydrologic fluctuation.	Increasing trend in nest success and reduced failure due to flooding of egg cavity. The target is nest success levels consistent with a restored Everglades ecosystem.
Nest density/distribution		Nest density and distribution throughout freshwater hydrologic basins of EVER have demonstrated an increasing trend in recent years.	Increasing trend in density of nests across hydrologic basins, particularly within shorter hydroperiod peripheral marshes. The target is nest density and distribution consistent with a restored Everglades ecosystem.
Alligator abundance		Results of spotlight surveys indicate reduced abundance estimates in all size classes within EVER.	Increasing trend in abundance for all size classes of alligators within freshwater wetlands. The target is an abundance of alligators consistent with a restored Everglades ecosystem.

Background and Importance

The American alligator (*Alligator mississippiensis*) is a keystone species that functions as an ecosystem engineer, directly or indirectly influencing nearly all aquatic life in the Everglades (Beard 1938, Craighead 1968, Mazzotti and Brandt 1994, Simmons and Ogden 1998). Alligators are important indicators of Everglades ecosystem health, especially for factors closely associated with, and responsive to, hydrologic change; these characteristics make them ideal candidates for inclusion in long-term ecological studies designed to assess the success or failure of restoration efforts.

Relationships between dry season refugia, aquatic fauna, wading birds, and alligators are not well understood and have been identified as areas of key scientific uncertainty in the 2000 Comprehensive Everglades Restoration Plan (U.S. Army Corps of Engineers 1999). In addition to National Park Service (NPS) long-term (1985–present) monitoring of aspects of alligator reproduction, in 2001 the multi-agency Alligator Survey Network Monitoring Program created routes within the park to gather data on alligator abundance in an effort to address these uncertainties.

Ugarte (2006), analyzed two decades of alligator nesting data, noted a negative relationship between nesting effort and water extremes (either high or low) during the period of courtship, mating, and nest construction. Extreme hydrologic conditions (wet or dry) typically depress nesting effort;

extremely dry conditions concentrate nesting around central sloughs. Over the course of the last two decades of monitoring, the spatial distribution of nests has become a more important indicator of conditions than the percentage of flooded nests. We hope to observe alligators nesting across larger areas as restoration progresses.

Desired State of Conservation

Positive trends in nesting effort/success, nest distribution, and abundance of the American alligator, to a level consistent with a restored Everglades wetland ecosystem, are identified as key targets for the removal of Everglades National Park from the World Heritage Sites in Danger list.

Description of Indicator Monitored

Park staff annually monitor alligator nesting effort, nest success, and spatial distribution of nests in different hydrologic basins (Photo 26). Abundance of alligators is monitored by university cooperators. Nesting effort is an annual count of the minimum number of nests built and observed within standardized survey transects. Nest success involves determining whether at least one egg hatched, and includes documentation of known causes of failure for each nest monitored. NPS monitoring is conducted through systematic reconnaissance flights (SRF) and subsequent monitoring of nests identified during SRF. Transects that cover all freshwater habitats for alligators within Everglades National Park (EVER) are flown by helicopter, and locations of alligator nests are recorded using a global positioning system (GPS). A subset of the total observed nests is chosen at random, then periodically visited throughout incubation until individual fate can be determined for each nest. Nesting surveys have been completed for 2012, but data analysis is not complete, and this document presents results through 2011.



Photo 26. Research staff counting and checking eggs for fertilization and development (banding). Credit NPS/Lori Oberhofer.

Abundance of alligators is monitored using spotlight surveys conducted along established transects. The spotlight survey has been ongoing for less than 10 years and is limited in terms of spatial coverage within the park. Survey routes are primarily restricted to Shark River Slough and may not reflect trends in other areas or account for possible dispersal from Shark Slough as conditions improve in peripheral marshes. Size class based on a two-stage hierarchical model of survey results estimates abundance. Spotlight surveys were not conducted in 2012, and estimates of alligator abundance are only available through 2008.

Status of Indicator in the Current Year and Trends over Time

Alligator nesting effort and distribution have overall exhibited an increasing trend within EVER since monitoring began in 1985 (Figure 4.60). The most consistent nesting effort of any 5-year period within the 27-year study occurred during 2005–2009 (Figure 4.60). Unexpectedly, and despite drought conditions, nesting effort/success in 2009 was only slightly lower than the prior 4-year average, and distribution was fairly widespread (Figures 4.61 and 4.62). The relative stability of water levels during the previous 5 years may have created conditions more favorable for maintenance and continuous occupation of alligator holes and other dry season refugia beyond the central sloughs (an important goal for restoration efforts). The 2009–2010 dry season was relatively wet and water levels park-wide remained high during courtship and mating: there was not a large change in stage from dry to wet season or from onset of nest construction to hatching. These conditions are typically favorable for alligator reproduction, and 2010 nesting effort was the highest on record with moderate hatching success and spatial distribution of nests (Figures 4.60, 4.61, and 4.62).

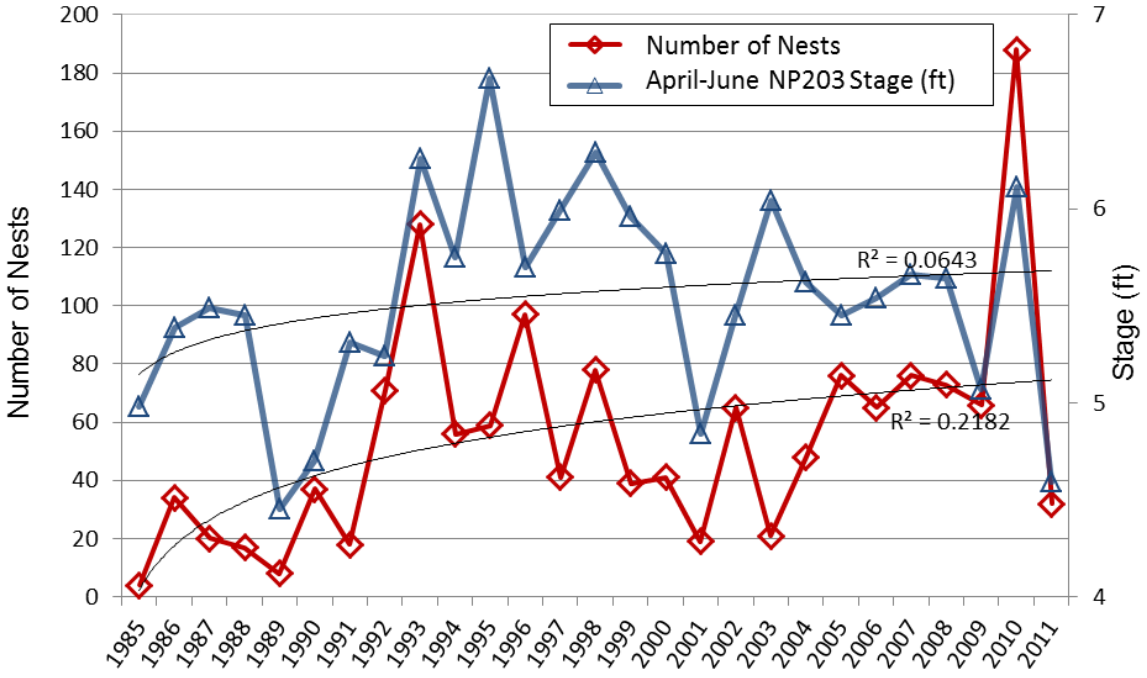


Figure 4.60. Alligator nests observed within 500-m transect boundaries during Systematic Reconnaissance Flights (1985–2011), compared to a summary of water levels in Shark River Slough. Only Shark Slough and Northeast Shark Slough were surveyed during 1985–1991.

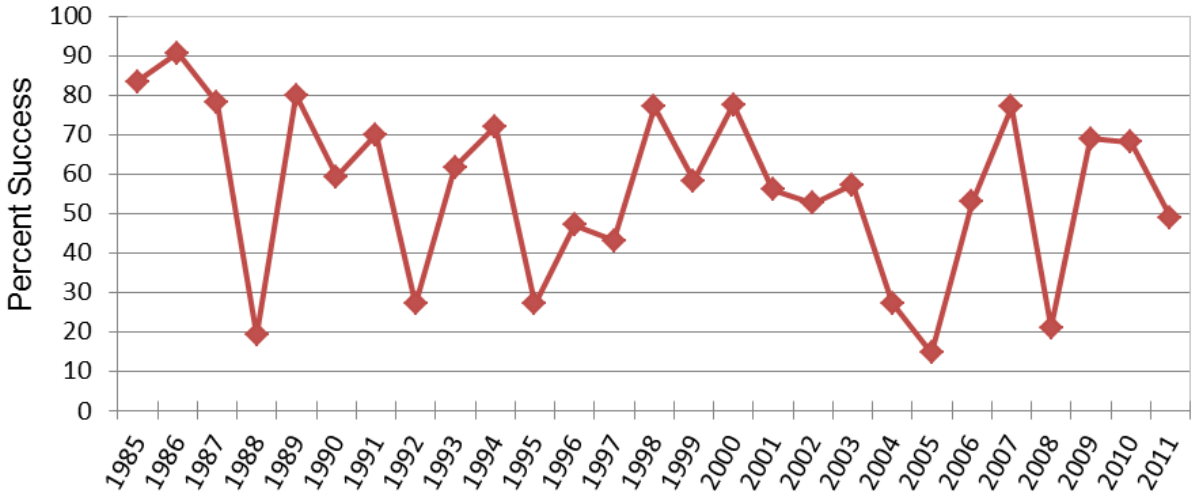


Figure 4.61. Alligator nest percent hatching success for all monitored nests within EVER, 1985–2011.

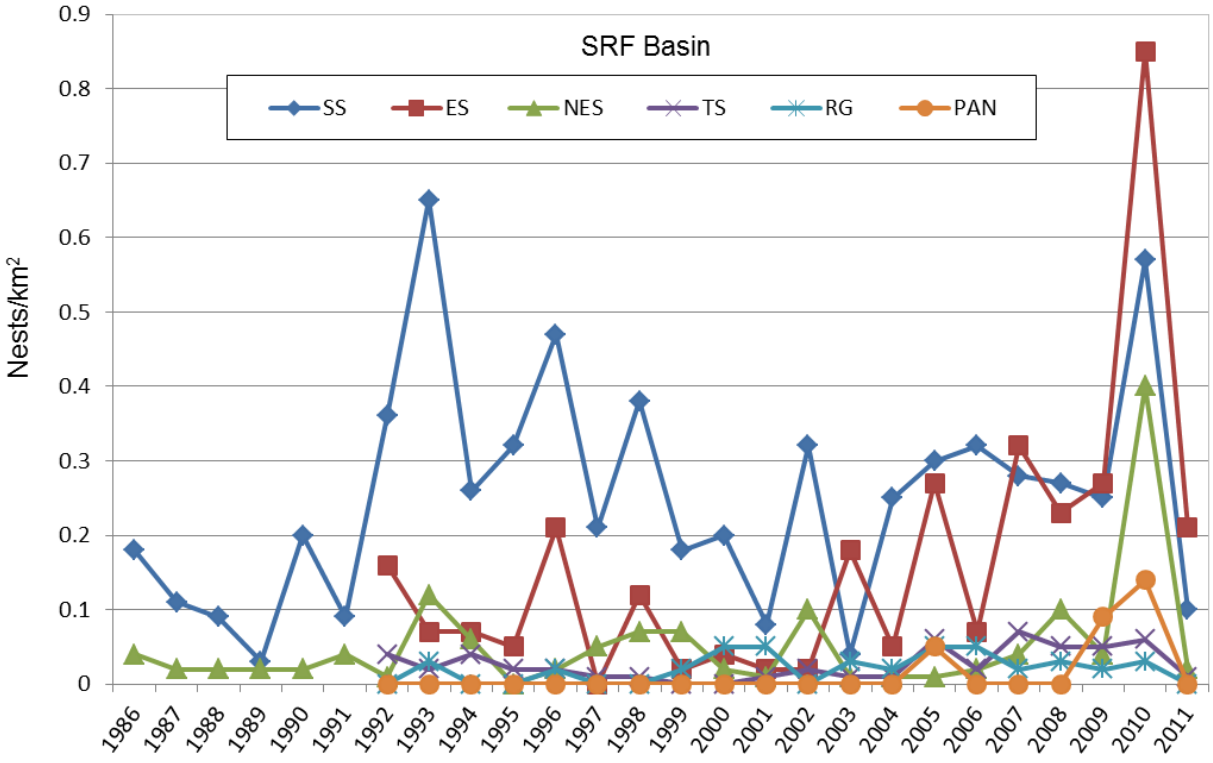


Figure 4.62. Observed annual nest density by hydrologic basin, 1985–2011.

Severe drought conditions experienced in the Everglades during the 2010–2011 dry season persisted well into the courtship, mating, and nest building period of 2011. Many of the areas in EVER that typically support alligator nesting had little to no surface water during this period, with the exception of only the deepest solution or alligator holes. Given these conditions, nesting effort was expected to be low in 2011 and ultimately only 32 nests were found in transect surveys (Figure 4.60). Considering the severe drought conditions that extended even into central sloughs, nests were fairly well distributed in 2011, yet nests were conspicuously absent from the driest areas of EVER.

Although alligator reproduction is improving, recent analysis suggests that populations are not growing in all size-classes. Fujisaki et al. (2011) analyzed abundance patterns of alligators within EVER during 2003–2008, and found that small and medium size-classes were declining during the 5-year period, while numbers of adults were increasing. Fujisaki et al. (2011) recognize that the observed pattern may reflect a natural population cycle but also theorize that it may be due to extremely low water depths occurring more frequently in recent years than they have been historically (see 4.6.5: Freshwater Fish and Aquatic Invertebrates). Low water conditions are generally poor for alligators yet more suitable for survival of adults than for juveniles. These early results do show a potential negative trend that demonstrates the need for continued monitoring, including expansion of the project into peripheral marshes. Though spotlight surveys and the associated captures were intended to detect long-term trends in the park, funding for these efforts has been cut and future ability to conduct this work remains uncertain at best. Elimination of this research reduces the ability of scientists and managers to detect the effects of landscape-level changes to Everglades hydrology on alligator populations.

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4.6.5. Freshwater Fish and Aquatic Invertebrates

Status and Trend

Attribute: Fresh Water Fish and Aquatic Invertebrates

Overall Condition & Trend:



Rationale: Freshwater fish are shifting species composition, with fewer long hydroperiod dependent species than desired. Fish biomass and species composition are below the very conservative targets used to design the assessment, and have declined over the last twenty years. Freshwater fish biomass is far below more aggressive, restoration-based goals.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

An increase in the abundance of native fish and aquatic invertebrates from present conditions to those that approximate pre-drainage conditions is necessary to achieve the desired state of conservation. Achieving the desired state of conservation in Taylor and Shark River Slough is necessary for Everglades National Park (EVER) to be removed from the "World Heritage Sites in Danger" list. EVER remains far from this goal. In the past water year, the overall conditions in Shark River Slough warranted significant concern (red stoplight) due to lower total fish abundance, lower abundance of drought intolerant species, and higher abundance of drought tolerant species (Table 4.32). Taylor Slough exhibited moderately lower total fish abundance and a lower abundance of drought intolerant species than expected. The difference between desired and observed conditions warrants a moderate concern stoplight indication overall (yellow stoplight, Table 4.32). In addition, conditions have declined from previous years in both Shark River and Taylor sloughs.

Table 4.32. Summary aquatic fauna condition assessment for Shark River Slough, 2011–2012 (modified from Brandt et al. 2012).

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Shark River Slough overall		Fewer fish were present than expected based on rainfall, and drought tolerant species were abundant. Represents a decline in condition from previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Total fish abundance		Drier than expected conditions resulted in fewer fish than expected and fewer than previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Bluefin killifish abundance		Drier than expected conditions resulted in lower abundance than expected and fewer than previous years.	Drought intolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions.
Flagfish abundance		Drier than expected conditions resulted in moderately higher than expected abundance and similar to previous years.	Drought tolerant species abundance is maximized in a manner that reflects pre-drainage conditions.
Mosquitofish abundance		Drier than expected conditions resulted in moderately lower abundance than expected and fewer than previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Everglades crayfish abundance		Drier conditions resulted in expected abundance that was similar to previous years.	Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions.

It is important to note that as hydrology is restored in EVER, the expectation is that thousands of acres will be wetter for longer. This should cause total fish biomass to increase. Wetter conditions should also increase total biomass of crayfish, which should occupy the less-wet transition areas (ridges of the ridge-slough-tree island landscape, and the marl prairie landscapes). Currently, the sloughs are not wet consistently across years. As a result, drought intolerant fish species do not occupy as many acres of the landscape as they would if there were more water. In addition, marl prairies do not have as much crayfish because the water table declines to very low levels, and the marl soils contain less carbon. Carbon-poor soils are heavier, and harder for crayfish to create burrows deep enough to escape the dry surface.

Background and Importance

Fish and aquatic invertebrate assemblages play an important role in Everglades food webs and can be used as indicators of ecosystem health. Although wading birds, alligators, and other visible species garner much public recognition, they are highly dependent upon prey availability for reproductive success. Factors that influence fish and aquatic invertebrate populations may cascade up the food web and affect the more charismatic species. An increase in the abundance of native fish and aquatic invertebrates from present conditions to those that approximate pre-drainage conditions is necessary

to achieve the desired state of conservation for removal of Everglades National Park (ENP) from the World Heritage Sites in Danger list. Knowing exactly what the abundance of the native fish and aquatic invertebrate assemblages were during pre-drainage conditions is impossible because we lack historical data. However, the goal of a measurable positive trend can be verified by monitoring conditions in the marsh over time and using models developed to predict population densities of freshwater fish and invertebrates relative to target hydrologic conditions (Trexler et al. 2003). In order to develop these relationships, both the aquatic community and hydrologic parameters are monitored.

Everglades National Park has a history of freshwater fish and invertebrate monitoring efforts dating back to the 1960's. One of the main projects, the Freshwater Aquatics Long-term Monitoring Project, began in the late 1970's. This project tracks trends over time and has proven invaluable for understanding the relationship between freshwater fish and large aquatic invertebrates and hydrologic conditions. Collected data has been used to develop targets for restoration in the absence of historical data (Trexler et al. 2003) and to assess changes in hydrologic management (Trexler et al. 2005). Additional monitoring in support of the Modified Waters Deliveries project has expanded monitoring efforts and, together with the long-term monitoring project, has been used to develop restoration assessment protocols (Trexler and Goss 2009).

Desired State of Conservation

The desired state of conservation is to maximize densities of small-sized freshwater fishes and aquatic invertebrates through ecological processes consistent with contemporary knowledge of the pre-drainage Everglades ecosystem (Figure 4.63). The hydrologic targets used for this assessment of freshwater fish and invertebrates are conservative compared to goals expressed in other categories, which are often derived from Natural System Models. It is likely that use of the Natural System Model would result in longer hydroperiod targets than those used here (which are derived from the 1993–1999 observed data - Doren et al. 2008). A longer hydroperiod target derived from the Natural System Model would highlight even more impacts than are reported here (the stoplight indicators would constantly warrant significant concern).

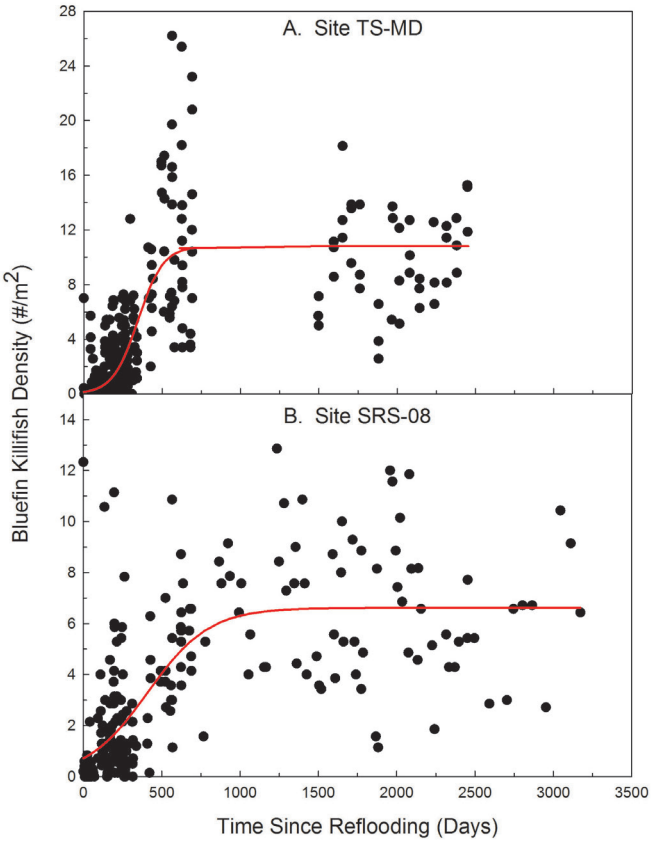


Figure 4.63. Example relationships between bluefin killifish density (#/m^2) and time since reflooding (days) at a site in Taylor Slough (panel A) and a site in Shark River Slough (panel B) used for performance measure development.

Description of Indicator Monitored

Prey base fish monitoring and assessment processes are among the most well developed natural resource management processes for living organisms in southern Florida. The long-term monitoring efforts in EVER focus on six sites located within Shark River Slough (SRS) and three sites within Taylor Slough (TS) sampled by staff of Florida International University (FIU) and EVER (Figure 4.64). The three northern SRS sites were sampled using current methods since 1985. Sampling at the southern SRS and the TS sites began in 1996, allowing consistent assessments from 1996–2012. Each site consists of three to five separate plots of either 45 by 75 m or 100 by 100 m (depending on local vegetation patterns). A 1-m^2 throw trap was used to collect seven randomly placed samples from each plot, five times per year (July, October, December, February, and April). Fishes and invertebrates were collected from each 1-m^2 sample, collated, and averaged to estimate a density of individuals at each site. Water depths for each site are estimated using a relationship between depths measured in each sample and data collected at nearby hydrologic monitoring stations.

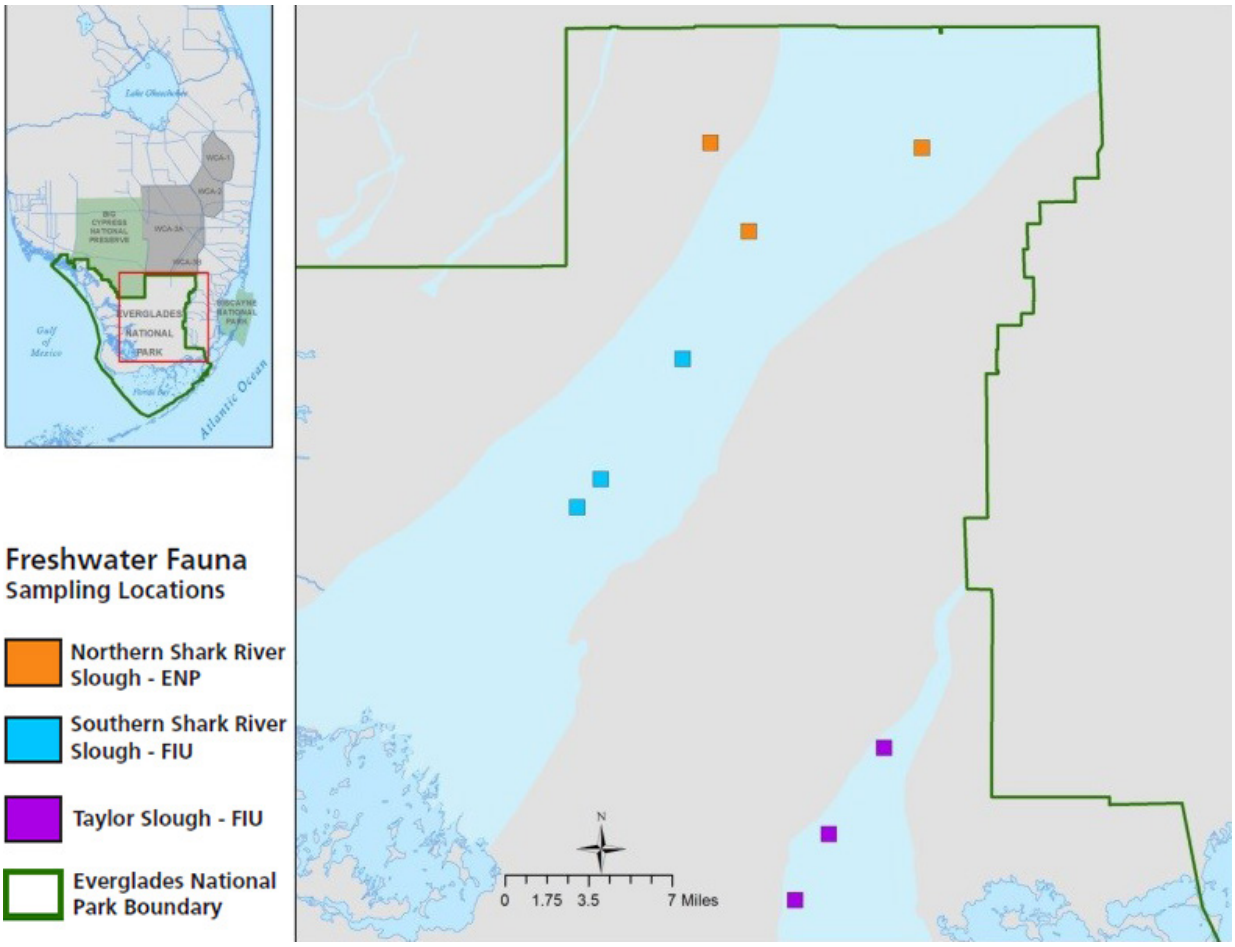


Figure 4.64. Map of freshwater fauna monitoring locations in Shark River and Taylor sloughs.

Statistical relationships between total fish abundance and the abundance of indicator taxa and days since a site was last dry (DSD) have been used to develop performance measures, evaluate observed conditions relative to target conditions, and assess restoration projects (Trexler et al. 2003, Trexler et al. 2005, Trexler and Goss 2009). Trexler and Goss (2009) used a variety of indicators for restoration assessment. These indicators consist of species that are drought intolerant (rare after a site dries and abundance increases the longer a site is flooded; e.g., bluefin killifish (*Lucania goodei*); see Figure 4.66), species that are drought tolerant (are most abundant soon after dry conditions; e.g., flagfish - *Jordanella floridae*)), species that are weakly related to time since a drying event (e.g., mosquitofish - *Gambusia holbrooki*)), species whose abundance is related to depth rather than hydroperiod (e.g., the Everglades crayfish - *Procambarus alleni*), and total fish abundance. This suite of indicators covers a broad range of the existing Everglades aquatic fauna. The indicators are calculated individually and are used in summary protocols to describe the status of the aquatic faunal community in the two major slough systems of EVER: Shark River Slough and Taylor Slough.

The application of these indicators to evaluate Everglades restoration was developed by Trexler and Goss (2009) and is used in the Freshwater Fish and Macroinvertebrate section of the System-wide Ecological Indicators for Everglades Restoration (SEIER) series of reports (Doren et al. 2008, Brandt

et al. 2012). The SEIER uses the 1993–1999 time period as a target hydrologic condition to develop forecasting statistical models linking rainfall and depth at monitoring sites and that is used to predict the DSD at each site from 2000 through 2012. Statistical relationships between the predicted DSD and fish abundance (Trexler et al. 2003, Trexler et al. 2005) are used to establish the target interval for fish abundance (mean ±2 SE). These target intervals were compared to the observed catches using criteria developed by Trexler and Goss (2009). An impact was defined by the magnitude of difference between the observed mean (with explicit estimate of Standard Error - SE) and the target interval; a simple system of stoplight indicators is used to summarize results for a general audience.

Red stoplight ratings are assigned to note significant concern because the measured annual target interval is above or below the mean ±3 SE, or when the target interval is above or below the mean ±2 SE in two out of three consecutive years, or when the target interval is above or below the observed mean ±1.5 SE in four out of five consecutive years (Trexler and Goss 2009). Yellow stoplights corresponded to years where the target was outside of the mean ±1.5 SE and indicate conditions that warrant further attention. Green lights correspond to years where the observed mean ±1.5 SE falls within the target region and indicates "Good Condition" (Trexler and Goss 2009), approximating the desired state of conservation. The most recent report includes trends over the 2000–2012 water years, with detailed analysis of the 2012 water year (2012 = May 2011 through April 2012). The results presented here are a summary of the results prepared by Dr. Joel Trexler (Florida International University) for the Brandt et al. 2012 report.

The target years of 1993–1999 are used because that time period contains wet season deep water conditions during 1995–1996 that are considered similar to what may have been expected under natural conditions (among the wettest two year period in the past 6 decades). A water management change in 2000 also separates the time period and allows assessment of the influence of water management change on the indicators. Doren et al. (2008) notes that alternative baseline models (e.g., Natural System Model) could be used that would likely predict longer hydroperiod conditions and more frequent wet season deep water events than the 1993–1999 model used.

Status of the Indicator in the Current Year and Trends over Time

Over the period of 1993–2012, fish abundance (as measured by number per unit area sampled - or density) of all species collected in Shark River Slough (SRS) and Taylor Slough (TS) decreased. Declines in fish density have been consistent over the past 20 years (Figure 4.65). Bluefin killifish abundance (a drought intolerant species) is a good example of the processes driving the decline. Bluefin killifish are a 1–5 cm long prey base fish that is commonly consumed by wading birds. These fish were always present at the sampled locations, and commonly greater than 4 per m^2 prior to 2000. The numbers of killifish observed became more variable after 2000, with abundances often below $4/m^2$ (Figure 4.66, 4.67). In contrast, the Everglades crayfish, a drought tolerant invertebrate, was collected at low densities (at or near $0/m^2$ in SRS prior to 2000), but has spiked in abundance several times since 2000 (Figure 4.68); Everglades crayfish were generally at or above target level during this period (Figure 4.69). Lower abundance of drought intolerant species and higher abundance of drought tolerant species indicate dry conditions after 2000 in SRS and TS.

In 2012, restoration targets were generally not met because of a drier marsh. Total fish abundance and bluefin killifish (a drought intolerant indicator) abundance were lower than expected, while drought tolerant species (flagfish and Everglades crayfish) were generally at or more abundant than target conditions in SRS (Table 4.32).

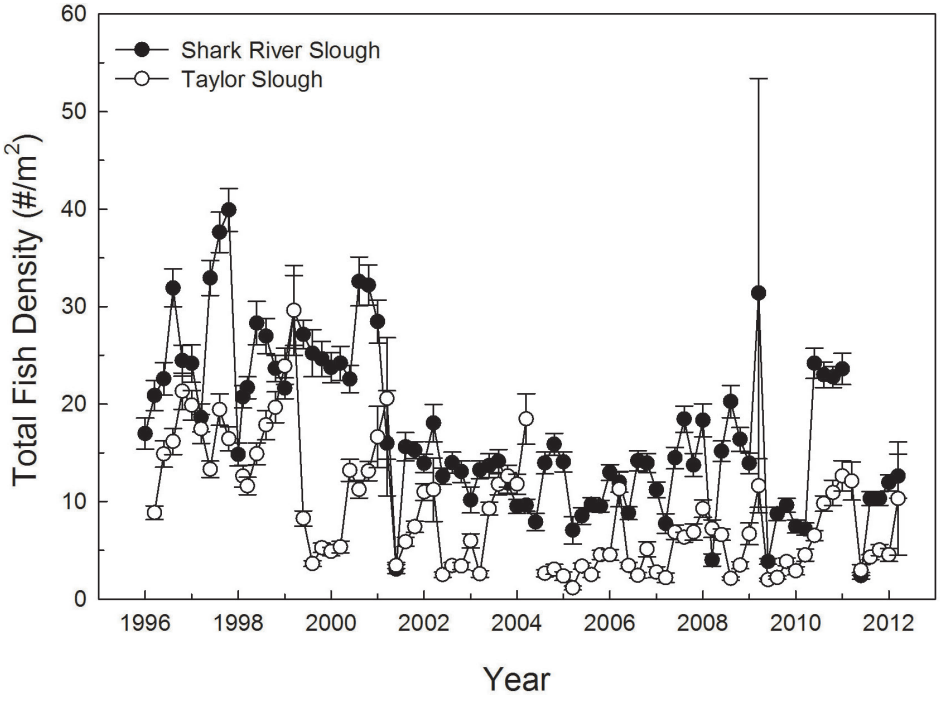


Figure 4.65. Total fish density (#/m^2) in Shark River and Taylor sloughs during 1996–2012.

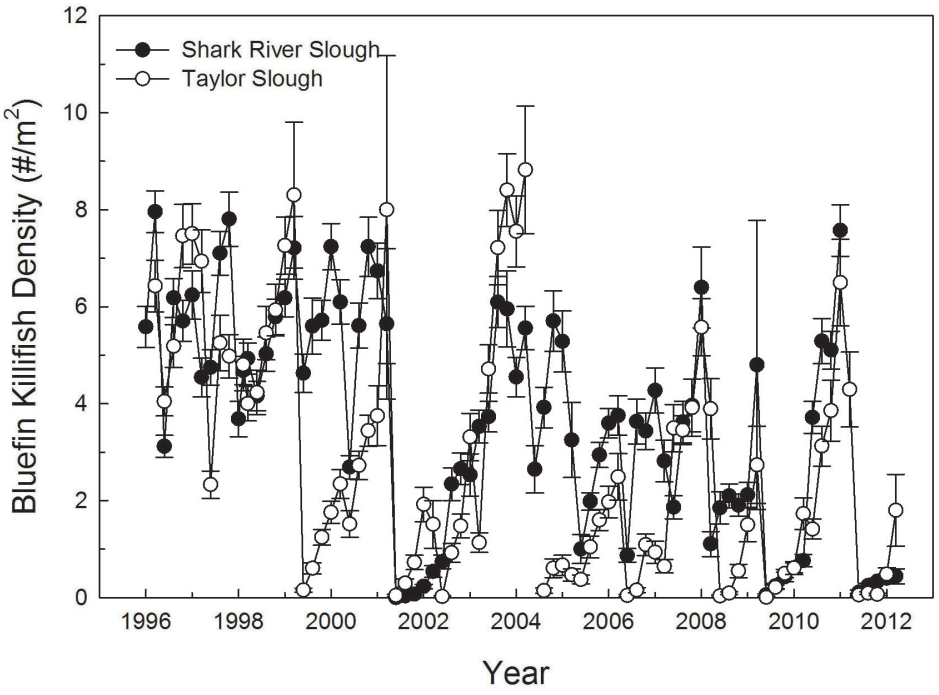


Figure 4.66. Bluefin killifish density (#/m^2) in Shark River and Taylor sloughs during 1996–2012.

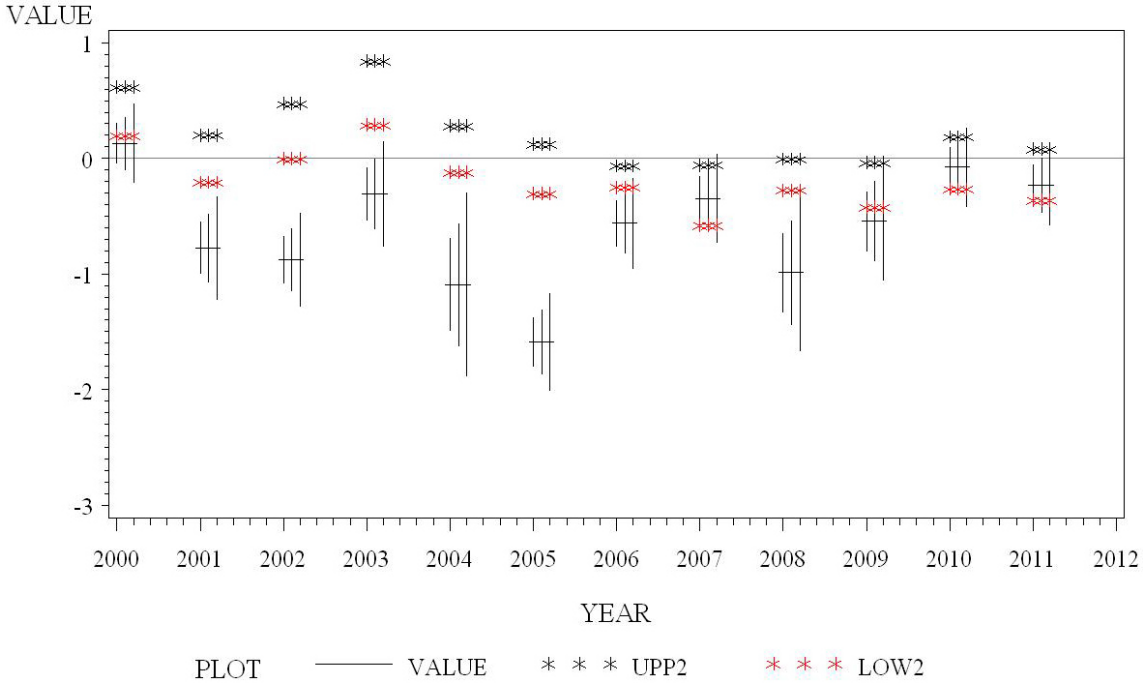


Figure 4.67. An example of the bluefin killifish assessment from one site in Taylor Slough, 2000–2011. The average observed density (value ±1, 2, and 3 SE) and target density is plotted with upper and lower intervals. Stoplight assessments are based on the average of all sites in the region.

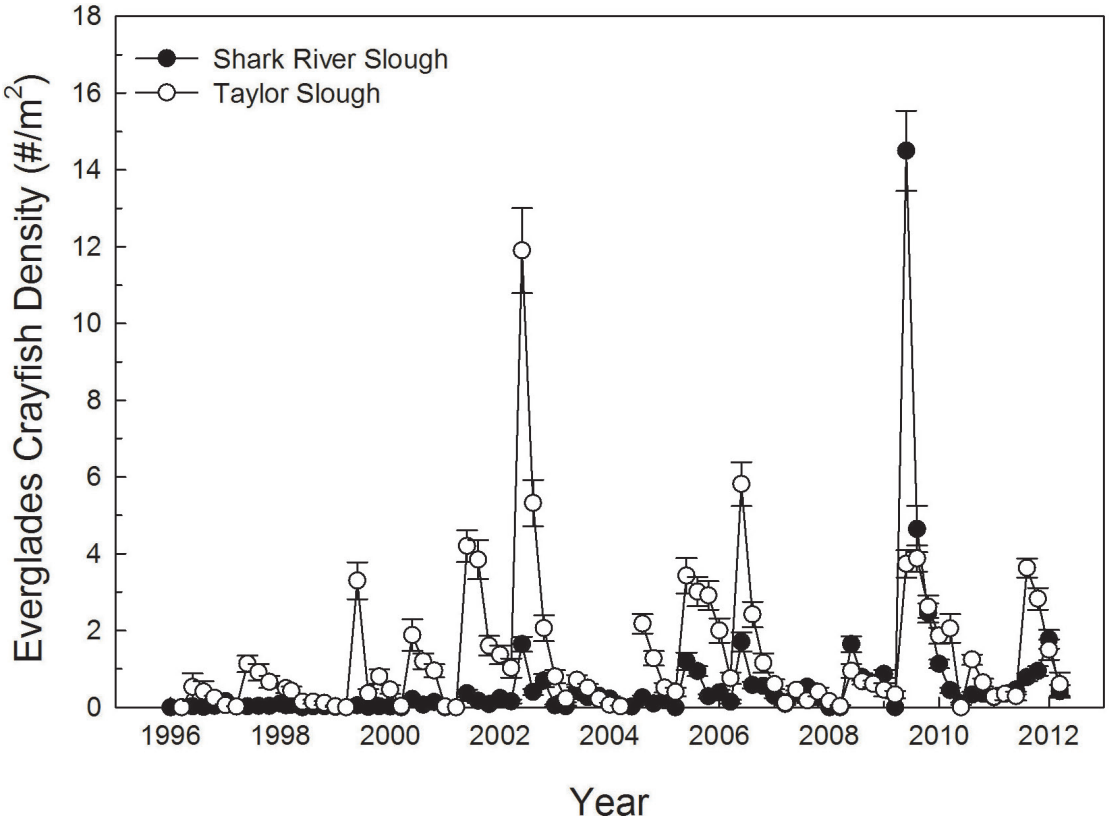


Figure 4.68. Everglades crayfish density (#/m^2) in Shark River and Taylor sloughs from 1996–2012.

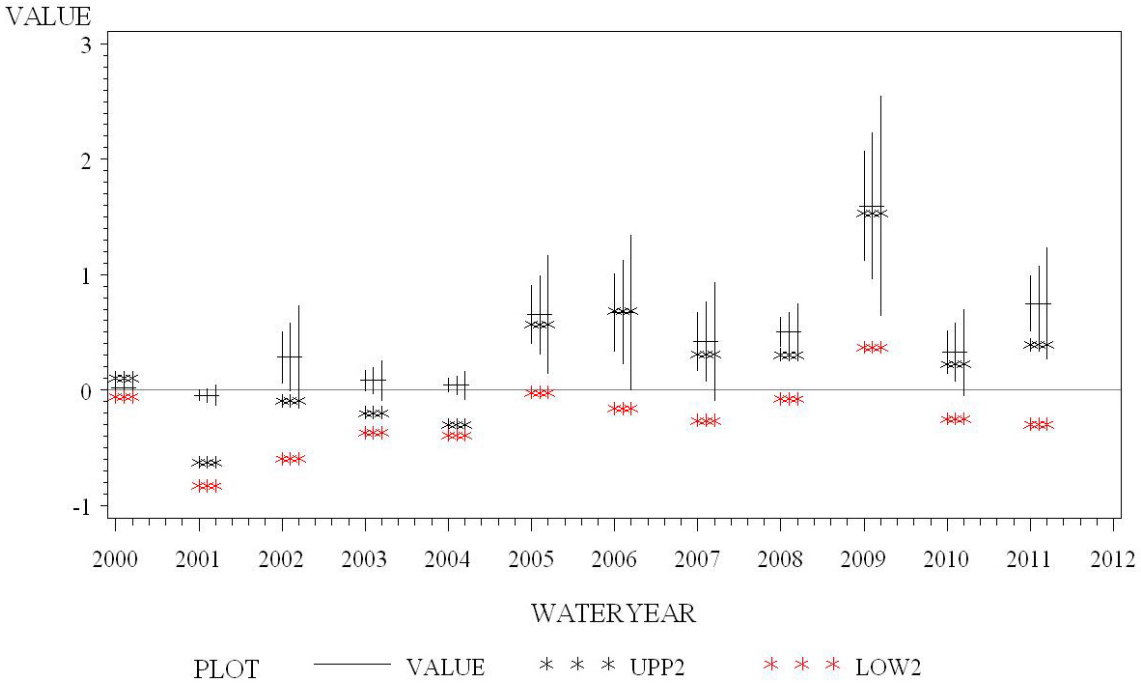
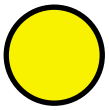


Figure 4.69. An example of the Everglades crayfish assessment from one site in Shark River Slough, 2000–2011. The average observed density (value ±1, 2, and 3 SE) and target density (with upper and lower intervals) are plotted. Stoplight assessments are based on the average of all sites in the region.

These findings warranted a red stoplight indicating significant concern for the conditions in SRS overall. Total fish abundance and bluefin killifish abundance were also lower than expected in TS, while abundance of drought tolerant species (flagfish and Everglades crayfish) was similar to expectations. These results indicated drier than expected conditions in TS and warranted a moderate concern (yellow) stoplight rating for the conditions in TS overall (Table 4.33).

Table 4.33. Summary aquatic fauna condition assessment for Taylor Slough, 2011–2012 (modified from Brandt et al. 2012).

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Taylor Slough overall		Moderately fewer fish were present than expected based on rainfall conditions and drought-tolerant species were abundant. Represents a decline in condition from previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Total fish abundance		Drier than expected conditions resulted in moderately lower fish abundance than expected and fewer than previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Bluefin killifish abundance		Drier than expected conditions resulted in lower abundance than expected and fewer than previous years.	Drought intolerant species. Abundance maximized in a manner that reflects pre-drainage conditions.
Flagfish abundance		Drier conditions resulted in expected abundance that was similar to previous years.	Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions.
Mosquitofish abundance		Drier conditions resulted in at or slightly below expected abundance that was similar to previous years.	Abundance is maximized in a manner that reflects pre-drainage conditions.
Everglades crayfish abundance		Drier conditions resulted in expected abundance that was similar to preceding years.	Drought tolerant species. Abundance is maximized in a manner that reflects pre-drainage conditions.

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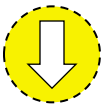
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4.6.6. Assessment of Biodiversity of EVER

Status and Trend

Attribute: Biodiversity

Overall Condition & Trend:



Rationale: EVER accumulates non-native species, and once established, non-natives are nearly impossible to completely eradicate. Reptiles and mammals are at greatest risk as a group. The co-occurrence of at-risk and non-native species is greatest in the Pinelands and Marl Prairies, Broad and Lostman's rivers, and Taylor Slough headwaters. There are 2–5 times more non-native species in Florida than non-natives that are already established in EVER, and there is a high risk that some of these species will establish in the near future.

Highlights

- Biodiversity is a foundational value of the Everglades ecosystem that is recognized in the legislation that established EVER, was reiterated in the legislation that expanded EVER in 1989, and is referenced as the rationale for all major international designations of EVER as an essential aspect of the world's heritage.
- The use of biodiversity as an indicator of natural resource condition is new.
- There are double the number of naturalized non-native reptiles in Florida that have not yet colonized EVER than there are species of native reptiles in EVER. This issue "Warrants Significant Concern."
- The Broad and Lostman's River (#2), the Taylor Slough Headwaters (#6), and the Pinelands and Marl Prairies (#7) warrant concern due to the co-occurrence of high numbers of at-risk and non-native species (Figure 4.70).
- Pinelands and Marl Prairies (#2) and Broad/Lostman's River (#7) regions are home to both high concentrations of native biodiversity across all species groups.
- Citizen science databases appear to be a good interim surrogate for compiling species richness patterns and assembling information about species richness for less easily recognized species groups.

Background and Importance

Biodiversity is a foundational value of the Everglades ecosystem. The Caribbean region is one of the world's hotspots for plant biodiversity. Everglades National Park contains a large number of plant, amphibian, reptile, and fish species that are found in very few other National Parks, and 199 special status species (threatened, endangered, or exploited). The importance of biodiversity in EVER is

magnified by the fact that it is the largest wilderness area east of the Mississippi River. If biodiversity is not conserved in EVER, it seems unlikely to be effectively conserved elsewhere in the eastern United States.

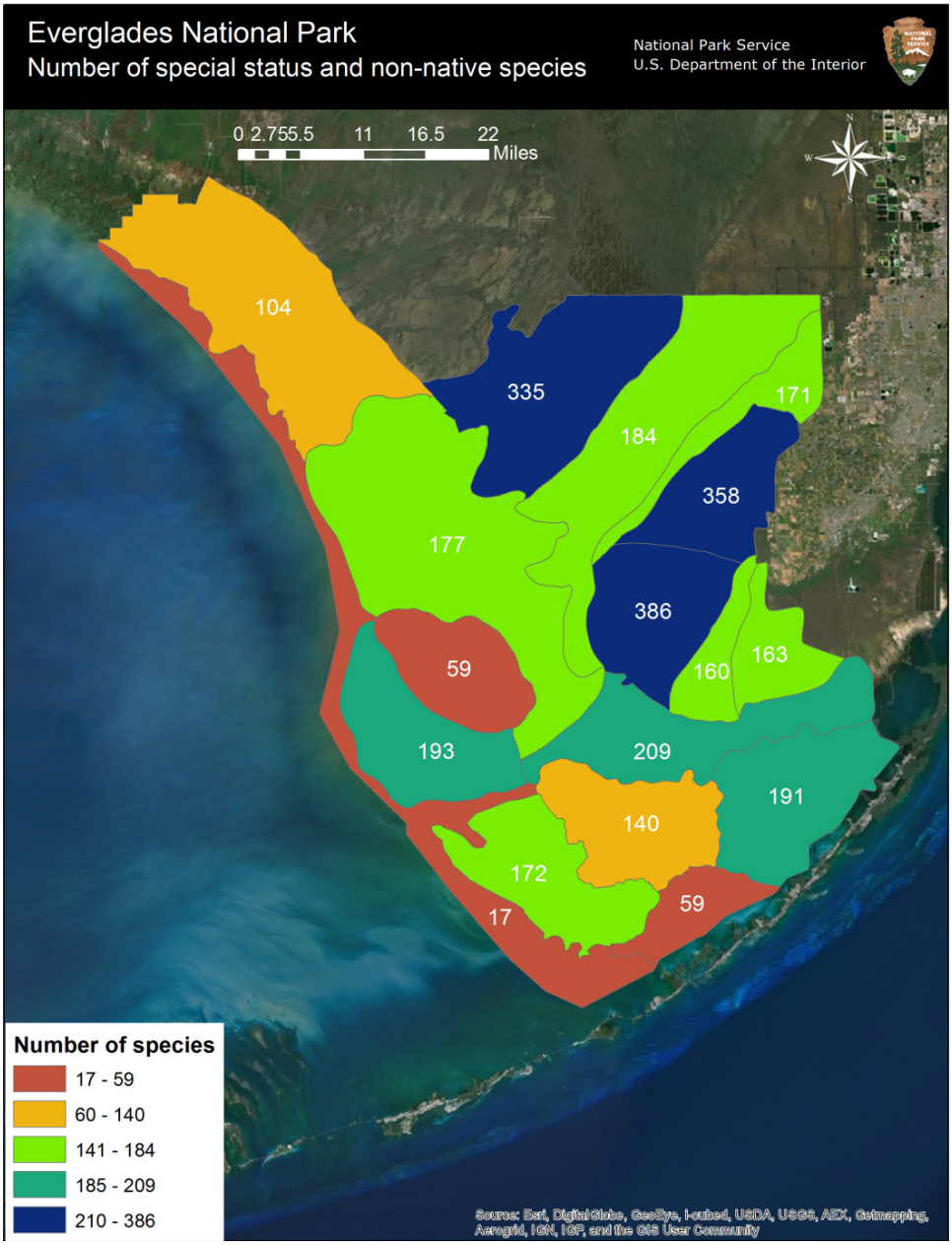


Figure 4.70. An estimate of the number of co-occurring at risk and non-native species are summed to create a biodiversity risk index among the different regions of EVER.

The status of overall biodiversity in EVER warrants concern and the overall trend is identified as declining, but the level of confidence in the overall assessment of status and trend is low. The number of non-native species that have established in EVER is clearly worrisome, as is the number of non-native species that are established in Florida, but not yet established in EVER. There is also

ample evidence that the ecosystem is resilient. Extirpation (or loss from the park) of species is extraordinarily rare and has only been inferred for four species – never observed directly. Recovery of desired hydrology patterns, habitats, and key indicator species has been observed to occur following hydrologic restoration in Taylor Slough, soil removal in the Hole-in-the-donut, and rehydration of the C-111 basin. Recovery of native vegetation and wildlife is a normal result of the removal of exotic plant species. The key uncertainty is whether the magnitude of the positive developments is as large as the magnitude of the challenges.

There are large differences (more than 1 order of magnitude) in total numbers of species across species groups (Table 4.34). EVER is home to hundreds of species of plants, birds, and fish; and tens of species of reptiles, mammals, and amphibians. Most of the species present in EVER in all groups are native to southern Florida. Unfortunately, a significant number (261 out of 1,589 total) of the native species are at-risk because they are endangered, threatened, commercially exploited, or are exhibiting rapid declines. Mammals and reptiles appear to be at greatest risk in EVER (Table 4.35). One out of three native mammal species is at-risk. As a group, mammals seem to be having problems surviving in EVER. There are almost twice as many reptile species that are naturalized in Florida (but not yet detected in EVER) as there are species of native reptiles present in the park. There appears to be a risk that invading reptiles could significantly alter the functions of the food web in EVER as the newly arriving reptiles fill empty niches, and systematically reduce the biomass of a broad spectrum of native animal species.

Table 4.34. Summary of number of species in EVER. Native species, non-natives, and at-risk native species counts are presented as counts and proportions.

Taxonomic group	Estimate of native species	% of all species that are native	#At-risk species	% of native species that are at-risk	#Non-native species	% of all species that are non-native	Total species
Birds	341	93.94%	71	20.82%	22	6.06%	363
Mammals	41	82.00%	15	36.59%	9	18.00%	50
Fish	385	97.22%	14	3.64%	11	2.78%	396
Reptiles	68	72.34%	10	14.71%	26	27.66%	94
Amphibians	19	86.36%	0	0.00%	3	13.64%	22
Plants	732	71.55%	151	20.63%	291	28.45%	1,023
Total	**1,586**	**–**	**261**	**–**	**362**	**–**	**1,948**

Table 4.35. Assessment of biodiversity and at-risk species in EVER. The desired state of conservation is that no species should be at-risk, the number of non-native species would be minimized, and the ratio of likely non-native species to existing species is low.

Metric	Integrity Measure	Condition	Rationale
Birds	Proportion at risk		Seventy one (20%) of the 341 native bird species in EVER are considered at-risk. Migratory populations incur significant risk outside EVER.
	% Non-Native Species		Twenty-two of the 363 species of birds present in EVER (6%) are non-native.
	Risk pool		125 non-native species are established in Florida, but not yet in EVER, which has 341 native bird species
Mammals	Proportion at risk		Fifteen of the 41 native mammal species (37%) are listed as special status.
	% Non-Native Species		Nine of 50 total mammal species found in EVER (18%) are non-native.
	Risk pool		Seventeen exotic mammals are established in FL, but not present in EVER, which has 41 native mammal species.
Fish	Proportion at risk		Fourteen of 385 fish species (4%) are considered at-risk EVER. Many small/cryptic fish species are included in this list, and thought to occur, but have not been observed in EVER.
	% Non-Native Species		Less than 3% of all species are non-native. Many small/cryptic fish species are thought to occur, but have not been observed.
	Risk pool		Twenty-three non-native fish are known to be established in Florida, but are not present in EVER, which has 385 native fish species.
Reptiles	Proportion at risk		Ten of the 68 native species (15%) of reptiles in EVER are at-risk.
	% Non-Native Species		Twenty-six of the 94 total reptile species observed in EVER are non-native. The Burmese python is the most well known non-native reptile.
	Risk pool		109 reptile species are naturalized in Florida, but not present in EVER. This is almost double the number of native reptiles.

Table 4.35 (continued). Assessment of biodiversity and at-risk species in EVER. The desired state of conservation is that no species should be at-risk, the number of non-native species would be minimized, and the ratio of likely non-native species to existing species is low.

Metric	Integrity Measure	Condition	Rationale
Amphibians	Proportion at risk		There are no known at-risk amphibians in EVER. Globally, amphibian species are thought to be in decline.
	% Non-Native Species		Three of the 22 amphibian species (14%) present in EVER are non-native.
	Risk pool		Eleven amphibian species are naturalized in Florida, but not yet detected in EVER, which has 19 native amphibian species.
Plants	Proportion at risk		151 plant species are considered at-risk, of 732 native plants species estimated to occur in EVER.
	% Non-Native Species		291 of the 1023 plant species (28%) in EVER are non-native.
	Risk pool		170 plant species are naturalized in FL, but not yet present in EVER, which has 732 native plant species.

Creating context for identifying management opportunities is helped by converting the raw numbers of species found in groups into summary metrics that are either proportions or ratios. This approach is useful because of the major differences in total numbers of species among the species groups. Converting raw numbers to metrics makes it easier to identify the degree of challenge for each species group.

The proportion of at-risk species, the proportion of non-native species, and the size of the risk pool of new invaders warrants “Moderate” or “Significant” concern for most species groups, and the trends of these metrics describing biodiversity are almost uniformly declining (Table 4.35). Most habitats found across the 1.5 million ac of EVER are fairly undisturbed, and likely to respond positively to restoration actions.

There are far more species present in EVER than are effectively assessed in Table 4.35. Most of the species that are not listed in NPSpecies have been detected only a few times, are represented only by museum collections, or are simply thought to occur in EVER because of the habitat associations that they exhibit in similar habitats in Florida, Central America, or the Caribbean. Table 4.36 provides estimates of the numbers of native species in EVER among some of the other organisms groups. Online datasets like the Global Biodiversity Information Facility (www.gbif.org), the encyclopedia

of life (www.eol.org), and fishbase (www.fishbase.org) are some of the sources of information on the many hard-to-recognize organisms that are occurring in EVER.

Table 4.36. Estimates of the total number and the number of unique families for species native to Everglades National Park.

Taxonomic Group	Native species	Families	Indicator Groups Under Study
Birds	341	53	wading birds, at risk, non-native
Mammals	41	14	small prey, at-risk
Fish	385	86	marsh fish, sport fish, non-native
Reptiles	68	15	alligators, crocodiles, non-native
Amphibians	19	9	currently none
Vascular Plants	732	141	All major habitat types, at-risk, non-native, seagrasses
*Insects: Butterflies and Skippers**	95	12	at-risk species
*Insects: Dragonflies**	63	6	currently none
*Insects (microinvertebrates): Midges**	126	TBD	currently none
*Crab/lobster/shrimp**	6	TBD	currently none
*Other crustaceans: Copepods**	39	TBD	currently none
*Spiders/Scorpions**	800	TBD	currently none
*Slugs/Snails**	TBD	TBD	at-risk, non-native
*Non-vascular plants (periphyton)**	TBD	TBD	response to water quality
*Fungi (estimated lichens)**	500	TBD	currently none
*Protozoa**	TBD	TBD	currently none
*Chromista**	TBD	TBD	currently none

* There are no species lists for groups in italics currently in NPSpecies – an online database of organisms present in many of the NPS administered lands

There is a tremendous amount of concern about global biodiversity in the last century, given the massive growth of human populations and the intensification of resource use. This context will not be repeated here, but the information developed in this report is intended to support an intelligent discussion about how best to support the underlying processes that maintain EVER's significant contribution to global biodiversity.

Assessing biodiversity is a bit different from assessing acreage of infestation of an exotic species, or biomass of a forest – both of which can change a lot over a decade. Biodiversity patterns change over much longer timescales, as species are created through evolutionary processes that play out over many generations.

It is likely that there are hundreds of thousands (of the 1.5 million total) acre-sized patches of habitat in EVER that are already affected by biodiversity loss, and it is this subtle erosion of biological function that is the leading risk to biodiversity in EVER. In healthy environments, even rare species can be found by an effective search of acre to km^2-sized areas. Loss of rare species in a habitat patch

is an early indicator of biological decline, some of which can result in “invasional meltdowns” and serious negative impacts to the food web that native organisms depend upon. Loss of rare species in patches is precisely the kind of decline that natural resource managers can detect early, and address with restoration actions (see 4.6.1.1 for a good example).

This is one of a very few assessments of overall biodiversity for EVER. The purpose of this assessment is to improve our understanding of biodiversity patterns in the park using the best available information and to identify areas where risks of native biodiversity loss are highest. There are inventories that cite an estimated number of species for various taxonomic groups and other studies that closely monitor the actual population size of specific functional groups or threatened and endangered species. Placing existing inventory and monitoring efforts into an overall framework of biodiversity patterns should help clarify the strengths and weakness among the different options for natural resource management in EVER.

Understanding how environmental drivers and stressors affect biodiversity is becoming more important now that national parks are last vestiges of wilderness areas - lands where human actions are not the primary determinant of landscape status. EVER is the largest remaining intact and contiguous wilderness area east of the Mississippi River. The Everglades ecosystem is recognized for its important contribution to global biodiversity. The preservation of flora and fauna in this region was identified in the enabling legislation and remains a fundamental value of natural resource management (H.R. 1455, 91st Congress, enacted into law December 6, 1947). This commitment was reconfirmed in the purpose of the EVER Protection and Expansion Act of 1989 (H.R. 1727, 101st Congress, enacted into law January 3, 1989). Biodiversity is also listed as one of the important factors that led to the park being designated as a World Heritage Site, International Biosphere Reserve, a Wetland of International Importance, and a specially protected area under the Cartagena Treaty.

Key aspects of biodiversity in EVER

Biodiversity information is typically summarized across a range of spatial scales. Scientists and natural resource managers can assemble locally collected data that count the number of species in small areas to compare the health of individual habitats and diagnose more complex management challenges across gradients of environmental stress. Comparisons of biodiversity among different locations are most meaningful when conducted within taxonomic groups of organisms that have reasonably similar life-history traits (i.e., trees, shrubs, herbaceous plants, birds, mammals, and reptiles) as a result of large differences in total number of species between these groups (MacArthur and Wilson 1967, Hubbell 2001).

Regions of the earth that are considered biodiversity hotspots are often associated with a coupling of climate and geographic contrasts. The Everglades occurs at the temperate-tropical convergence zone, where global circulation patterns are generally associated with arid environments. Most of the earth’s deserts occur at this conversion zone. The peninsular geography of southern Florida interacts with the warm oceans on either side of the peninsula to deliver consistent rains during the summer months. Regular rains combine with tropical storm events, flat topography, and transmissive geology to produce an expansive wetlands system covering the majority of southern Florida. Wetlands cover 4–

6% of the earth's land surface (Mitsch and Gosselink 2000), and are typically very small components of drainage basins. The position of thousands of square miles of continuous wetlands at the interface between temperate and tropical climates has created this unique area, where the much larger number of species that are present in tropical climates can colonize a small, isolated area with a subtropical climate. As a result, the forests, prairies, marshes and sloughs contain unique groupings of species.

The high rate of endemism in southern Florida is a second important aspect of the biodiversity of EVER. Endemism is a designation conferred on species that are restricted to a relatively small geographic area. The island biogeography of the Caribbean is thought to facilitate allopatric speciation processes that cause high rates of endemism. In Everglades National Park, tropical species are subject to selection for the physical characteristics that would allow them to colonize temperate conditions, and the isolation of populations of species that colonize southern Florida from their source populations on the tropical islands of the Caribbean hastens the rate of change in characteristics that allow species to thrive in the subtropical climate.

A third factor that promotes high biodiversity in EVER is its low nutrient status (Noe et al. 2001, 2002). The formation of a wetland system that is the scale of the Everglades ecosystem is more commonly found within the delta system of a larger, deeper, faster flowing river. Larger rivers typically have a surplus of nutrients due to erosion of topsoils that are carried into the river plain, but the Everglades is a very large, low nutrient wetland. Lower nutrient levels reduce plant biomass and create the context for the expression of high plant biodiversity at small spatial scales. Species richness (i.e., the number of species) of plants in small (10–100 m^2) patches of wetlands tends to be highest in medium biomass conditions (Keddy 2000). The low nutrient status of the Everglades watershed generally restricts the accumulation of biomass on the landscape and supports the development of large numbers of habitat patches that are packed with plant species.

The interaction of these three types of climate and geographic contrasts (tropical-temperate convergence, peninsula with basins dominated by low nutrient wetlands, and regional island geography, which supports high rates of endemism) have produced a unique and diverse ecosystem. Everglades National Park contains large numbers of species in several different organism groups, and the species that occur in EVER are found in only a few other National Park Service units (see section 2.2 of this document).

Why biodiversity matters to natural resource managers

All of the threats to the park identified in Chapter 2 of this report (altered fire conditions, climate change and sea-level rise, exotic species infestations, historical land use, nutrient pollution, pesticides and environmental contaminants, recreation and fishing in Florida Bay, reduced spatial extent of habitats in the landscape surrounding the park, and regional water management infrastructure) can negatively impact biodiversity. Some of the stressors (like fire) can be well managed, and can stimulate the expression of high biodiversity. Vegetated landscapes demonstrate high biodiversity at hectare to square mile spatial scales when the landscape contains a mosaic of well-developed habitats with clear boundaries and sharp ecotonal transitions (Folke et al. 2004).

Recent studies of ecosystem change suggest that the impacts of species loss (21–40% reduction in number of species in a patch) on basic ecosystem processes (like productivity and decomposition) are similar in magnitude to the impacts of climate change and pollution (David 2012, University of Michigan 2012). These insights have influenced the decision to focus this assessment on the highest priority risks to management of biodiversity: (1) local extirpation of at-risk native species, and (2) the proliferation of non-native species.

Non-native species are a particular concern in EVER (see section 4.6.1 and subsections therein), and the risks to biodiversity presented by non-natives receive special attention in this assessment. Non-natives can alter ecosystem functions (Doren et al. 2009) and can crowd out whole communities of native species (Loope and Dunevitz 1981, Ewel et al. 1982, Krauss 1987, and section 4.6.1.1 of this report). Multiple exotic invasive species can interact to produce "invasional meltdown" of local food webs (Simberloff and Von Holle 1999). The spread of exotic species threatens to impair biodiversity at all three relevant spatial scales: global, regional and local.

Description of Indicator Monitored

This assessment of biodiversity was limited to using native species richness (or the number of species), since abundance data was not available for most categories of taxonomic groups (Table 4.37). A first step in the assessment simply identifies a few common groups of species (birds, mammals, reptiles/amphibians, fish, and plants) and compares the number of species in EVER to the number of species found in the State of Florida. This provides a general orientation of how many species occur in each group and the role of EVER in supporting biodiversity statewide. Whole park metrics for each group of organisms are based on the proportion of at risk species in each group, and the proportion of non-native species in each group. The assessment of patterns of biodiversity within EVER utilizes the physiographic regions to provide contrast in patterns of biodiversity among the different regions of the park, and the degree of risk presented by non-native species to these different regions (Table 4.38).

Table 4.37. Whole park indicator metrics of biodiversity status/trend. Desired state of conservation is to maximize the proportion of native species and minimize the proportion of natives at-risk and the pool of non-natives that are likely to establish.

Metric	Scale	Threshold
Proportion nonnative	Whole park	Assessed by proportion of species in a group that are nonnative: Good Condition: ≤10%; Moderate Concern: 11–30%; Significant Concern: > 30%
Proportion of natives at risk	Whole park	Assessed by proportion of native species that are special status: Good Condition: ≤10%; Warrants Moderate Concern: 11–30% ; Warrants Significant Concern: < 30%
Risk Pool	State of Florida	Assessed by calculating a ratio of the number of likely non-native species arriving divided by the number of native species in EVER (risk pool = naturalized in Florida, as indicated by EDDMaps.org): Good Condition: ≤0.5; Warrants Moderate Concern: 0.51–1.0; Warrants Significant Concern: < 1.0

Table 4.38. Physiographic region based indicators of biodiversity status. Status is assigned to each guild in each region.

Metric	Scale	Threshold
Proportion native	Physiographic region	Resource in Good Condition: ≥95% of species are native Warrants Moderate Concern: 80–95% of species are native Warrants Significant Concern: < 80% of species are native
Meltdown risk	Physiographic region	Good Condition: ≤0.5; Warrants Moderate Concern: 0.51–1.0; Warrants Significant Concern: < 1.0

The number of species found in each organism grouping was determined by combining a species/attribute database created by Howington (2008) with the species list that is publically available through NPSpecies.gov (NPS IRMA Portal 2014). The species/attribute database identifies the habitats where a species expected to be present during at least one critical part of its life cycle. Each species present in this list is associated with one or more of 59 possible habitat types described in the landscape analysis of the Florida Gap (F-Gap) study (Pearlstine 2002). Each habitat type was associated with one or more of the physiographic regions. The combination of these two associations made it possible to associate each species with one or more physiographic regions.

Assessment of biodiversity patterns among physiographic regions is conducted in two steps. First, the concentration of native biodiversity is assessed by ranking each region (1–17 lowest rank = largest number of species in a group) by number of species in each category. The sum of these rankings across groups are used to identify which regions tended to contain a large proportion of the total biodiversity in EVER. These rankings are not used to assign status or trend since the assessment simply seeks to identify natural hotspots of biodiversity.

The assessment of risks to effective conservation of biodiversity across physiographic regions is designed to identify and prioritize the risks for each species group in each region. The number of at-risk biota, the total number of native species, and the number of non-native species are calculated for each region. The proportion of all species per group that are non-native is calculated for the first assessment metric. A second metric subtracts the number of at-risk species from the number of native species, and calculates the ratio of non-native/not-at-risk native species. The second metric provides a sense of the risk of "invasional meltdown" for a region. The idea is that if there a high proportion of the species in a group are non-native and if a high proportion of the native species are at-risk, the area is at a greater risk of an ecological meltdown.

Assessments of biodiversity status by region

There are two parts to the regional assessment of biodiversity. Part one is identifying where biodiversity is concentrated among the regions indicated in Figure 4.71. Part two is assessing the potential vulnerabilities associated with different species groups among the seventeen regions in EVER.

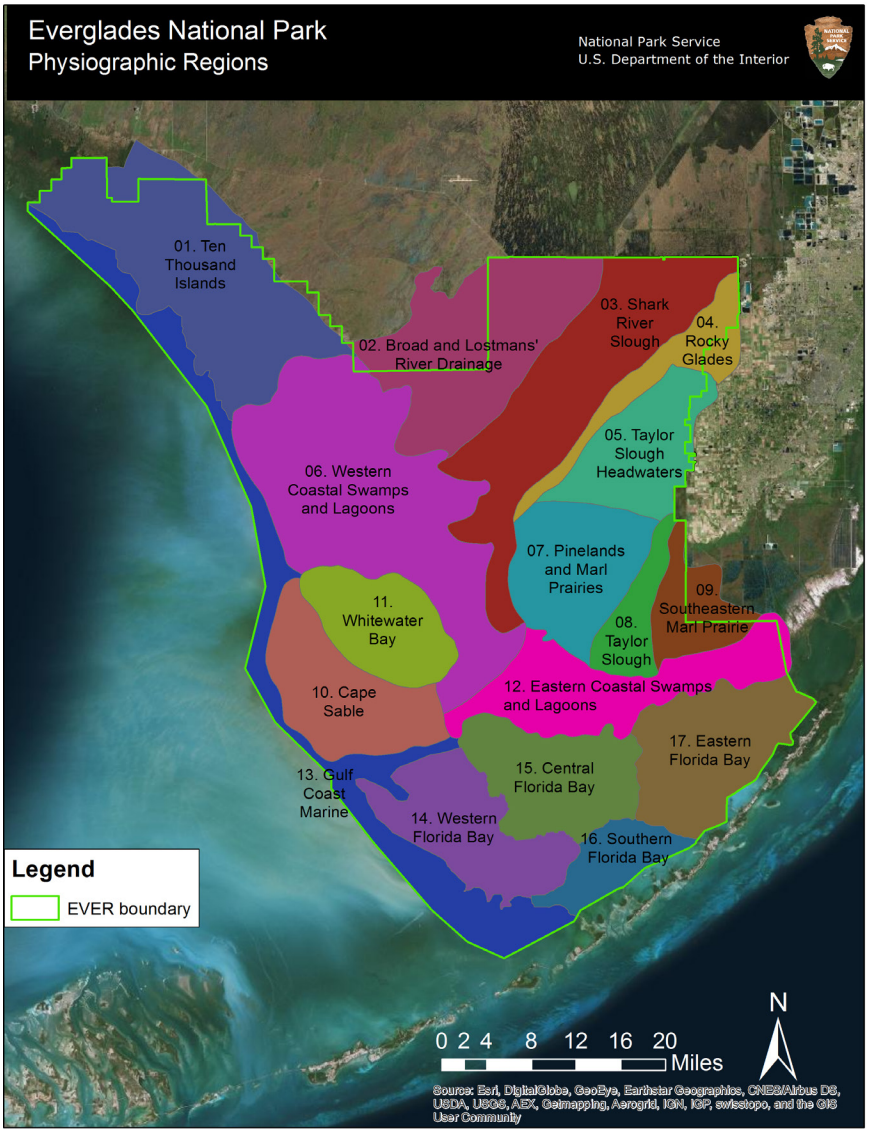


Figure 4.71. The seventeen regions of EVER that contain unique landscapes and conditions based on the interaction of physical geography and agents of change.

The overall assessment of biodiversity concentration is conducted by ranking regions within groups, and aggregating the rankings across groups within a region. This process reduces the influence of birds and fish on the overall assessment of biodiversity. The result indicates that biodiversity of mammals, birds, fish, reptiles, and amphibians is concentrated in the Pinelands and Marl Prairies, Broad/Lostman's River Drainage, and Eastern Coastal Swamps and Lagoons regions (Figure 4.72). If raw numbers of species were used to conduct this assessment, Cape Sable and Central/Western Florida Bay would be biodiversity hotspots – mostly because these areas are home to many species of birds and fish. At the time of this assessment, there was not sufficient information to authoritatively assign plant species presence/absence to each region. It is likely that the inclusion of plants would change the outcome of the counting result (because pinelands contain so many of the

732 native plant species), but not the ranking result (because the high-ranking areas would rank high for plant species as well).

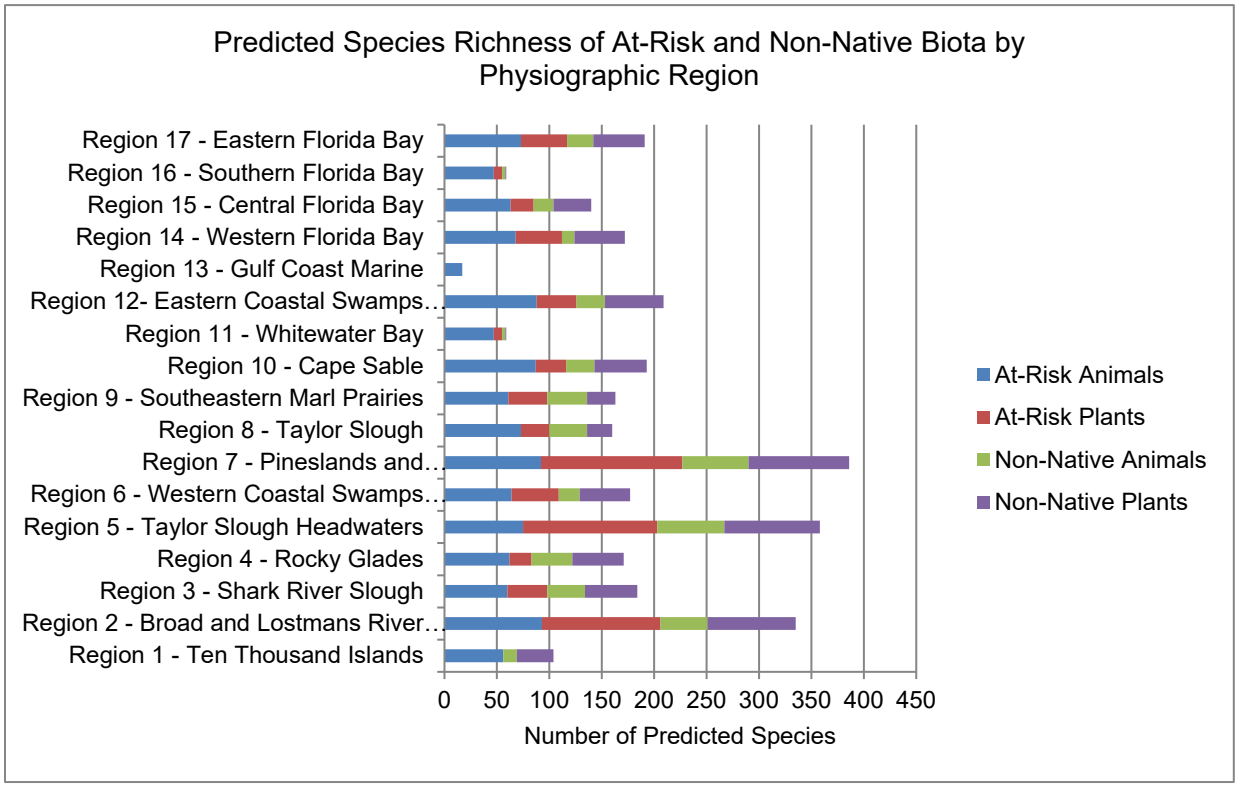


Figure 4.72. The number of at-risk and non-native plants and animals predicted to occur across the 17 regions of EVER. Note that the highest species counts in these categories are nearly double the average value (181 species) across all regions.

Risks to effective conservation of biodiversity are associated with the loss of at-risk and the addition of non-native species. A leading indicator of biodiversity challenges is illustrated in Figure 4.70, and summarized in a graph in Figure 4.72. The co-occurrence of large numbers of at-risk species and large numbers of non-native species is conspicuously high in Broad/Lostman's River, Taylor Slough headwaters, and Pinelands and Marl Prairies regions (Tables 4.39 and 4.40).

It is interesting to note that the Pinelands, Marl Prairies, and Broad/Lostman's River Drainage regions appear to be home to both high concentrations of native biodiversity and risks to biodiversity.

"Risk pools" summarize the fraction of non-native species found in the State of Florida that are present in EVER (as reported by EDDMaps.org, a citizen science database). EVER contains 15–59% of the non-native species that are found in Florida, when species are separated into six major groups (Table 4.40).

Table 4.39. Percentage of species in EVER that are considered at-risk for having a very low or rapidly declining population.

Taxonomic Group	#At-risk Species	% Total Species	Region(s) where most At-Risk species occurring
Birds	71	21% (out of 341 total)	2, 7, 12
Mammals	15	37% (out of 41 total)	2, 4, 7, 12
Fish	14	4% (out of 385 total)	11, 16, 17
Reptiles	10	15% (out of 68 total)	2, 5, 11, 12, 17
Amphibians	0	0% (out of 19 total)	–
Plants	151	21% (out of 732 total)	2, 6, 7

Table 4.40. Percentage of Non-Native Species in Florida found in EVER.

Taxonomic Group	#Non-Native Species	% Total Non-native Species in Florida (EDDmaps.org)	Region(s) where most Non-native species occurring
Birds	22	15% (out of 147 total)	6, 7
Mammals	9	35% (out of 26 total)	6, 7
Fish	11	32% (out of 34 total)	2, 3, 8
Reptiles	26	19% (out of 135 total)	2, 6, 7
Amphibians	3	21% (out of 14 total)	All regions except 1 and 16
Plants	243	59% (out of 413 total)	2, 6, 7

Risk metrics

Unacceptably high proportions of non-native reptile species could occur in almost all regions of EVER (20–48% of species; Table 4.41), and while the risk of "invasional meltdown" (a term coined by Simberloff and Von Holle (1999) that identifies the synergistic impacts that occur when a critical mass of non-natives invade, facilitate the spread of non-natives, and significantly affect ecosystem functions) appear low for most organism groups, these risks are clearly highest for reptiles. Mammals are the next highest risk group, as a result of the high proportions of non-natives that can potentially occur. Regions 6, 7, 8, and 9 yield the highest number of moderate (yellow) or significant (red) concern results.

The good news is that the invasional meltdown risk metric is low across EVER. Even the regions where at-risk species and non-natives are concentrated (Pinelands and Marl Prairies and Broad/Lostman's river) contain enough other species to prevent non-native species from attaining numerical dominance in any region/species group combination.

Table 4.41. Assessment of biodiversity risks in the five major guilds across the 17 regions of EVER.

Species Group	Assessment Category	Region 1 Ten Thousand Islands	Region 2 Broad and Lostman's River Drainage	Region 3 Shark River Slough	Region 4 Rocky Glades	Region 5 Taylor Slough Headwaters	Region 6 Western Coastal Swamps and Lagoons	Region 7 Pineland and Marl Prairie	Region 8 Taylor Slough	Region 9 Southeastern Marl Prairie	Region 10 Cape Sable	Region 11 Whitewater Bay	Region 12 Eastern Coastal Swamps and Lagoons	Region 13 Gulf Coast Marine	Region 14 Western Florida Bay	Region 15 Central Florida Bay	Region 16 Southern Florida Bay	Region 17 Eastern Florida Bay
Birds	Proportion nonnative	2%	2%	2%	1%	2%	7%	6%	3%	1%	2%	2%	2%	0%	1%	3%	2%	3%
	Meltdown risk	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Mammals	Proportion nonnative	20%	18%	22%	19%	12%	27%	24%	19%	17%	15%	0%	19%	0%	15%	17%	0%	25%
	Meltdown risk	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.0	0.3	0.0	0.3	0.3	0.0	0.4
Fish	Proportion nonnative	0%	8%	19%	23%	3%	23%	20%	20%	20%	2%	0%	1%	0%	1%	1%	0%	7%
	Meltdown risk	0.0	0.1	0.2	0.2	0.0	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Reptiles	Proportion nonnative	37%	29%	26%	41%	26%	47%	44%	32%	48%	27%	8%	26%	NA	10%	38%	8%	24%
	Meltdown risk	0.5	0.3	0.3	0.4	0.3	0.6	0.5	0.4	0.5	0.4	0.1	0.3	0.0	0.1	0.5	0.1	0.3

Table 4.41 (continued). Assessment of biodiversity risks in the five major guilds across the 17 regions of EVER.

Species Group	Assessment Category	Region 1 Ten Thousand Islands	Region 2 Broad and Lostman's River Drainage	Region 3 Shark River Slough	Region 4 Rocky Glades	Region 5 Taylor Slough Headwaters	Region 6 Western Coastal Swamps and Lagoons	Region 7 Pineland and Marl Prairie	Region 8 Taylor Slough	Region 9 Southeastern Marl Prairie	Region 10 Cape Sable	Region 11 Whitewater Bay	Region 12 Eastern Coastal Swamps and Lagoons	Region 13 Gulf Coast Marine	Region 14 Western Florida Bay	Region 15 Central Florida Bay	Region 16 Southern Florida Bay	Region 17 Eastern Florida Bay
Amphibians	Proportion nonnative	0%	17%	13%	18%	14%	18%	18%	13%	19%	15%	0%	18%	NA	15%	25%	0%	15%
	Meltdown risk	0.0	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.0	0.2	NA	0.2	0.3	0.0	0.2

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4.7. Florida Bay and Marine Biological Integrity

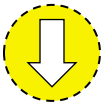
The health of the biological communities in Florida Bay is currently evaluated through careful consideration of a spectrum of indicator communities (seagrasses/softbottom and sponges/hardbottom), organism functional groups (estuarine fish), indicator species (pink shrimp, sea trout, Crocodiles, and spoonbills), and overall patterns of biodiversity. Invasive species are also evaluated, given the potential threat that they pose to conserving coherent ecosystem functions that can be experienced by future generations.

4.7.1. Invasive Species (fish, invertebrates, sea-grasses)

Status and Trend

Attribute: Invasive Species

Overall Condition & Trend:



Rationale: No systematic monitoring of invasive marine species occurs. Although there is a growing list of organisms that have been detected in the region. Lionfish are a growing concern.

Desired State of Conservation: The desired state of conservation is to eliminate the presence of exotic marine species, or realistically, to minimize the number of introduced marine exotic species in EVER to an acceptable level through periodic and repeated monitoring and removal efforts.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Background and Importance

Biological invasions can negatively affect the distribution and abundance of native species through predation, competition, and habitat alteration. Invasive species are a major contributor to local and global extinctions (Vitousek et al. 1997, Mack et al. 2000).

Several marine invasive species have been reported in south Florida, including several acorn barnacle species (*Balanus* spp.), Asian green mussel (*Perna viridis*), the Pacific Ocean jellyfish (*Phyllorhiza punctata*), and lionfish (*Pterois volitans* and *P. miles*; Baker et al. 2004). However, the primary marine invasive in Everglades National Park (EVER) is lionfish. Introduced predators such as lionfish, with novel characteristics and behaviors, exploit the naïveté of local prey; thus, invasive predators often have stronger effects on native prey than native predators (Salo et al. 2007).

Lionfish are native to the Indo-Pacific and were first introduced to Florida waters during the mid- to late 1980's (Hamner et al. 2007). Self-sustaining breeding populations are now widespread, making

lionfish the first truly invasive marine fish in the Atlantic (Albins and Hixon 2011). Lionfish possess a broad range of traits that make them successful invaders: venomous spines, cryptic form, habitat generality, high competitive ability, efficient predation, rapid growth, high reproductive rates, and resistance to parasites (Albins and Hixon 2011). In addition, there is serious concern that lionfish could act synergistically with existing stressors of marine systems, such as overfishing, hypersalinity, and ocean warming, resulting in severe negative consequences for the local ecosystems, and consequently negatively affecting valuable fisheries (Albins and Hixon 2011).

Lionfish are generalist predators that feed on at least 25 families of native fishes, along with a variety of invertebrates including shrimp and crabs (Albins and Hixon 2008, Côté et al. 2013). They prey on economically and ecologically important species such as groupers, snappers, and parrotfishes (Côté et al. 2013). Although anecdotal information suggests that Atlantic grouper occasionally consume lionfish (Maljkovid et al. 2008), these predators have been systematically overfished throughout the region (Ault et al. 2005). The apparent paucity of predators may be due in part to venomous dorsal, anal, and pelvic fins on lionfish (Albins and Hixon 2011). Densities of lionfish in Atlantic waters often exceed those of the most common native mesopredators (Whitfield et al. 2007) and far exceed lionfish densities in their native range (Green and Côté 2009, Darling et al. 2011). In addition, lionfish in invaded regions reach larger maximum sizes and higher abundances than they do in their native range (Darling et al. 2011).

Lionfish occupy a wide range of habitats including coral reef, seagrass, mangrove, estuary, and man-made structures (Barbour et al. 2010). Lionfish have a wide salinity tolerance and are capable of surviving at lower salinities (Jud et al. 2011); hence, lionfish can potentially invade any habitat type within Florida Bay. Because seagrass beds and mangrove areas are known to be important nursery areas for juvenile fish and invertebrates (Hunt and Nuttle 2007), the impact of the lionfish invasion into Florida Bay is a serious concern.

In the Turks and Caicos Islands, preliminary catch-per-unit-effort (CPUE) of lionfish was about two times higher in seagrass beds, and about four times higher in mangrove areas, than on reef of similar depth (Claydon et al. 2010). Similarly, CPUE for lionfish in the Bahamas was also higher in mangroves than on reefs (Barbour et al. 2010). In addition, prey diversity was higher in mangroves than on reefs (Barbour et al. 2010). Lionfish that reside in mangrove habitats are of smaller average size than lionfish that reside on reefs of equal depth, suggesting that mangroves may serve as lionfish nurseries (Barbour et al. 2010, Claydon et al. 2010).

Seagrasses are the dominant biological community in Florida Bay and have historically covered more than 90% of the bay; about 7% of the bay is mangrove habitat (Hunt and Nuttle 2007). With higher lionfish, CPUE reported elsewhere for these habitats than on reefs (Barbour et al. 2010, Claydon et al. 2010), the importance of seagrass in Florida Bay as a habitat for lionfish should not be underestimated.

Prey diet also differs among lionfish that reside in reef, mangrove, or seagrass habitats. Lionfish diets in estuaries, seagrass meadows, and mangrove habitats are typically dominated by small shrimp (Jud et al. 2011). This may have far-reaching effects since Florida Bay serves as one of the principal

nurseries for the offshore Tortugas pink shrimp fishery (Hunt and Nuttle 2007). Florida Bay also provides important spawning habitat for spotted seatrout (Powell 2002), as well as other commercially important species (Powell et al. 1989) that lionfish may impact.

Lionfish are slow-swimming fish that are easily captured or speared. Tagging studies suggest that the majority of lionfish have high site fidelity, even after weeks or months at liberty (Jud and Layman 2012). Their high site fidelity and small ranges may make localized population control feasible since lionfish removed from a given habitat would be replaced largely through larval recruitment rather than migration (Jud and Layman 2012).

Lionfish are less likely to be observed and reported in Florida Bay than on coral reefs since there are far fewer visitors in the water making observations. Thus, it is possible that invasions in locations like EVER may go undetected for considerable periods of time. To date, only nineteen lionfish have been sighted in EVER. The low number of reports is likely due to the absence of a monitoring program rather than the absence of lionfish, as lionfish are present throughout the surrounding region. Early detection and control of lionfish in these areas may be crucial to preventing their long-term ecological impacts on these critical ecosystems. Since the Everglades provide critical habitat for numerous commercially, recreationally, and ecologically important species, establishment of lionfish is of particular concern.

Desired State of Conservation

The desired state of conservation is to eliminate the presence of lionfish (Photo 27), or realistically, to minimize the number of introduced lionfish in EVER to an acceptable level through periodic and repeated monitoring and removal efforts. Since adult lionfish have few (if any) predators in their introduced habitats, the potential for introduced lionfish to displace native predators is high. Furthermore, in a situation of increasing lionfish abundance, it is possible that lionfish will begin preying upon other economically important native predators whose populations may already be threatened due to overfishing, habitat degradation, and other factors. Thus, the predation impact of lionfish also should be measured to track the effect of their invasion on the native community. In addition, the spatial distribution of lionfish within EVER should be documented throughout the invasion. Lionfish densities will likely increase until resources become limiting, either by exceeding the carrying capacity of the local environment or through competition with native species; thus, the potential for predation pressure on the forage fish community, and ultimately the competition with economically important species, is of grave concern.



Photo 27. Lionfish (*Pterois volitans*). Photo by James Morris Jr., NOAA.

Description of Indicator Monitored

EVER currently has no established lionfish monitoring program. Nineteen lionfish have been reported from opportunistic sightings from either park staff or visitors. Five of the lionfish were found in hardbottom habitat, while one sighting was from a seagrass bed. All of the lionfish reported were under 27 cm total length.

EVER should establish a monitoring program to measure the effect of lionfish on the Florida Bay ecosystem. Monitoring the effectiveness of lionfish removals and setting removal frequency targets are critically important to measuring the extent of the invasion. To manage the lionfish invasion, EVER would focus on controlling the size of local lionfish populations because the number of lionfish in an area largely dictates the extent of their impact.

To assess lionfish predation impacts, EVER should monitor trends in the diversity and biomass of prey-sized invertebrates and fish in relation to lionfish density and biomass. The maximum size of prey that lionfish can consume is largely determined by their gape size (i.e., mouth-opening size).

Lionfish have been documented to consume prey greater than 40% of their total length. As a result, the vulnerability of native species to lionfish predation depends on the size of the lionfish in the area. Lionfish are capable of growing to well over 40 cm total length in their introduced range; therefore, fishes and crustaceans up to 15 cm length could be consumed. Lionfish of this size can be easily enumerated during visual surveys at predetermined locations within the marine areas of EVER.

Lionfish have been reported from all major marine seafloor and substrate types within the Atlantic and are capable of establishing themselves in all habitat types found in Florida Bay. All lionfish reports will be documented and the spatial location, habitat type, and depth of the lionfish sighting will be recorded.

Status of the Indicator in the Current Year and Trends over Time

Lionfish were first reported in EVER in 2010. Due to the absence of monitoring and the short time period since introduction, no trend can be established at this time. However, the potential for lionfish recruitment into Florida Bay is very high. The Florida Fish and Wildlife Conservation Commission and other research entities have reported lionfish in large numbers right outside the park boundary along the Intracoastal Waterway. We expect that the number of lionfish sightings within EVER will continue to increase over time (Table 4.42).

Table 4.42. Summary of the lionfish indicator criteria of significance in Everglades National Park.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Lionfish density		Lionfish density in mangroves and on seagrass beds often exceeds density on reefs (Barbour et al. 2010, Claydon et al. 2010).	Minimize the number of lionfish in Florida Bay
Biomass of prey species		Lionfish have a large impact on prey species	Minimize the impact from lionfish on post-settlement native fish and invertebrate populations
Distribution of lionfish		Lionfish are able to invade any habitat type within Florida Bay	Minimize the spatial distribution of lionfish

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4.7.2. Seagrass/softbottom communities in Florida Bay

Status and Trend

Attribute: Seagrass

Overall Condition & Trend:



Rationale: Initial efforts at regional restoration of freshwater flows have improved conditions for seagrass. Additional restoration will be necessary to achieve goals for species composition, biomass, and stability of seagrass beds in Florida Bay.

Desired State of Conservation: Increased frequency of low-salinity seagrass species, higher diversity of seagrass beds at small spatial scales (1–10 m^2), and reduced frequency of seagrass bed die-off events.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

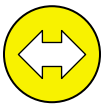
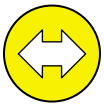
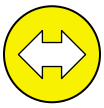
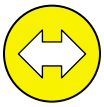
Highlights

Although the SAV indicators show a positive trend in some areas (Table 4.43), this assessment should be interpreted cautiously because the system is still vulnerable to drought-induced hypersaline conditions. Seagrass communities are not yet near the desired condition. These communities are threatened and will remain threatened until improvements in terrestrial water management system are installed and operated effectively. Restoration efforts to improve freshwater delivery into the system need to continue.

Table 4.43. Status of seagrasses in various zones within Florida Bay, Everglades National Park.

Zone	Criteria	Condition & Trend	Rationale	Desired State of Conservation
Northeastern Zone	Seagrass Abundance		Aggregate Abundance Index is in the good range, with signs of recovery from the 2005–2008 algal bloom. However, moderate concern is warranted because salinity levels in the area remain high.	Abundance of seagrass consistent with a restored Everglades ecosystem.
	Target Species Diversity		Good measurements of current species mix along with the presence of subdominants (*Halodule* and *Ruppia*). Desired mixed-species communities have not yet established.	Seagrass species diversity and niche diversity consistent with a restored Everglades ecosystem.

Table 4.43 (continued). Status of seagrasses in various zones within Florida Bay, Everglades National Park.

Zone	Criteria	Condition & Trend	Rationale	Desired State of Conservation
Transition Zone	Seagrass Abundance		Aggregate Abundance Index was fair for 2010–2011, since density levels fell in 2006.	Abundance of seagrass consistent with a restored Everglades ecosystem.
	Target Species Diversity		A good mix of target species decreased during 2006–2007 and has yet to recover due to dominance of turtle grass.	Seagrass species diversity and niche diversity consistent with a restored Everglades ecosystem.
Central Zone	Seagrass Abundance		Aggregate Abundance Index was fair for 2010–2011, since improving from poor in 2008.	Abundance of seagrass consistent with a restored Everglades ecosystem.
	Target Species Diversity		Reflects the increasing presence of target species of *Halodule* and *Ruppia*.	Species diversity and niche diversity consistent with a restored Everglades ecosystem.
Southern Zone	Seagrass Abundance		Poor rating due to reduced and declining densities of seagrass in this area.	Abundance of seagrass consistent with a restored Everglades ecosystem.
	Target Species Diversity		Fair after improving in 2009 from several years in the poor range. Species dominance component improved to fair.	Species diversity and niche diversity consistent with a restored Everglades ecosystem.
Western Zone	Seagrass Abundance		High scores in the Abundance Index, sustaining improvement from 2008.	Abundance of seagrass consistent with a restored Everglades ecosystem.
	Target Species Diversity		Reflects good scores because the target species component increased.	Species diversity niche diversity consistent with a restored Everglades ecosystem.

Background and Importance

Submerged aquatic vegetation (SAV) communities composed of seagrasses and macroalgae form the basis for the keystone community of the Florida Bay ecosystem (Fourqurean et al. 2002). SAV communities are an important indicator of ecosystem health because they provide key ecological services, including sediment stabilization, nutrient cycling, and food resources for upper trophic levels, and they provide habitat structure that enhances local biodiversity (Orth et al. 2006). These plants are not just the base for a highly productive food web; they also provide essential habitat for

invertebrates and juvenile, adult, and spawning fish in upper trophic levels, including many economically important species. Seagrasses also provide a large nutrient sink, which restricts nutrient availability to phytoplankton, thereby ameliorating potential algal blooms (Madden et al. 2009).

Because SAV communities reside at the land and sea interface, they are subject to physical disturbances and water quality changes associated with anthropogenic influences. Spatial and temporal salinity patterns and nutrient and light levels affect SAV species composition, abundance, and spatial distribution. Freshwater inflow quantity, timing, and distribution affect salinity, nutrient, and light levels. Seagrasses are useful reflections of the health of an ecosystem because they respond to highly variable and not easily detectable aspects of the system, including pulses of nutrients and changes in sediment conditions (Madden et al. 2009). Thus, seagrasses are considered one of the best indicators of change in Florida Bay (Fourqurean et al. 2002).

Thalassia testudium (turtle grass) is the dominant seagrass and is considered the climax species in the Florida Bay ecosystem. *Halodule wrightii* (shoal grass) and *Syringodium filiforme* (manatee grass) are found to be mixed with turtle grass, although manatee grass is typically found in deeper marine areas in the western part of the bay. *Ruppia maritima* (widgeon grass) occurs in the northern areas of the bay. *Halophila engelmannii* (star grass) and *Halophila decipinens* (paddle grass) are two rare species found in various regions of the bay. Along with macroalgae, these species form the SAV community of Florida Bay.

The seagrass community underwent a widespread mortality event in 1987, which began with observations of "potholes" in seagrass beds in the north-central part of Florida Bay. Extensive areas of *Thalassia* began dying rapidly in the central and western basins, resulting in a 30% loss of the community by 1990 (Madden et al. 2009). These mortality events led to a cascade of ecological effects, such as increased turbidity, frequent algal blooms, and negative impacts to the sponge community, spiny lobsters, pink shrimp, and game fish landings. Years of hypersaline conditions most likely triggered these mortality events, creating favorable conditions for Thalassia to exceed its carrying capacity and consequently crash (Fourqurean et al. 2002). In order to improve conditions for the seagrass community and the Florida Bay ecosystem, restoration goals are focused on an improved salinity regime and increased freshwater inputs.

Desired State of Conservation of the Indicator

The Desired State of Conservation for SAV community composition is an increase in low-salinity seagrass species that are currently less dominant in the bay's overall seagrass community than they were historically. In Florida Bay, the desired condition would include the recovery of seagrass beds over most of the bay bottom, extending west along the Gulf of Mexico coastal shelf, as well as to restore a diverse mosaic of Thalassia, Halodule, Ruppia, and Syringodium seagrass communities.

The seagrass indicators are created from a set of metrics that reflect the attributes of the SAV community. These metrics include spatial extent, abundance, species dominance, and presence of target species. All four metrics are combined to produce a single Abundance Index that reflects the status and health of the community. For the Abundance Index metric, the desired state of

conservation would demonstrate a long-term positive trend in community composition (abundance and extent) of SAV in the Florida Bay ecosystem.

The Target Species Index is a metric measurement of the frequency of occurrence of the desirable non-dominant SAV species that are expected to increase with increased freshwater flow to Florida Bay, resulting in improved habitat quality (Madden et al. 2009). Indicator targets vary spatially and are zone-specific (see description of the indicator for a complete explanation of the zone-specific targets). For the Target Species Index, the desired state of conservation would see a long-term positive trend in target species of SAV in the Florida Bay ecosystem.

Description of Indicator Monitored

SAV assessment indicator data are collected under a multi-agency monitoring program. Data for Florida Bay in Everglades National Park are being collected primarily through two programs: 1) SAV monitoring in northeastern Florida Bay by the Miami-Dade Department of Environmental Resource Management (Miami-Dade DERM) and 2) in northern and central Florida Bay by the South Florida Fisheries Habitat Assessment Program (FHAP). Monitoring for SAV in Florida Bay has been in progress since the early 1990's.

DERM monitors SAV within basins of two regions in northeastern Florida Bay (Figure 4.73). The Northern Transition Zone includes Highway Creek, Long Sound, Joe Bay, Alligator Bay in Eagle Key basin, Davis Cove and Trout Cove in Deer Key basin, Little Madeira Bay, and an area south of Little Madeira Bay near Eagle Key Basin. The Northeastern Zone includes Manatee Bay, Barnes Sound, Little Blackwater Sound, and Blackwater Sound. These basins were selected to detect potential effects of managed water releases into Taylor Slough and the C-111 canal system.

FHAP provides spatially explicit data on the distribution, abundance, and species composition of Florida Bay SAV. South Florida FHAP annual sampling is at the end of the dry season (May–June) when salinity stress on seagrasses is typically highest. SAV is visually quantified at 30 randomly selected sites within 20 basins of Florida Bay (Figure 4.73). Intensive sampling efforts are conducted twice annually (May–June at the end of the dry season, and October–November at the end of the wet season) at 15 permanent transects in Florida Bay.

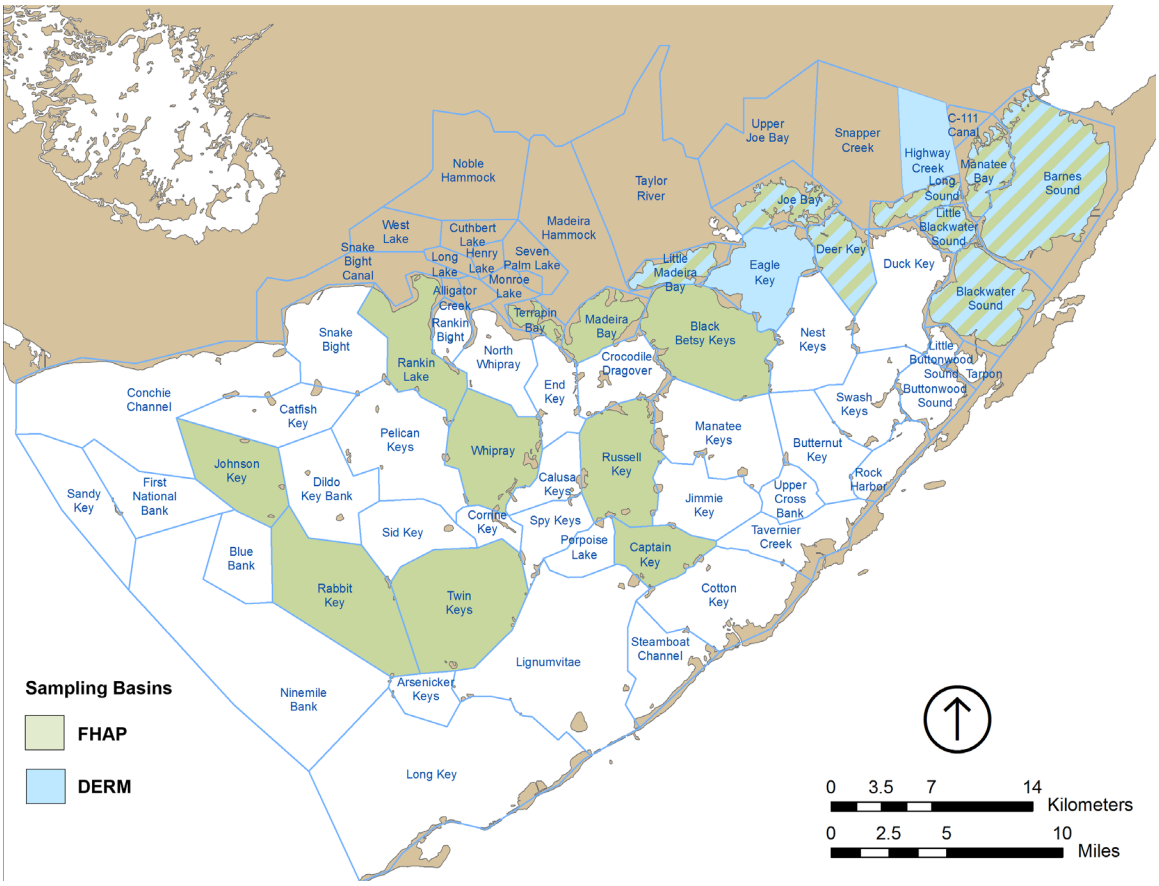


Figure 4.73. Location of all submerged aquatic vegetation (SAV) areas that are monitored in Florida Bay by Miami-Dade DERM and FHAP.

Status of the Indicator in the Current Year and Trends over Time

Abundance Index data collected during 1995–2011 suggest that Thalassia cover has declined in western Florida Bay basins where density was highest in 1995 (i.e., Rabbit Key and Twin Key basins; Figure 4.73 for locations, Figures 4.74a and b for summarized data). However, Thalassia cover has increased substantially in the basins most heavily affected by the die-off (i.e., Rankin Lake, Whipray Basin, and Johnson Key Basin). Halodule and Syringodium densities have increased in all these basins (Figure 4.73); thus, the seagrass communities of western and central Florida Bay (i.e., Rankin Lake, Whipray Basin, Johnson Key Basin, Rabbit Key Basin, and Twin Key Basin) were generally more diverse in 2011 than they were in 1995. Changes in seagrass species abundance in western Florida Bay during 1995–2011 appear to be driven primarily by secondary succession following the turtle grass die-off and subsequent phytoplankton blooms. These patterns of succession are associated with increasing light availability (and less turbidity) during that time period, especially from 1995 through 2001.

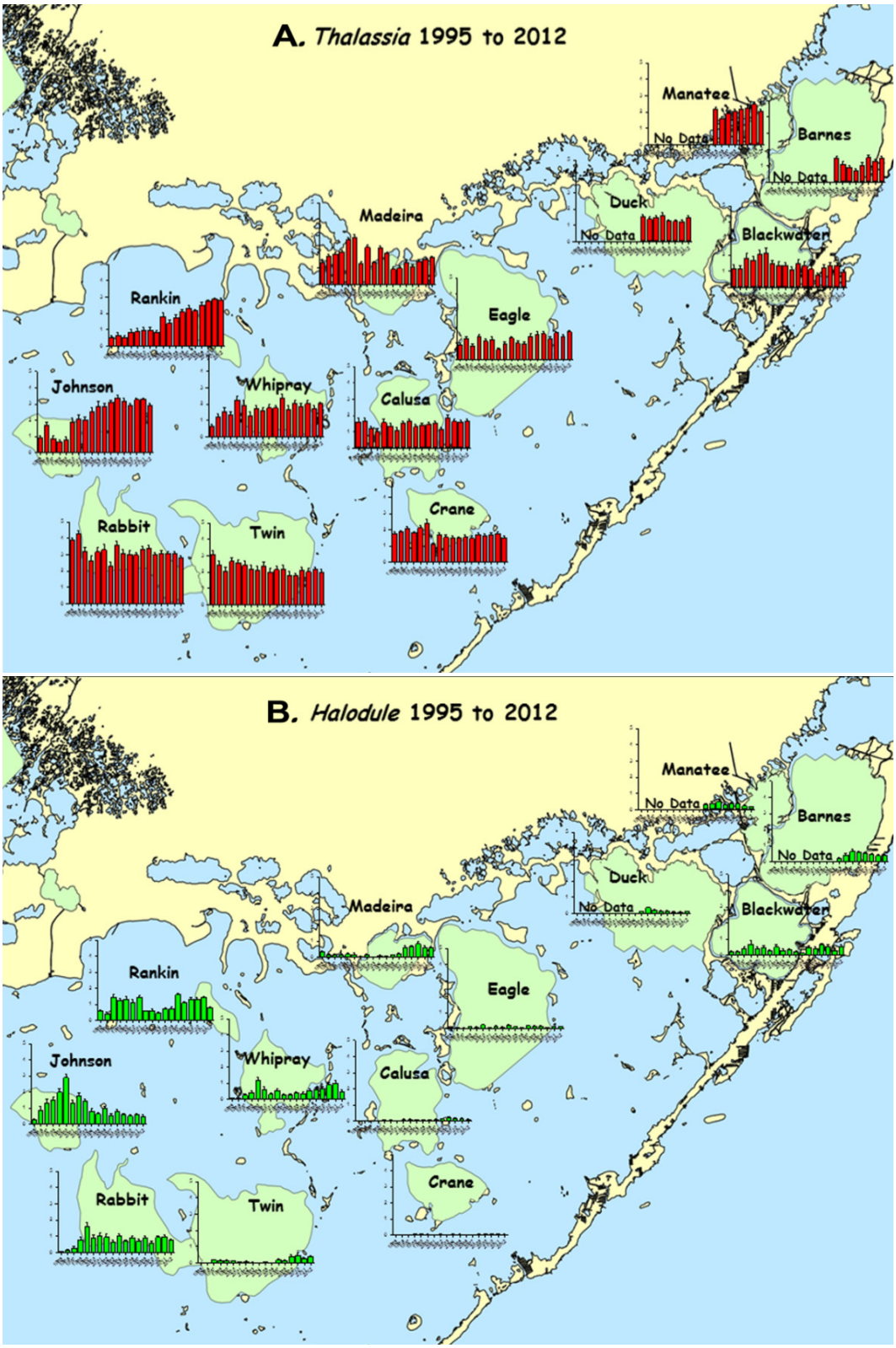


Figure 4.74a. Mean density (± standard error) of seagrass species A) Thalassia, and B) Halodule in monitored regions of Florida Bay from 1995 to 2011. Used with permission from Hall and Durako (2012).

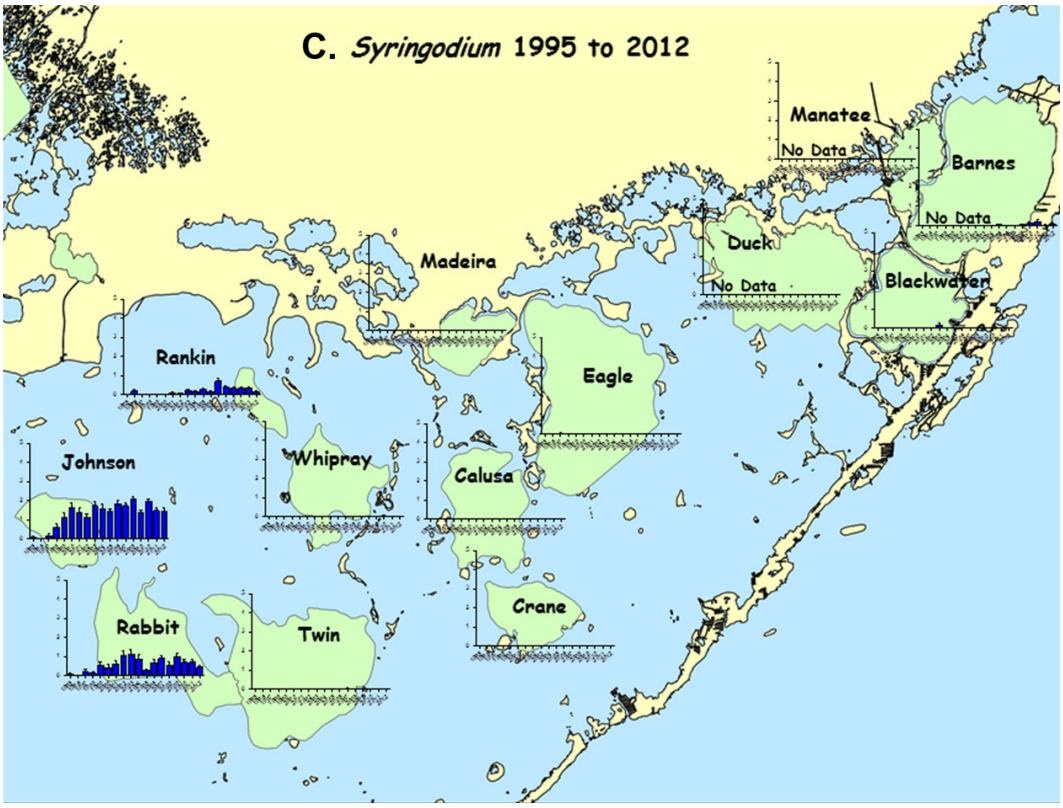


Figure 4.74b. Mean density (± standard error) of seagrass species C) Syringodium in monitored regions of Florida Bay from 1995 to 2011. Used with permission from Hall and Durako 2012.

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4.7.3. Estuarine sport fish and invertebrates

Status and Trend

Attribute: Estuarine Sport Fish and Invertebrates

Overall Condition & Trend:



Rationale: Four sportfish species are near desired conditions. Snook are below desired condition, and pink shrimp are significantly compromised.

Desired State of Conservation: Increasing populations of sportfish. Clear evidence that fishing pressure is sustainable.

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Highlights

Four of the five indicators monitored show a stable or increasing trend in abundance in the park (Table 4.44). The relative abundance of all four sport fish species was consistent with the desired state of conservation for the indicator, although snook remains in a cautionary status due to lingering effects of the 2010 cold event. Only pink shrimp densities were below baseline levels at the majority of the sampling sites in Florida Bay and along the southwest coast of the park. Decline of pink shrimp is a concern for the sport fish populations since shrimp are an important component of the prey base for sport fish.

Table 4.44. Status of estuarine fish (sport fish) and invertebrates.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Snook (*Centropomus undecimalis*) catch-per-unit effort (CPUE)		Snook populations declined in response to a cold-spell kill in 2010. The CPUE has indicated a return to a stable condition but has not yet indicated recovery.	The target is the CPUE levels during 2007–2009, or at least a stable CPUE trend, indicating sustainable recreational use and environmental conditions.
Red drum (*Sciaenops ocellata*) CPUE		Red drum CPUE has been relatively stable for the POR and has increased in recent years.	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.
Spotted seatrout (*Cynoscion nebulosus*) CPUE		Spotted seatrout CPUE has been relatively stable for the POR, with indications of a slightly increasing trend since 2004.	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.

Table 4.44 (continued). Status of estuarine fish (sport fish) and invertebrates.

Criteria	Condition & Trend	Rationale	Desired State of Conservation
Gray snapper (*Lutjanus griseus*) CPUE		Gray snapper CPUE has been relatively stable for the POR, with indications of an increase in CPUE since 2006.	The target is a stable to increasing trend in CPUE, indicating sustainable recreational use and environmental conditions.
Pink shrimp (*Farfantepenaeus duorarum)* density		Pink shrimp density was generally below baseline levels and showed a declining trend at most sites compared to the pre-restoration baseline.	The target is densities at or above those recorded during the pre-restoration baseline at the majority of sites in Florida Bay and along the southwestern coast. Note: restoration projects are not yet complete.

Background and Importance

The salt and brackish waters of Everglades National Park contain world-class fishing opportunities for recreational anglers. A prohibition on commercial fisheries within EVER since 1985 has helped to sustain these high-quality recreational fisheries. The coastal areas of the park support rich and diverse flora and fauna that depend on the condition and quality of the marine and estuarine communities in the region as a whole. Nursery habitat and fish and invertebrate communities are of great importance to coastal food webs and form the basis of regional commercial and recreational fisheries. Many sport fish species are high trophic-level predators and their populations rely on invertebrate populations, including the commercially valuable pink shrimp (*Farfantepenaeus duorarum*), and a variety of fish species for their prey base. The abundance and availability of these high trophic-level native species reflect the condition of nearshore marine and estuarine communities because they rely on this region for their entire lifecycle.

The information presented in this indicator assessment is based on the following data-collection methods. Recreational sport fishing anglers were interviewed every weekend to glean information about their fishing trips. Additionally, park-permitted professional fishing guides submitted similar daily charter fishing logbook reports, as outlined in the requirements of their permit. These records of angler effort and success help biologists determine the relative abundance, distribution, and trends in species fished for throughout the period of record (POR). Angler interview data have been collected in nearly continuously since 1958; however, data for this report were limited to the past 19 years (1993–2011), the period when data were collected most consistently.

Pink shrimp are an ecologically important and commercially valuable species. For this reason, pink shrimp are an essential biological indicator for assessing the response of southern Florida's estuaries to upstream changes in hydrology related to the restoration of the greater Everglades (Browder and Robblee 2009).

Desired State of Conservation

The desired state of conservation for nearshore faunal communities is for the fishery to maintain or increase the current abundance of high trophic-level predators, as well as their required prey base.

Fluctuations in species abundances are expected, but a generally stable or increasing trend would indicate favorable conditions, and populations should rebound quickly following any declines. Ultimately, the system can be deemed healthy if it supports a resilient and sustainable fishery with enough fish and invertebrates remaining in the population to reproduce and contribute to the next year's recruitment. We expect this resilient and sustainable fishery to be supported by a diversity of suitable habitats distributed throughout the park's coastal waters and estuaries. For example, habitat in the Gulf Coast region should be sufficient to support resilient eastern oyster (*Crassostrea virginica*) beds and populations of red drum (*Sciaenops ocellata*), blue crabs (*Callinectes sapidus*), and stone crabs (*Menippe mercenaria*). Florida Bay seagrass (Halodule, Ruppia, Thalassia) beds (see 4.7.2) should support substantial populations of pink shrimp, spotted seatrout (*Cynoscion nebulosus*), and gray snapper (*Lutjanus griseus*).

Description of Indicator Monitored

The relative abundance and distribution of four species of sport fish were monitored within the park-by-park staff to determine their status. The species evaluated were snook (*Centropomus undecimalis*), red drum (*Sciaenops ocellata*), spotted seatrout (*Cynoscion nebulosus*), and gray snapper (*Lutjanus griseus*). Researchers from the U.S. Geological Survey evaluated pink shrimp density and the National Oceanic and Atmospheric Administration through a project called the South Florida Fish and Invertebrate Assessment Network (FIAN), an element of the Monitoring and Assessment Plan under the auspices of the Comprehensive Everglades Restoration Plan.

Sport Fish

Information collected by EVER personnel from anglers and guides includes the number of fish caught (including kept and released) by species, the number of hours fished, the number of people fishing, species preference, and the area(s) where the majority of the fish were caught. The metric used in this analysis is called the catch per unit effort (CPUE), also known as catch rate, and is an index of relative abundance. The amount of catch is the total number of fish of a given species that were kept and released during a given fishing trip. Effort is defined as the number of people fishing on the boat multiplied by the number of hours spent fishing that day. The CPUE for each interview can be calculated by dividing the fishing party's catch (keeping track of each species separately) by their effort expended while fishing. CPUEs for this analysis were calculated using interviews where the species analyzed was either preferred and/or caught.

Monitoring involves interaction with the public as well as acquisition of information from permitted fishing guides. Face-to-face interviews (also known as creel surveys) are conducted as fishing groups arrive at points of contact (Flamingo and Everglades City/Chokoloskee). Permitted fishing guides send in their logbook reports via mail or email submission. Anglers arriving at the points of contact are selected on a random basis for interviews; thereby, information is acquired from throughout the park's saltwater fishing areas. These areas are defined as six zones on the basis of ecological differences, location, and habitats as follows: northern Florida Bay (Area 1) is characterized as directly influenced by mainland freshwater runoff from Taylor Slough; southern Florida Bay (Area 2) typically has higher salinities because it is enveloped by the Florida Keys on the eastern side and the Gulf of Mexico on the western side; western Florida Bay and Cape Sable (Area 3) are

characterized by expansive saltwater mud banks and saltwater tidal creeks; Whitewater Bay (Area 4) is characterized by its brackish, tannin-colored waters and freshwater runoff from Shark River Slough; Shark River area from Little Shark River to Broad River (Area 5) is influenced by freshwater runoff from Shark River Slough and variable salinities that are affected by saltwater intrusions in much of this area; and Lower Ten Thousand Islands from Lostman's River to Chokoloskee (Area 6) is characterized by inshore bays and oyster beds near the park's west coast (Figure 4.75). These six zones represent different ecological areas of the park's marine waters.

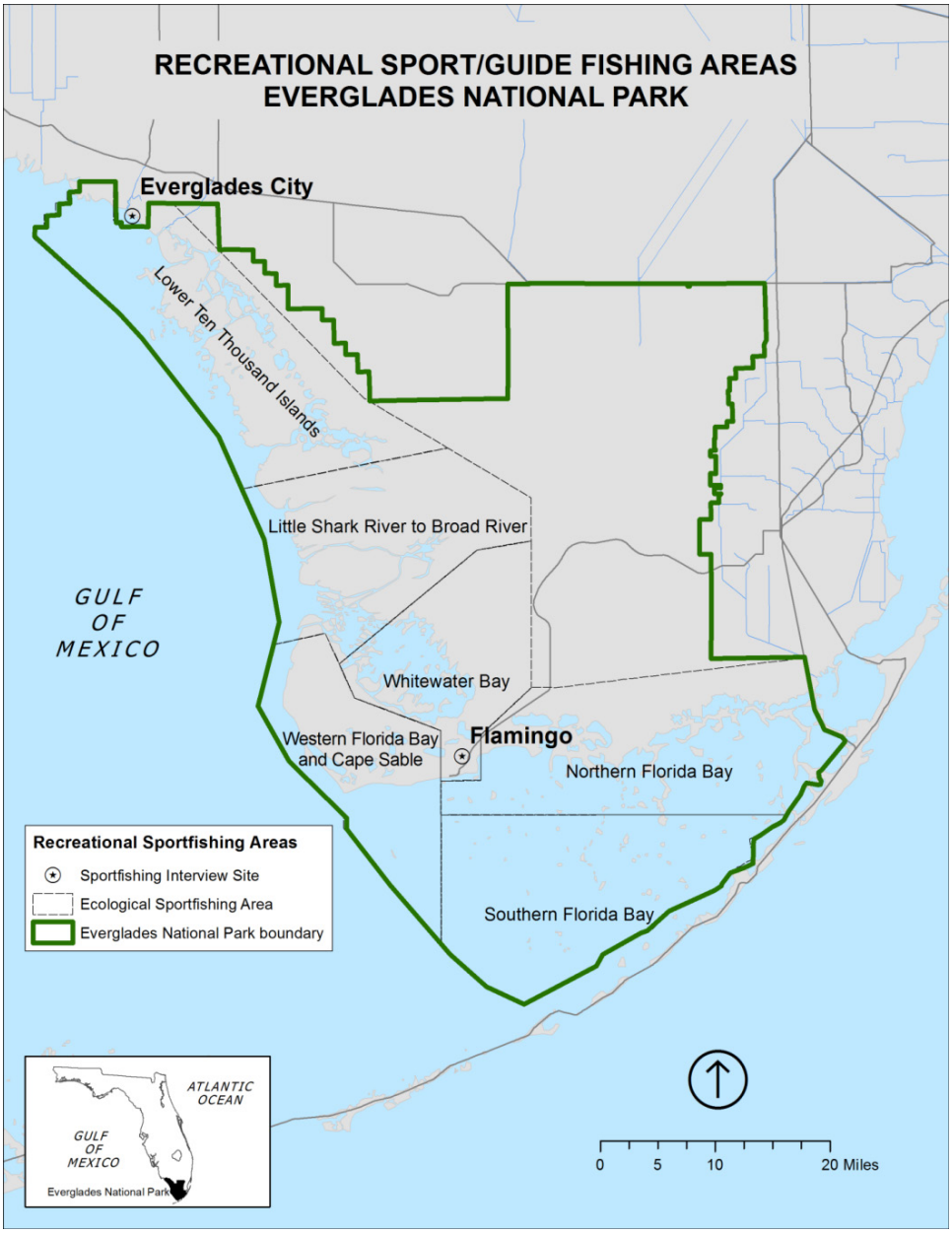


Figure 4.75. Location of recreational sport/guide fishing areas in Everglades National Park.

Pink Shrimp

This report summarizes results of the FIAN program (Robblee et al. 2012). A 1-m^2 throw trap (Robblee et al. 1991), the basic sampling tool of FIAN, collects discrete, quantitative samples of epibenthic fish and invertebrates that are associated with benthic vegetation or that seek shelter in benthic vegetation when disturbed. Throw trapping is conducted at 19 sites throughout south Florida estuaries, with 12 occurring within EVER (Figure 4.76). At each site, 30 throw trap samples are collected, and the density of pink shrimp is measured. At present, the annual assessment consists of comparison of spring and fall mean shrimp density in relation to available reference data for each area.

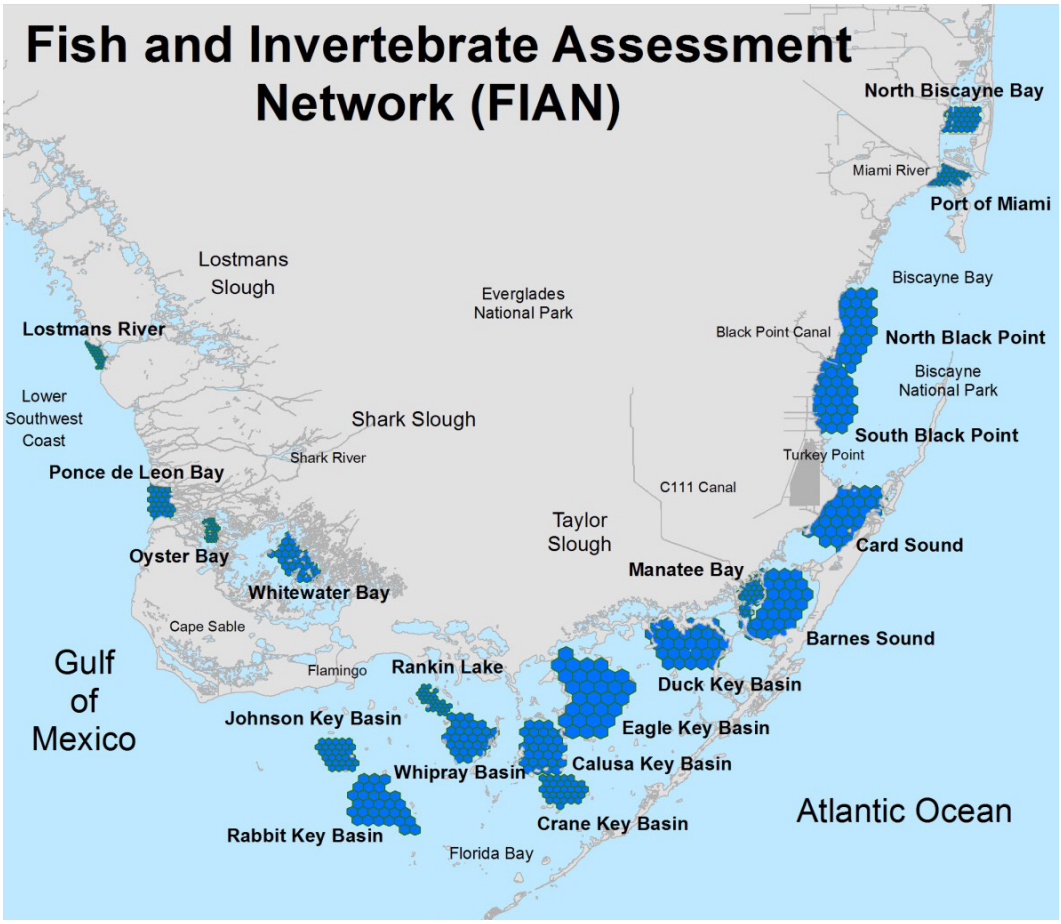


Figure 4.76. Fish and Invertebrate Assessment Network. Sampled areas indicated in blue. Used with permission, Robblee et al. (2012).

The pink shrimp ecological indicator assesses the status of the pink shrimp in southern Florida estuaries by comparing shrimp density in the current year (for this report, 2010 and 2011) to a reference data set that represents a pre-restoration pink shrimp density, based on FIAN measurements for 2005–2009 (Robblee et al. 2012). Pink shrimp densities that are less than the 1st quartile are scored as 0 (poor performance), values greater than or equal to the 1st and less than or equal to the 3rd quartile are scored as 0.5 (neutral performance), and values greater than the 3rd quartile are

scored as 1 (positive performance). The stoplight colors are used to summarize pink shrimp performance are red (< 1st quartile, poor performance), yellow (≥ 1st and ≤ 3rd quartile, neutral performance) and green (> 3rd quartile, good performance). Trend in pink shrimp delta-density over the 7-year period-of-record (2005–2011) is provided with arrows indicating direction; open arrows = non-significant trend, blue closed arrows = significant trend at $p < 0.05$.

Status of the Indicator in the Current Year and Trends over Time

Sport Fish

Trends in catch rates for the four focal sport fish species monitored throughout the period of record (POR, 1993–2011) are shown in Figure 4.76. The relative abundance (indicated by catch-per-unit-effort or CPUE) for each of the sport fish species maintained a generally stable trend over the 28 year POR. Each species of sport fish was distributed throughout the park for all 28 years, and regional differences in CPUE likely reflect differences in habitat suitability in different ecological zones (Figure 4.77).

The generally positive long-term trend in snook catch rates from the mid-1990's through 2009 (Figure 4.77) was largely due to regulation changes enforced by the Florida Fish and Wildlife Conservation Commission (FWC) that allowed successfully management for that sport fishery. Low catch rates in 2010 were the result of a significant cold weather fish kill that occurred in January of that year. Water temperatures of 12–14° C are known to be lethal for most snook (Shafland and Foote 1983) and 9–10° C for larger snook (Howells et al. 1990). Nighttime water temperatures were below 14° C for 14 consecutive days and were below 9° C for six of those nights. As a result, there was extensive mortality of snook (along with other sport fish species) throughout the park. An estimated 214,000 snook succumbed during this event (Hallac and Ziegler 2010). In 2011, the relative abundance of snook in the park stabilized (Figure 4.77), and an increasing trend in snook catch rates is expected in 2012. Snook were well-distributed throughout the park over the POR, with the lowest numbers in southern Florida Bay and the highest in the Lower Ten Thousand Islands area (Figure 4.78).

Catch rates for red drum in 2011 were the highest they have been for the POR (Figure 4.76). Catch rates have been stable, except for the significant increase in CPUEs in 2010 and 2011 (Figure 4.76). Similar to the snook fishery, an increasing trend in red drum catch rates is expected in 2012. Red drums were well-distributed throughout the park during the POR, with the lowest numbers in Whitewater Bay and the Shark River areas and the highest in all of Florida Bay (northern, southern, and western), Cape Sable, and the Lower Ten Thousand Islands area (Figure 4.78).

Generally, catch rates have been stable for spotted seatrout throughout the POR (Figure 4.77), though some variation was recorded. There has been a slightly increasing trend in spotted seatrout catch rates since 2004 (Figure 4.77). This species did not seem to be affected by the cold weather fish kill in 2010. Spotted seatrout were well-distributed throughout the park during the POR, with the lowest numbers in Whitewater Bay and the Shark River areas, and the highest in northern and southern Florida Bay (Figure 4.78).

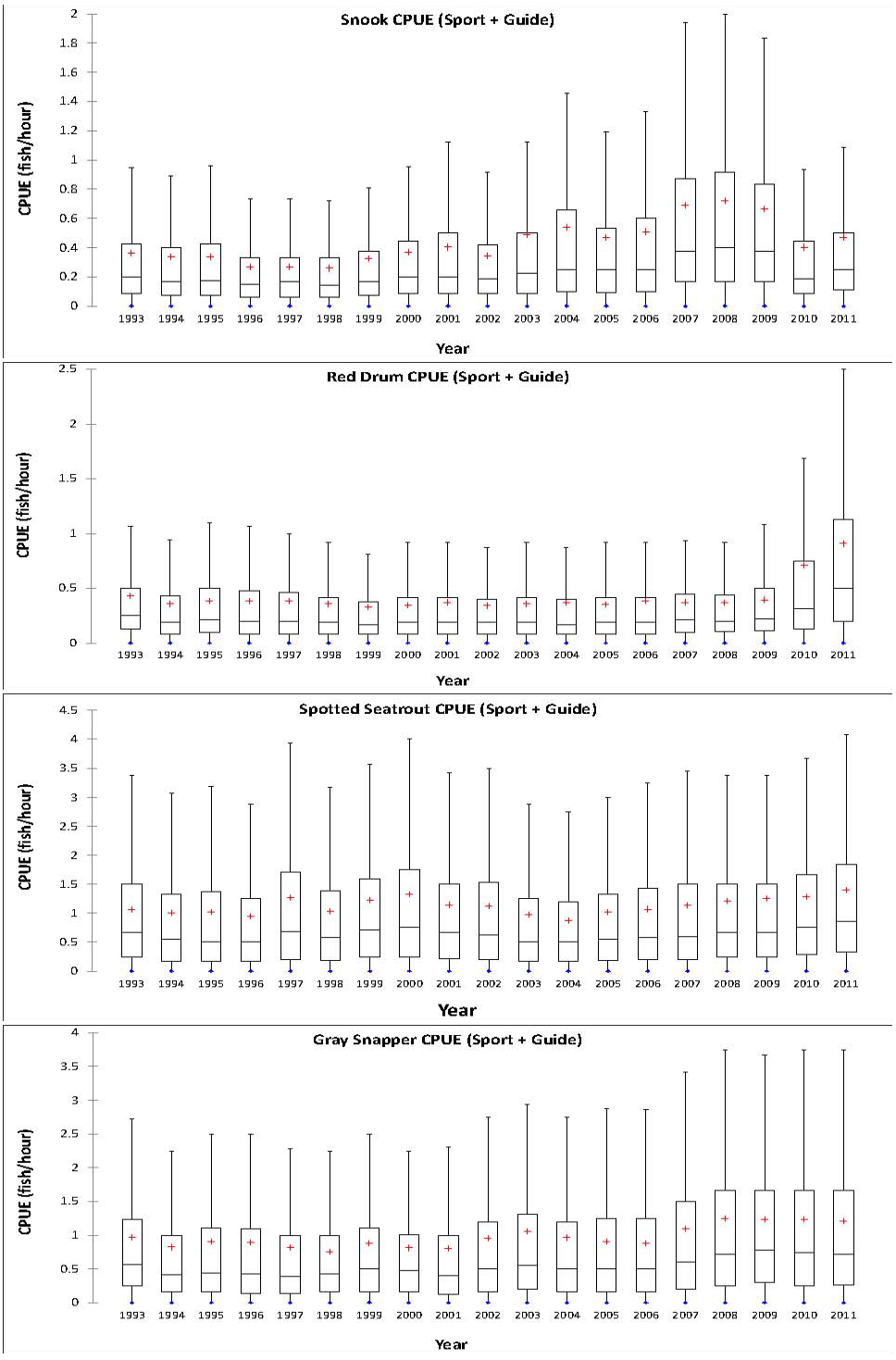


Figure 4.77. Annual catch rates for recreational (sport) and guided anglers for common snook, Red Drum, Spotted Seatrout, and Gray Snapper in Everglades National Park, 1993–2011. Note: The "boxes" contain 75% of the data. The horizontal line inside the box represents the median. The upper and lower "whiskers" represent 95% of the data. Outliers in the data, representing both the upper and lower 2.5%, are not portrayed in this "box and whisker" plot. The red plus signs represent the mean (average).

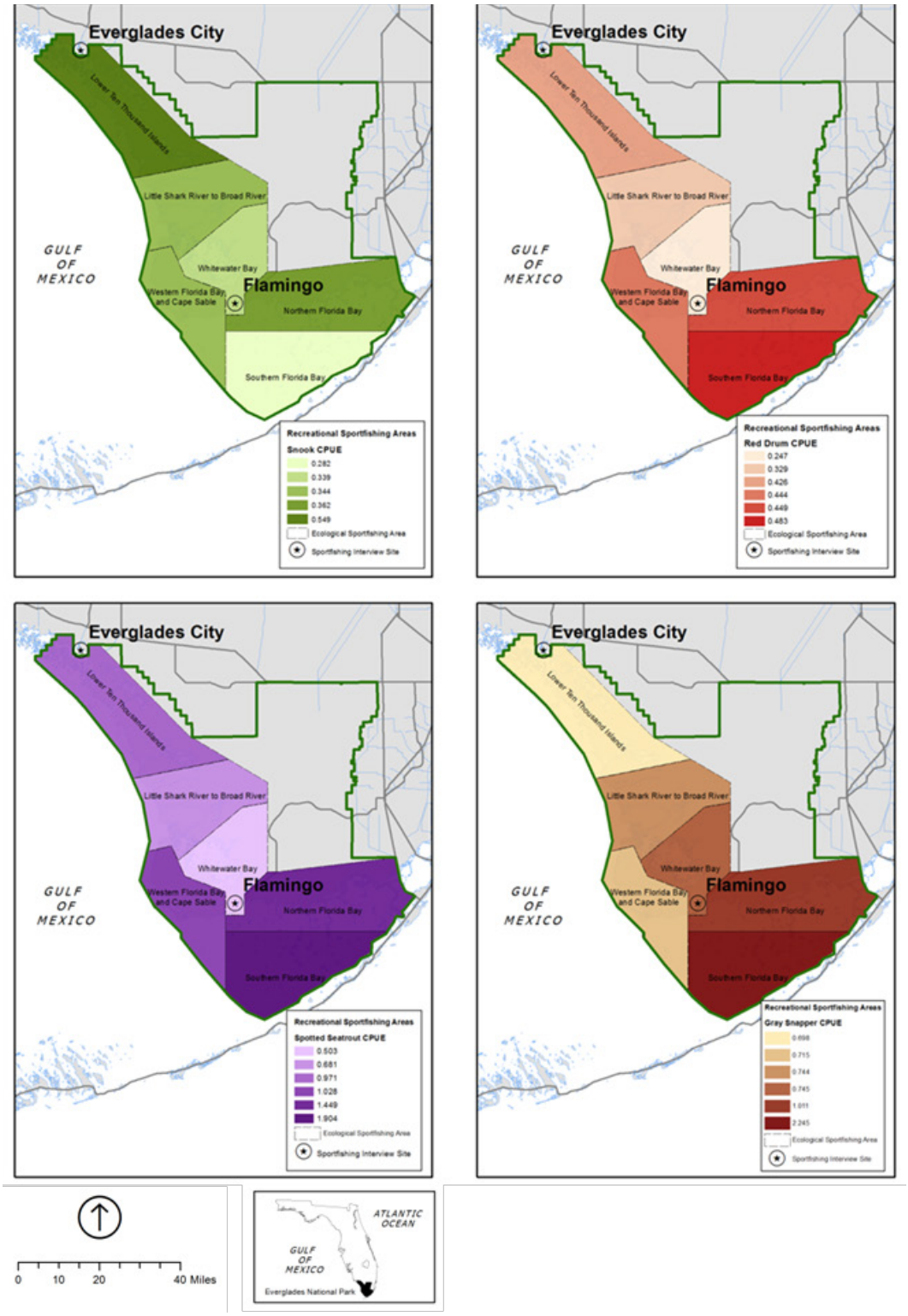


Figure 4.78. Distribution of Four Focal Sportfish Species in Everglades National Park, 1993–2011. Each species' CPUE for the 19-year POR is displayed for each sports fishing area to show how each species is distributed throughout the park, based on its "catchability". The higher the CPUE for any given area, the easier it is to catch that species.

Catch rates for gray snapper (Figure 4.77) have been relatively high for the last five years (2007–2011). Generally, catch rates have been stable throughout the POR (Figure 4.77). Gray snapper were affected by the cold weather fish kill in 2010, though to a lesser degree than snook. An estimated 18,000 gray snapper succumbed during this event (Hallac and Ziegler 2010). Gray snapper were well distributed throughout the park during the POR, with the lowest numbers in western Florida Bay/Cape Sable, Whitewater Bay, Shark River areas, and the Lower Ten Thousand Islands area, and by far the highest in southern Florida Bay (Figure 4.78).

Pink Shrimp

A comparison of the distribution of pink shrimp performance at monitoring locations in the spring and fall of 2010 and 2011, using the stoplight indicator colors, is provided in Figure 4.79. The distribution of pink shrimp in south Florida during the wet and dry seasons, averaging the FIAN data collected over a 7-year period (2005–2011), is shown in Figure 4.80.

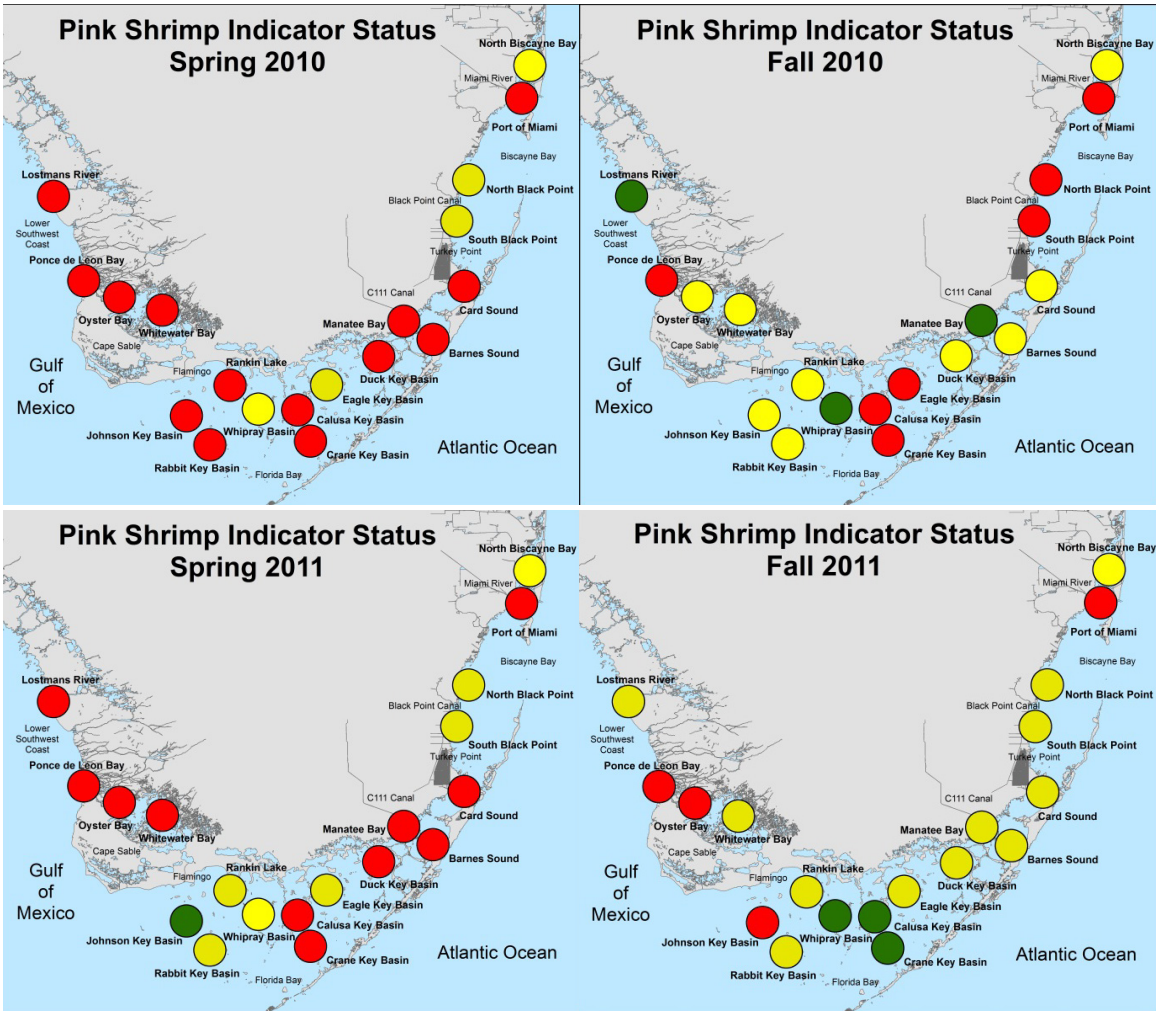


Figure 4.79. Comparison of the distribution of pink shrimp performance in the spring and fall of 2010 and 2011. The stoplight colors are used to summarize pink shrimp performance; red (< 1st quartile, poor performance), yellow (≥ 1st and ≤ 3rd quartile, neutral performance) and green (> 3rd quartile, good performance). Used with permission, Robblee et al. (2012).



Figure 4.80. Pink shrimp, *Farfantepenaeus duorarum*, distribution in South Florida averaged over the seven years of FIAN, 2005–2011. The size of each pie diagram equals the sum of average dry and wet season density scaled from a maximum of 6.17±7.66/m^2 (±1sd) in Johnson Key Basin to a minimum of 0.04±0.27/m^2 in Duck Key Basin. Spring and fall densities observed in Johnson Key Basin, 1.92±2.05/m^2 and 10.42±8.78/m^2, and in Duck Key Basin, 0.04±0.33/m^2 and 0.03±0.21/m^2, respectively. (Used with permission, Robblee et al. 2012).

Pink shrimp status was classified as poor to neutral in the regions encompassed by FIAN in both 2010 and 2011 (Tables 4.45 and 4.46); patterns in pink shrimp performance among monitoring locations were not consistent between spring and fall or between the two years (Figure 4.79). Johnson Key Basin was the sole monitoring location to perform well (achieve positive status) in the spring of 2011 (Table 4.46). Five of twelve locations performed well in the fall (Figure 4.79). Whipray Basin was the only monitoring location to achieve a positive status in the fall of both 2010 and 2011 (Tables 4.45 and 4.46). The central area of Florida Bay performed well in the fall of 2011 achieving a positive status at Whipray Basin, Calusa Key Basin, and Crane Key Basin (Table 4.46).

The lower mangrove coast region achieved poor status at all monitoring locations in spring of both years (Tables 4.45 and 4.46). Lostman's River was one of two locations to achieve a positive status in fall 2010, but had a neutral status in fall 2011 (Tables 4.45 and 4.46).

Table 4.45. Spring and fall 2010 pink shrimp performance in relative to the FIAN 5-year baseline. The 1st and 3rd quartiles of the base condition are indicated as Q1 and Q3, spring and fall, respectively. Good, neutral, and poor (also in stoplight colors) are used to summarize pink shrimp performance (poor performance [red] = <1st quartile; neutral performance [yellow] = ≤3rd quartile; good performance [green] = >3rd quartile). Trend in pink shrimp delta density over the 6-year period of record (2005–2010) is provided. Adapted and used with permission, Robblee et al. (2012).

Region	Basin Name	Q1	Q3	Spring	Trend	Q1	Q3	Fall	Trend
Florida Bay Region	Duck Key Basin	0.03	0.07	Neutral	Increase[a]	0.00	0.03	Neutral	Decrease[a]
	Eagle Key Basin	0.00	0.07	Neutral	Decrease[a]	0.07	0.11	Poor	Decrease[a]
	Calusa Key Basin	0.14	0.17	Neutral	Decrease[a]	0.28	0.56	Poor	Decrease[a]
	Crane Key Basin	0.17	0.53	Neutral	Decrease[a]	0.53	0.80	Poor	Decrease[a]
	Rankin Lake	0.43	0.90	Poor	**Decrease[b]**	0.66	2.30	Neutral	Decrease[a]
	Whipray Basin	0.03	0.56	Neutral	Decrease[a]	0.53	0.73	Good	Decrease[a]
	Johnson Key Basin	1.94	2.29	Poor	**Decrease[b]**	5.81	15.63	Neutral	Decrease[a]
	Rabbit Key Basin	0.84	1.57	Poor	**Decrease[b]**	2.42	7.89	Neutral	Decrease[a]
	Regional Summary	**0.50**	**0.71**	Poor	**Decrease[b]**	**1.36**	**4.07**	Neutral	Decrease[a]
Lower Southwest Mangrove Coast	Lostmans River	1.22	7.11	Poor	Increase[a]	1.74	5.57	Good	Increase[a]
	Ponce de Leon Bay	0.72	0.91	Poor	Increase[a]	0.95	1.55	Poor	Decrease[a]
	Oyster Bay	0.63	1.47	Poor	Increase[a]	1.14	3.57	Neutral	**Decrease[b]**
	Whitewater Bay	0.43	0.50	Poor	Increase[a]	1.53	6.70	Neutral	Decrease[a]
	Regional Summary	**1.36**	**2.66**	Poor	Increase[a]	**1.93**	**4.21**	Neutral	Decrease[a]

[a] non-significant trend

[b] significant trend at $p < 0.05$

Table 4.46. Spring and fall 2011 pink shrimp performance in relative to the FIAN 5-year baseline. The 1st and 3rd quartiles of the base condition are indicated as Q1 and Q3, spring and fall, respectively. Good, neutral, and poor (also in stoplight colors) are used to summarize pink shrimp performance (poor performance [red] = <1st quartile; neutral performance [yellow] = ≤3rd quartile; good performance [green] = >3rd quartile).Trend in pink shrimp delta density over the 6-year period of record (2005–2010) is provided. Adapted and used with permission, Robblee et al. (2012).

Region	Basin Name	Q1	Q3	Spring	Trend	Q1	Q3	Fall	Trend
Florida Bay Region	Duck Key Basin	0.03	0.07	Poor	Increase[a]	0.00	0.03	Neutral	Decrease[a]
	Eagle Key Basin	0.00	0.07	Neutral	Decrease[a]	0.07	0.11	Neutral	Decrease[a]
	Calusa Key Basin	0.14	0.17	Poor	Decrease[a]	0.28	0.56	Good	Decrease[a]
	Crane Key Basin	0.17	0.53	Poor	Decrease[a]	0.53	0.80	Good	Decrease[a]
	Rankin Lake	0.43	0.90	Poor	**Decrease[b]**	0.66	2.30	Neutral	Decrease[a]
	Whipray Basin	0.03	0.56	Neutral	Decrease[a]	0.53	0.73	Good	Decrease[a]
	Johnson Key Basin	1.94	2.29	Good	Decrease[a]	5.81	15.63	Poor	Decrease[a]
	Rabbit Key Basin	0.84	1.57	Neutral	**Decrease[b]**	2.42	7.89	Neutral	Decrease[a]
	Regional Summary	**0.50**	**0.71**	Poor	**Decrease[b]**	**1.36**	**4.07**	Neutral	Decrease[a]
Lower Southwest Mangrove Coast	Lostmans River	1.22	7.11	Poor	Increase[a]	1.74	5.57	Neutral	Increase[a]
	Ponce de Leon Bay	0.72	0.91	Poor	Decrease[a]	0.95	1.55	Poor	Decrease[a]
	Oyster Bay	0.63	1.47	Poor	Increase[a]	1.14	3.57	Poor	**Decrease[b]**
	Whitewater Bay	0.43	0.50	Poor	Increase[a]	1.53	6.70	Neutral	Decrease[a]
	Regional Summary	**0.80**	**2.66**	Poor	Increase[a]	**1.93**	**4.21**	Neutral	Decrease[a]

[a] non-significant trend

[b] significant trend at $p < 0.05$

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4.7.4. Crocodiles

Status and Trend

Attribute: Crocodiles

Overall Condition & Trend:



Rationale: Crocodiles in EVER have improved significantly since plugs were installed in 2002. Juvenile crocodile survival and growth rates remain below the rates observed in nearby crocodile nurseries.

Desired State of Conservation: Recovery of crocodile populations until they resemble what is expected in a restored ecosystem.

Publisher's note: This section in this report has been copied or modified from the "Status and Trends Report: Everglades National Park 2013 Indicators of Integrity" and its companion report, "Everglades National Park 2013 State of Conservation." See Prologue on page xxiv.

Highlights

Crocodiles in EVER are significantly improved! Reproductive effort is improving. Hatchling growth and survival has not changed, as hatchlings grow slower than those found in nearby crocodile nursery sites.

Background and Importance

American crocodiles (*Crocodylus acutus*) were federally listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1975. The species decline was largely due to extensive habitat degradation (including nesting sites) and overhunting. Crocodile recovery has been a story of cautious success in south Florida. While still in need of continuing protection, there are more crocodiles in more places today than there have been for at least the prior 35 years, thus leading to USFWS reclassification of the species to threatened status in 2007. This ecological indicator summary provides an assessment of the species status trend from 1993 to 2011 and describes the methods used for verification. The University of Florida Fort Lauderdale Research and Education Center (UF–FLREC) provided all data presented here.

The American crocodile is a flagship species of the Everglades that functions as an ecosystem indicator because its lifecycle is closely responsive to patterns of freshwater inputs to the estuaries and resultant nearshore salinity patterns. The majority of the crocodile population in south Florida exists within or adjacent to Everglades National Park (ENP), where brackish marshes close to Florida Bay serve as important nursery habitat for juveniles and as foraging and breeding habitat for adults. Though currently greatly reduced due to lack of funding, intensive monitoring of the crocodile population and associated ecological research has been ongoing since the mid-1970's. These efforts

have produced detailed information on the life history of the species and the relationship between the American crocodile and the health of the Everglades system.

The most critical and measurable metrics believed to directly relate crocodiles to hydrologic restoration include nest distribution and nesting effort, and differential growth and survival from hatchling to late juvenile stages. Hatchling and juvenile survival is critical to species recovery and strongly influenced by salinity, growth rate, and the dispersal distance required for reaching suitable nursery habitat (Mazzotti 1983 and 1999, Green et al. 2001, Mazzotti et al. 2009). Mortality is naturally high in young crocodiles yet decreases significantly and proportionately at relatively distinct growth stages, these stages being most rapidly attained under low salinity conditions (Mazzotti 1983, Moler 1991). Hatchlings experience the greatest mortality rate and least tolerance to high salinity (>20 ppt) prior to reaching approximately 200 g (or 40–45cm total length), typically 3–4 months post-hatching under fair conditions (Mazzotti and Dunson 1984, Kushlan and Mazzotti 1989, Moler 1991). Mazzotti et al. (2007) estimated first-year survival of crocodiles within ENP to be only 1.5%, the lowest reported in Florida. Moler (1991) reported nearly 20% higher first-year survival when hatchlings grew rapidly enough to obtain this size prior to exposure to higher salinities, less abundant food, and more numerous predators characteristic of the dry season. Newly recruited juveniles (>200 g) continue to grow most rapidly in lower salinity, while becoming increasingly more tolerant of seawater and less susceptible to predation. A second survival milestone is reached at approximately 75 cm total length and typically occurs between 15 and 20 months of age in ENP. Juveniles larger than this face very low predation risk and by 4 to 5 years of age, survival is not influenced by salinity, predation risk nears zero, and annual survival likely approaches 100% (Kushlan and Mazzotti 1989, Moler 1991).

Female crocodiles generally select elevated nest sites in close proximity to suitable nesting habitat. Historically (from anecdotal records in the 1950's and 1960's), most known crocodile nests in ENP were located on shorelines and islands in northeastern Florida Bay. This region received large volumes of freshwater input originating from Taylor Slough and effects of these inputs on salinity continued well into the dry season. Upstream land-use modifications have severely reduced the quantity, quality, timing, and distribution of flow into northeastern Florida Bay, resulting in higher than natural salinities. As for many other native species, in order for Everglades restoration to be truly successful for crocodiles, freshwater inputs to south Florida estuaries, especially those in northeastern Florida Bay, must be restored to approximate natural conditions. Unnatural hypersaline conditions in particular must be reduced in frequency, magnitude, and duration. Hydrologic restoration will create better habitat quality leading to increased prey base, growth and survival of hatchlings, reproductive effort, and ultimately, increased crocodile population density.

In the Cape Sable region of ENP, a system of canals was excavated in the 1920's in an effort to drain the interior marsh, resulting in increased salinities (sometimes hypersaline) well into the interior and reduced fitness as crocodile habitat. Canals were plugged circa 1960, failed circa 1990, and were plugged again in 1997. By 2002, the dams were again failing and canals widening, decreasing habitat suitability and allowing continued marine intrusion, which occurred faster than ever following 80 years of intermittent canal erosion. In 2007, the Cape Sable Canal Mitigation Project was undertaken

to again address these problems; new dams were completed in 2010 and designed with the expectation that they last for 50 years. This expensive and high profile project is expected to substantially restore habitat quality for many species of flora and fauna and is particularly promising for the continued recovery of crocodiles throughout the park.

Desired State of Conservation

A positive trend in recovery of the American crocodile (*C. acutus*), to a level consistent with a restored Everglades ecosystem, is identified as a key target for EVER's removal from the World Heritage Sites in Danger list. Key components of recovery include increased species relative abundance and spatial distribution, increasing trend in nesting effort, and increased hatchling-juvenile growth and survival.

Description of Indicator Monitored

UF–FLREC and National Park Service personnel, in conjunction with other agencies, collectively monitor the total annual number of nests in EVER and adjacent primary nesting sites (Figure 4.81), including northern Key Largo/Crocodile Lake National Wildlife Refuge (CLNWR) and Turkey Point Power Plant. Relative abundance, demographic structure, and survival of crocodiles throughout EVER are monitored by UF–FLREC cooperators.

Status of the Indicator in the Current Year and Trends over Time

Results of spotlight surveys, combined with mark-recapture events, indicate that the relative abundance of *C. acutus* has increased throughout the species range in southern Florida (Figures 4.81, 4.82, Table 4.47). Hatchling and juvenile growth and survival within EVER continue to be low compared to adjacent nesting sites and likely differ among locales within the park (Table 4.48). Survival estimates within EVER may be artificially low due to the substantially greater difficulty of recapturing young crocodiles in EVER's expansive habitat relative to the more accessible habitats of adjacent nursery sites. Additional research efforts must be conducted to differentiate between growth and survival at different locales within EVER and this is a primary focus of current park-funded research efforts.

Although nighttime spotlight surveys combined with mark and recapture data are the primary means of assessing population dynamics beyond reproductive effort in EVER, the best directly detectable metrics of successful recovery for crocodiles are sustained increases of nesting effort, distribution, and success. Nest monitoring is performed annually by air, water, and on foot during nest construction and hatching. The primary criterion considered for federal reclassification from endangered to threatened status (2007) was the existence of 60 or more documented nests each year for three consecutive years. While the overall number of nests has been rising for more than three decades following effective protection, there was a definitive change point within EVER circa 2002–2003 that is not replicated elsewhere in Florida (Figure 4.83). Nesting has increased elsewhere, yet overall observed rapid increase in nesting of Florida's American crocodile population, spanning the period 2003 to 2011, is almost entirely comprised of nests that lie within the Cape Sable region of the park.

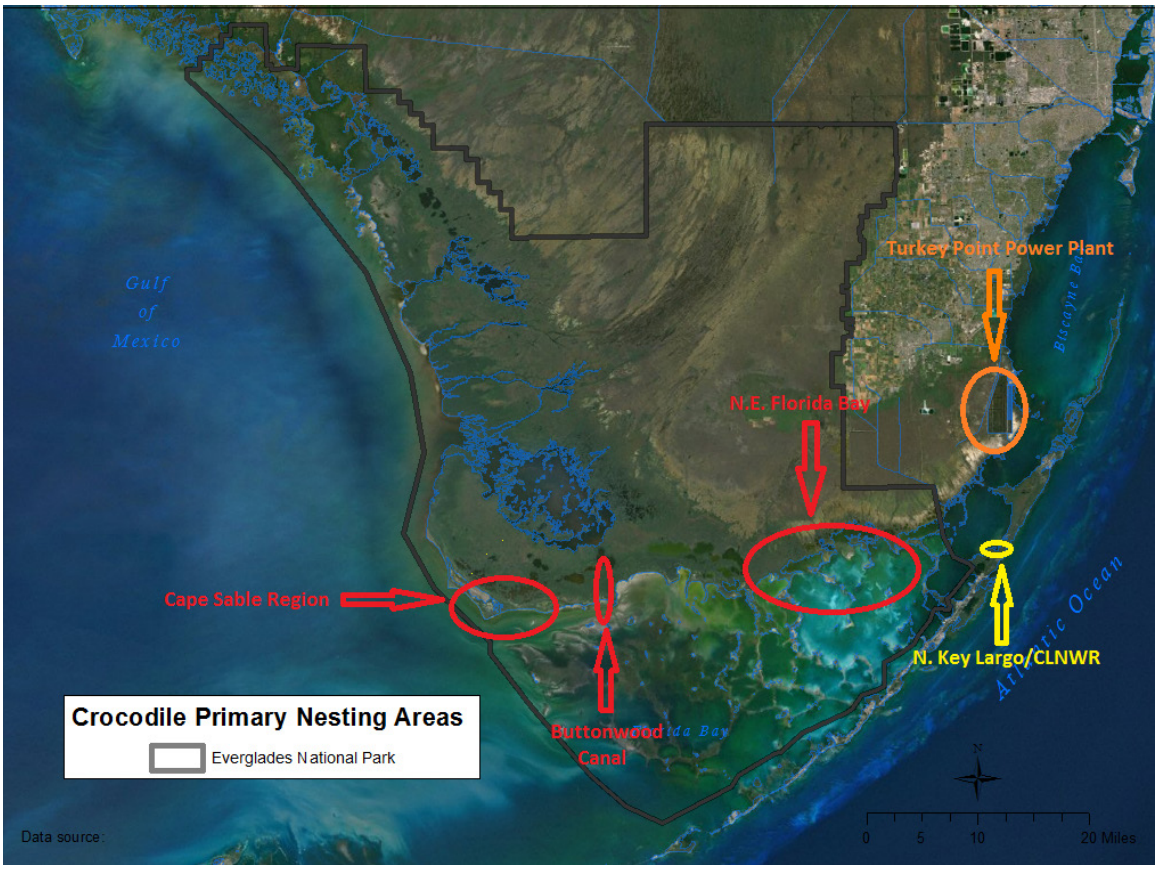


Figure 4.81. Primary crocodile nesting locales within Everglades National Park and adjacent primary nesting sites in southern Florida.

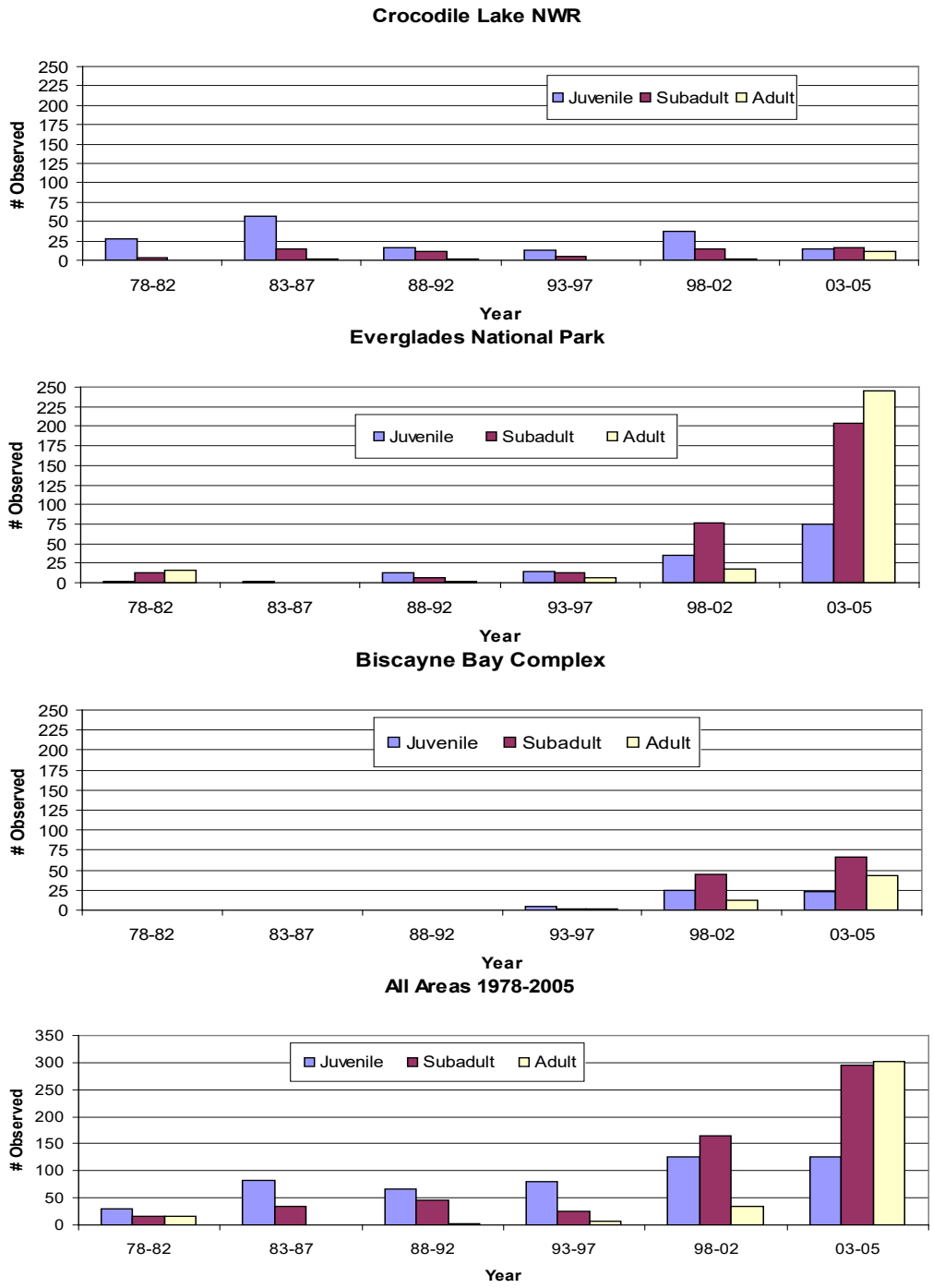


Figure 4.82. Summary of crocodile spotlight observations by size class distribution over time and between locations in south Florida. The Turkey Point Power Plant is included in “All Areas”. Reproduced and modified from Mazzotti and Cherkiss (2007).

Table 4.47. The current status and desired state of conservation of indicators of the American Crocodile population described in the summary above.

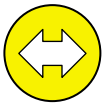
Criteria	Condition & Trend	Rationale	Desired State of Conservation
Total population		Total population and distribution has exhibited an increasing trend, historic population is uncertain.	Population increase consistent with a restored Everglades ecosystem. Occupation throughout historic range
Reproduction		Reproductive effort within some areas of EVER has exhibited an increasing trend and is the best indicator of continued species recovery.	Increasing trend in nesting effort, distribution, and success in EVER including historical nesting sites in NE Florida Bay. Increasing trend in growth and survival of juvenile crocodiles, consistent with a restored Everglades ecosystem.
Hatchling-juvenile growth and survival		Survival is directly linked to increased hatchling-juvenile growth rates, which increase with lower salinities. Hatchlings within EVER consistently exhibit lower growth rates than adjacent nursery sites.	Reduced salinity regimes which encourage rapid hatchling growth rates approaching mass > 200g, 3–4 months post hatching, and juveniles to more rapidly reach total length ≥ 75 cm.

Table 4.48. Hatchling crocodiles' growth, survival (proportion that survived for at least 12 months), and dispersal (proportion that survived and dispersed out of their natal area) rates in south Florida. Growth was different among the three nesting areas (ANOVA, $F_{2, 541} = 3.91$; $p = 0.02$; LSD T-test, $\alpha = 0.05$). More hatchlings survived than expected by chance at CLNWR ($X^2 = 423.9$; $p \leq 0.001$), whereas more hatchlings dispersed from the Turkey Point site ($X^2 = 7.4$; $p \leq 0.025$). Reproduced with modifications from Mazzotti et al. (2007b).

Location	Juvenile Growth (cm/day) Mean (Range)	Minimum # (%) Survived for >12 months	Minimum # (%) Dispersed from Natal Area
Turkey Point Period of Record: 1978–2004	0.11 (-0.8 to 1.30)[a] (N = 205)	59 (1.71 %) (N_1 = 3452)	17 (29.0 %) (N_2 = 59)
Crocodile Lake NWR Period of Record: 1978–1999	0.10 (0.000 to 0.42)[a] (N = 246)	94 (17.97 %) (N_1 = 523)	14 (15.0 %) (N_2 = 94)
Everglades National Park Period of Record: 1978–2004	0.07 (-0.057 to 0.16)[b] (N = 93)	28 (1.50 %) (N_1 = 1,871)	2 (7.0 %) (N_2 = 28)

[a,b] Different superscripts indicate significant differences among growth rates.

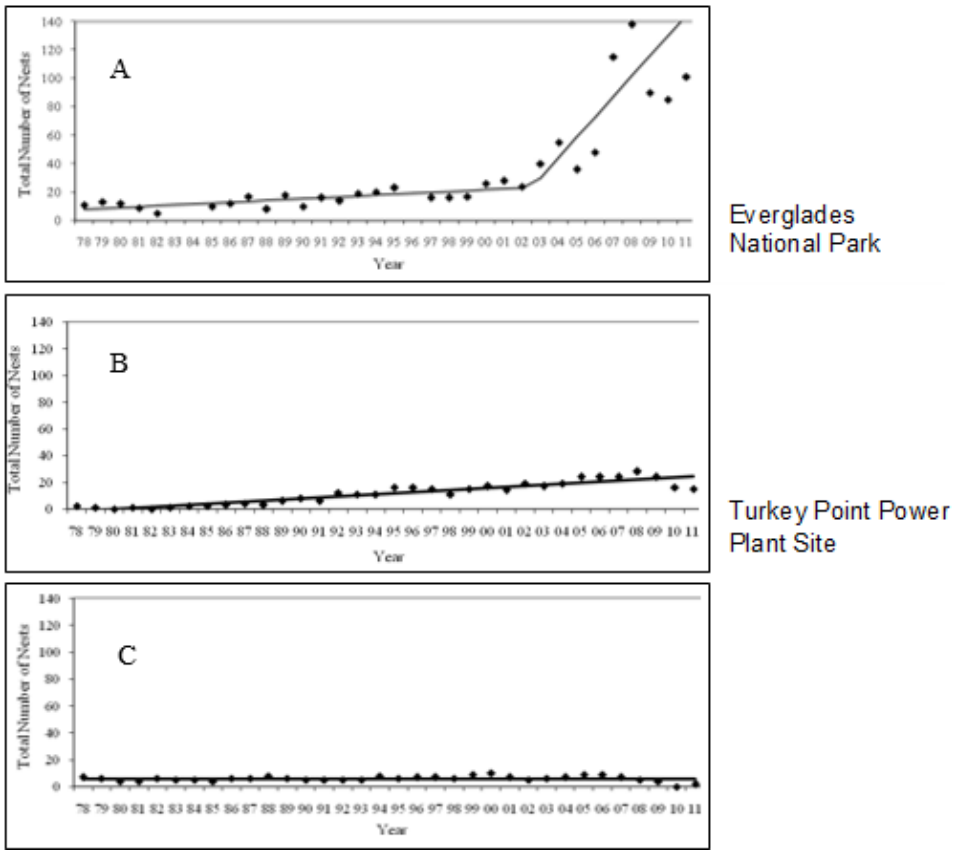


Figure 4.83. Linear regression for total number of American crocodile nests found between 1978 and 2011 in the three primary nesting areas (A) Everglades National Park (R^2 = 0.5801; p = 0.0001; nests = 1052), (B) Turkey Point Power Plant (R^2 = 0.8563; p = 0.0001; nests = 387) and (C) Crocodile Lake National Wildlife Refuge (R^2 = 0.0; p = 0.9762; nests = 201). Reproduced from Mazzotti and Cherkiss (2011).

Increased nesting in the Cape Sable region may be linked to restoration efforts undertaken to correct unnatural saltwater intrusion into the formerly freshwater interior marsh, thereby reversing the associated habitat degradation. In addition to an overall more numerous crocodile population, increased nesting beginning circa 2002 may be partially a result of crocodiles responding to improved salinity regimes after implementation of plugging in 1997, and offspring from the few prior nests in the area reaching maturity (typically at 7–9 years of age).

Contrary to the nesting trends observed at Cape Sable and despite increasing occurrence of crocodiles since 1975, there has not been a large increase of nesting effort in other monitored areas within EVER. Additionally, nesting sites have shifted away from islands and beaches of Florida Bay toward mainland water sources, which have very little terrain at an elevation suitable for successful nesting. These observations support the perspective that there is a dire need for further restoration of flows into northeastern Florida Bay and affirm the “Warrants Concern” indicator status assigned to crocodiles.

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4.8. Human Experience

Assessment of the sensory environment from a human perspective helps us become aware of the specific characteristics of our sensory experiences. Intuitively, we know that National Parks feel different from other places. This part of the Natural Resource Condition Assessment is focused on quantifying just how different the sensory environment in EVER is from the surrounding areas, and begin to identify connections between the sensory environment and the other categories of natural resources that are assessed. The original intention was to assess sights, sounds and smells, but time and information constraints allowed only night skies to be assessed.

4.8.1. Night skies in Everglades National Park

Status and Trend

Attribute: Night Skies

Overall Condition & Trend:



Rationale: Night skies in EVER Warrants Concern and the trend is declining. The light environment of urban areas in Miami-Date County are the most significant influence, followed by light sources in the Keys and lit areas on Tamiami trail. The most natural night skies in EVER are similar to rural areas of the Midwest, and occur near Cape Sable.

Highlights

- Cape Sable and the western coastal marshes experience the least amount of light pollution in EVER.
- Light domes from urban Miami, the Florida Keys, and developed areas on Tamiami trail are routinely visible.
- Less than 5,000 stars can be counted in any area of EVER, and probably less than 100 stars can be counted in the East Everglades addition lands. In the absence of light pollution over 15,000 stars are countable by a typical person with good vision.

The condition of the night sky in Everglades National Park Warrants Concern and the trend is declining (Table 4.49). Trends are inferred, with a high degree of confidence, as light levels are assumed to have increased in proportion to the population growth of Miami-Dade County. The night sky condition is clearly not in keeping with the intent of the Wilderness act - the influence of humans on the night sky is obviously perceptible throughout the park (Figures 4.84–4.86).

Table 4.49. Night skies in Everglades National Park.

Indicators of Condition	Condition & Trend	Rationale
Luminance		Bortle Dark Sky Scale is 4–5 across EVER. A Bortle scale of 4 is found in Cape Sable and along the Gulf coast, while 5 or greater occurs in the eastern portion of EVER
Star count		Up to 5,000 stars can be counted per night at a single location in Cape Sable. Less than 500 stars can be counted per night along the eastern boundary. The northeastern corner of the East Everglades Addition Lands are likely to have less than 100 countable stars on the clearest nights.

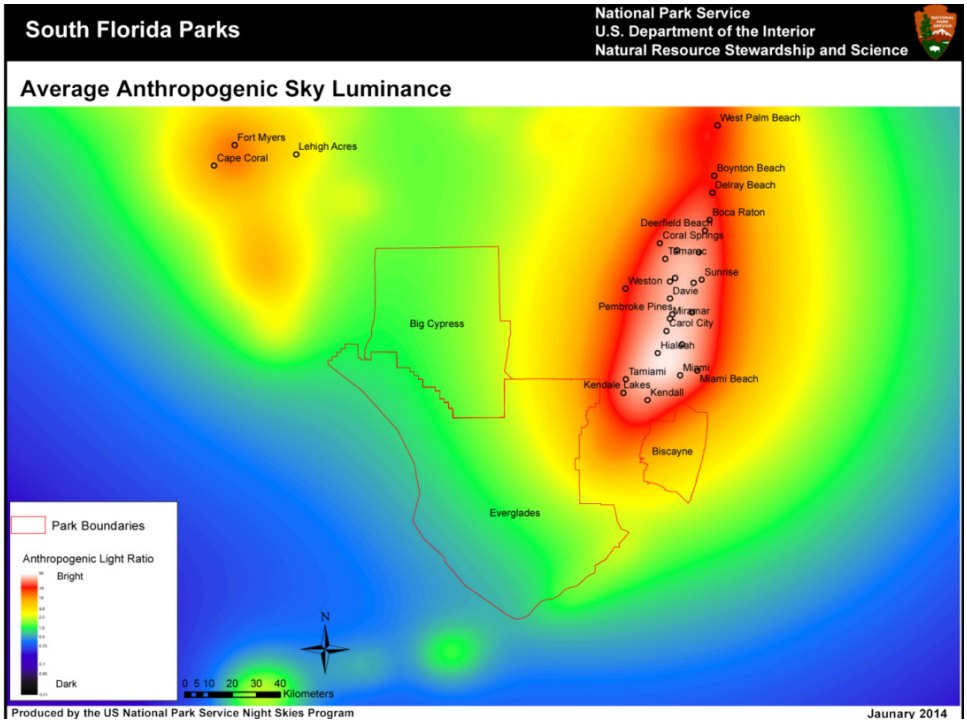


Figure 4.84. A model of the ratio of luminance caused by humans divided by luminance from natural sources in southern Florida.

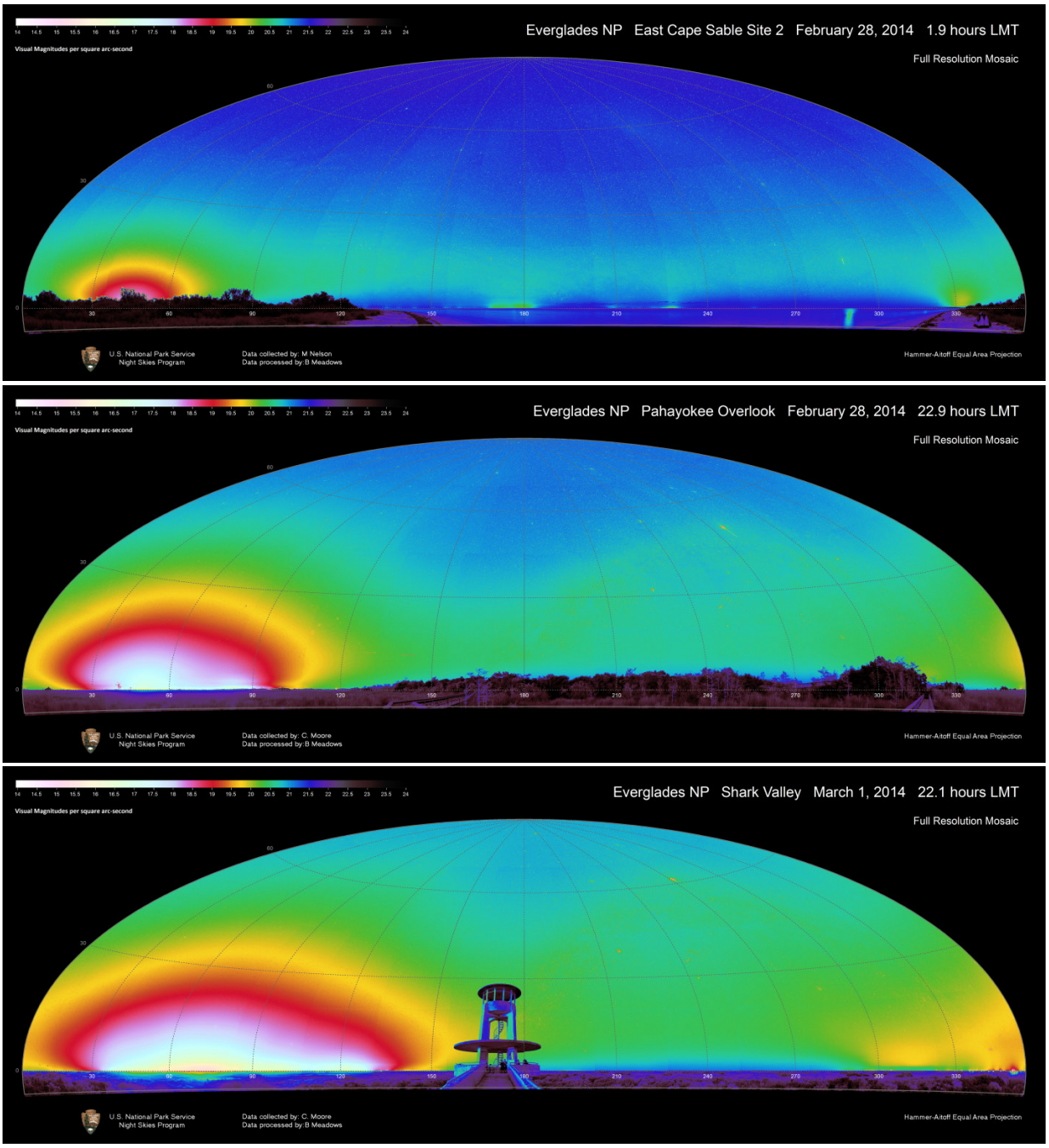


Figure 4.85. The best night sky in EVER at Cape Sable (top panel) is influenced by scattering and light domes of Miami (left side) and several light domes from the Florida Keys (green color across the bottom). The influence of the light dome grows (along with scattering effects) at Pahayokee Overlook (center panel) and Shark Valley (bottom panel).

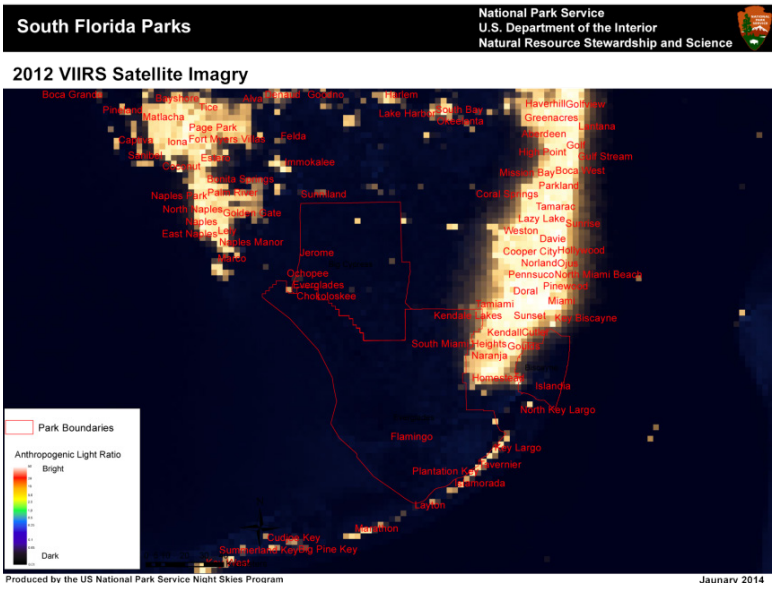


Figure 4.86. Satellite image of light sources in southern Florida – 2012.

Background and Importance

Darkness is habitat for the ~50% of wildlife on the planet that is nocturnal. Human sources of light dominate the urban areas of southern Florida, while light domes and scattered light are present throughout EVER.

Light pollution from nearby urban areas significantly impacts EVER, and wilderness areas in EVER are far from pre-human conditions during the night. While major constellations are visible in the western half of EVER, there are significant night sky features that are not visible, including: ~10,000 faint stars, much of the Milky Way galaxy, and the gegenschein (a faint brightening of the night sky created by the backscatter of sunlight reflecting from dust in the solar system).

Learning more about the science of light and human vision will help us understand the value and fragility of natural lightscapes. At night, in the absence of bright light, our atmosphere turns transparent and allows us to see beyond our planet into the vastness of the cosmos.

Understanding the manner in which the human eye-brain combination perceives light is important for supporting our awareness of how light influences our aesthetic appreciation of the night sky. The eye can safely perceive light over a 10^{13} (or 10 trillion) range of intensity (i.e., on a logarithmic scale). This is roughly the difference between the faintest star in the sky and the reflection of sunlight from snow. The biology of our eyes, and in particular our retina is formed this way to allow our eyes to see faint objects better. As a result of the biology of our retina, most people can see the difference between the shadow of a tree in front the darkest part of the night sky on a moonless night, but most of us are not naturally able to distinguishing the magnitude of the difference between very bright objects (like the disc of the sun) as different from simply bright objects (like a 40 Watt light bulb). Instead, we simply register a sense of pain when we look directly at the sun's disk, and if we

continue to look at the sun for any amount of time, our retina will be permanently damaged. Visual contrast is also seen in an analogously non-linear manner.

Light pollution from cities can be detected at distances of over 170 km (Duriscoe et al. 2007; Figure 4.85). Three basic forms of light create light pollution at night – direct sources, scattering, and light domes. One consequence of the way that we perceive light is that direct sources of light from bright objects impact very large areas at night – much larger than the areas that they are intended to illuminate. Conversely, when light pollution is absent, we are able to see very well at night – particularly in the Everglades, where the ambient light from the moon and stars scatters and reflects off the white soils to illuminate the night.

Most of what we recognize as light pollution in EVER is a result of light scattering. Scattering is the combined effect of refraction, diffraction, and absorption of a light beam as it travels through a sky that contains suspended particles (some of which can be pollution), moisture/clouds, and typical atmospheric gases (molecules of nitrogen, oxygen, carbon dioxide, and other trace substances). Scattering is the process that causes haze during the day (see section 4.3.1 for a discussion of haze in EVER). Scattering degrades the view of the night sky by reducing the contrast between faint stars and the background atmosphere.

Light domes are a third type of light pollution that is prominent in EVER. Light domes form over any significant area where humans deploy streetlights. Light domes are the most easily perceived form of light pollution in natural areas.

Description of Indicator Measured

The Bortle Dark Sky Scale is used to rate sky quality in intervals from 1 to 9, where 1 is pristine and 9 represents a sky dominated by anthropogenic light in which only the very brightest dozen or so stars and planets may be seen (look online for more description about the Bortle scale or for deeper insight into night skies and the night sky program for the National Park Service, Table 4.50). A second, simple metric is the number of stars that can be counted from single location at night. More than 15,000 stars can be counted in areas with no light pollution, while fewer than 50 stars are visible in the most densely populated urban areas.

Table 4.50. Night sky indicators for Everglades National Park are evaluated at a set of representative sites across the park where visitors are likely to be present, and where the full range of night sky conditions can be observed (across the sites).

Measurement	Metric	Scale	Threshold
Luminance	Bortle Dark sky index	Observable sky at representative locations in EVER	Assessed by Bortle scale score: Good Condition: 1–2 ; Warrants Moderate Concern: 3–4; Warrants Significant Concern: ≥ 5
Star count	Number of countable stars per night	Observable sky at representative locations in EVER	Assessed by the number of countable stars per night: Resource is in Good Condition: > 15,000 stars per night; Warrants Moderate Concern: 500–15,000 stars per night; Warrants Significant Concern: < 500 stars per night;

References

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Chapter 5: Synthesis and Discussion

5.1. General Condition

Every aspect of the Everglades ecosystem that was assessed in this report reveals evidence of challenges associated with human activities. This is not surprising; given the historical context that led to the establishment of EVER, the rapidly expanding human population that now exceeds 7.5 million people within 100 miles of the park boundary, and the position of the park at the downstream end of a large watershed – where cumulative impacts of upstream water diversions are most severe.

Everglades National Park continues to experience profound challenges. Thirty-four ecological indicators are identified in this report. Ten of the ecological indicators were not assigned a status/trend due to either limited availability of information or the lack of the report author's time to locate and assess existing information. Twenty-four indicators were assessed in this report, and nearly all of these indicators currently either warrant concern (16 – yellow stoplight icon) or significant concern (seven – red stoplight icon). Only one ecological indicator, Nutrients and Florida Bay Algal Blooms) is identified as in good (green stoplight icon) condition across all of the regions of the park where it occurs (Table 5.1), even though challenges with marine phytoplankton are now widespread along the Florida Gulf Coast, and near population centers along the Atlantic Coast.

Table 5.1. Assessment by attribute – whole park.

Heinz (2002) Ecological Attributes	Attributes	Condition & Trend	Rationale
System Dimension	Landscape Context		Large set of conserved areas, regional planning underway, hydrologic restoration still needed, land use intensification likely to continue
Chemical/Physical	Air Quality		Ozone sensitive plant species are reasonably likely to be injured each year, particulate deposition of nitrogen and sulfur are high, visibility is poor (relative to natural conditions), and there is a concern about atmospheric deposition of toxic materials (including mercury).
	Surface Water Hydrology		The total volume of water that is delivered to EVER is usually less than half of what is desirable given historical patterns and the needs of desired habitat types. The location of deliveries is mismatched to downstream land management goals.
	Salinity Patterns in Florida Bay		Florida bay is too salty every year. In dry years, salinity can become much higher than the open ocean, particularly in the Central and Eastern coastal zones. Region's status has not changed for several decades.
	Total Phosphorus		Phosphorus concentration in waters flowing into EVER are between the long-term limit and the phosphorus target.

Table 5.1 (continued). Assessment by attribute – whole park.

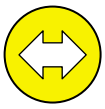
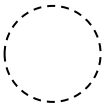
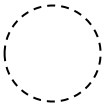
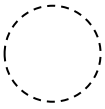
Heinz (2002) Ecological Attributes	Attributes	Condition & Trend	Rationale
Chemical/Physical (con'td)	Nutrients in Freshwater Wetlands and Periphyton		Periphyton communities in Shark River Slough indicate slightly elevated nutrient concentrations at 25–50% of sampling stations, while periphyton communities in Taylor Slough and Coastal basins were similar to the desired reference condition.
	Nutrients & Florida Bay Algal Blooms		The last period of extended blooms was between 2005 and 2007. Conditions subsequently improved.
	Soils		Soils in EVER appear to have stabilized following significant loss of organic soils since 1946 (with loss prior to 1946 very likely). Improvement to soils will require significant progress with the Everglades Restoration Program.
	Mercury and Other Contaminants		Mercury deposition is high and is a significant concern for EVER. Most organisms sampled are above both wildlife and human consumption toxicity thresholds.
Biological - Plants	Vegetation Communities Extent & Distribution		A vegetation map for EVER is in progress. While much is known about the vegetation in EVER, systematic assessment remains elusive.
	Seagrass Communities		Initial efforts at regional restoration of freshwater flows have improved conditions for seagrass. Additional restoration will be necessary to achieve goals for species composition, biomass, and stability of seagrass beds in Florida Bay.
	Ridge, Slough, and Tree Island (RSTI) Landscape		The RSTI landscape in the north half of Shark Slough and Rocky Glades is seriously impaired. White water lilies are not abundant in any portion of the park due to insufficient water volume deliveries, and sawgrass marshes have expanded into areas that were formerly sloughs. Exotic plants are more prevalent in areas of severe impairment to the landscape. Habitat quality for birds and mammals is likely to be significantly diminished in the compromised portions of the RSTI landscape.
	Wetland Ecotones and Community Structure		Changes in the location of wetland ecotones have been observed in response to changes in rainfall, however an assessment of the condition of ecotones has not occurred.
	Mangrove-Marsh Ecotone		A system of marsh-mangrove ecotone transects has been installed. Direct observation of changes over time is now possible. The mangrove forest is believed to have expanded inland as a result of storm surge interacting with sea-level rise and systematic alteration of the regional watershed.

Table 5.1 (continued). Assessment by attribute – whole park.

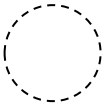
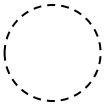
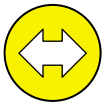
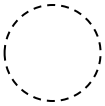
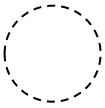
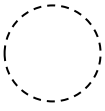
Heinz (2002) Ecological Attributes	Attributes	Condition & Trend	Rationale
Biological – Animals and Invertebrates	Marine Exploited Invertebrates		No systematic assessment possible with sparse available information on lobster, stone crabs, and other harvested marine invertebrates.
	Marine Fish Communities		No systematic assessment possible. Marine fish monitoring is limited to sportfish. Effective monitoring that is independent of fisheries is desired, but not yet occurring.
	Estuarine Sport Fish and Invertebrates		Four sportfish species are near desired conditions. Snook are below desired condition, and pink shrimp are significantly compromised.
	Freshwater Fish and Aquatic Invertebrates		The species composition of freshwater fish is shifting, with fewer long hydroperiod dependent species than desired. Fish biomass and species composition are below the very conservative targets used to design the assessment, and have declined over the last twenty years. Freshwater fish biomass is far below more aggressive, restoration-based goals.
	American Alligator		Alligator populations in EVER have improved since 1985, and while nesting numbers have increased, nesting success remains erratic, and population numbers appear to have stabilized below the numbers expected in a restored ecosystem. Future monitoring uncertain.
	Amphibians		No systematic monitoring of amphibians is occurring in EVER.
	Wading Birds		The total numbers of pairs of nesting birds in the region are increasing, ibis are doing well. Nesting locations remain too far inland from the coast, and woodstorks remain too scarce with erratic nesting timing as a result of water management infrastructure and operations.
	Threatened or Endangered Marine Invertebrates		Marine monitoring may be set to restart in the next few years.
	Sea Turtles		Monitoring has lapsed, brief assessment suggests one of five listed sea turtles are improving due to enhanced nest success while four species have unknown status.

Table 5.1 (continued). Assessment by attribute – whole park.

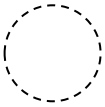
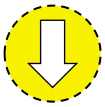
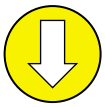
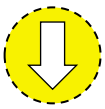
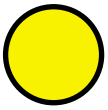
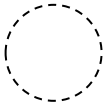
Heinz (2002) Ecological Attributes	Attributes	Condition & Trend	Rationale
Biological – Animals and Invertebrates (continued)	American Crocodile		Crocodiles in EVER have improved significantly since canal plugs were installed in 2002. Juvenile crocodile survival and growth rates remain below the rates observed in nearby crocodile nurseries.
	Florida Panther		Florida panther is assessed in BICY NRCA. Population generally improving north of Everglades National Park.
Biological - Comprehensive	Biodiversity		EVER accumulates non-native species, and once established, non-natives are nearly impossible to completely eradicate. Reptiles and mammals are at greatest risk as a group. There are 2–5 times more non-native species in Florida than non-natives that are already established in EVER. There is a high risk that some of these species will establish in the near future.
Agents of Change (Stressors that are not captured elsewhere)	Altered Fire Regime		Severe fires less frequent, still too little fire applied across EVER. Pine rockland burning not sufficient.
	Climate Change		Sea-level rise is estimated to be 2.2 mm per year. Shifts in land surface temperature and rainfall patterns are possible but less definitive.
	Terrestrial Invasive Exotic Plants		There are over 55,000 ac infested with invasive exotic plant species in EVER. Management processes are increasing and a wide range of partnerships are being developed to address exotic plants. The main concern is whether the rate of expansion is greater than the rate of reduction in infested areas due to management.
	Invasive Marine Species		No systematic monitoring of invasive marine species occurs,although there is a growing list of organisms that have been detected in the region. Lionfish are a growing concern.
	Exotic Fish in Freshwater Marshes		The rate of introduction of new exotic fish species is increasing. Less than 2% of fish monitored in Shark River Slough and Taylor Slough are exotic species. Exotic species are being observed in more locations in recent surveys, suggesting that they are spreading.
	Exotic Herpetofauna		The rate of introduction of new exotic herpetofauna species is increasing. Burmese pythons are widespread and reproducing in the wild. Eradication of exotics outside of EVER is effective in small areas, but challenges remain. Tegu populations are growing outside of EVER, and are being detected inside EVER more frequently.

Table 5.1 (continued). Assessment by attribute – whole park.

Heinz (2002) Ecological Attributes	Attributes	Condition & Trend	Rationale
Human Experience	Night Skies		Night skies in EVER Warrants Concern and the trend is declining. The light environment of urban areas in Miami-Dade County are the most significant influence, followed by light sources in the Keys and lit areas on Tamiami trail. The most natural light skies in EVER are similar to the rural areas of the Midwest, and occur near Cape Sable.
	Soundscapes		Preliminary assessment of soundscapes has occurred, and initial investigation of the sound environment underwater in Florida Bay is underway.

Trends in natural resource conditions are harder to summarize concisely than the cumulative assessments described above. A few of the indicators have ideal designs – the monitoring system developed for these indicators supports an ability to clearly identify changes in conditions that are larger than would be expected if due solely to weather. Most of the biological resource assessments are affected by this challenge, and with these natural resources, the approach to assigning trends is simply to identify trends over longer timeframes – rather than year-to-year changes. In this report, surface water hydrology is a good example of how to assess trends in the context of year-to-year changes in weather. The consequence of methodological differences across subjects for making an inference of trend is that the concise summary of trends across all assessed resource categories needs to be interpreted cautiously. The NRCA for Sequoia and Kings Canyon (NPS 2013, chapter 5) provides extensive discussion about the challenges associated with summarizing across resource categories in different locations. This discussion does not need to be repeated here, other than to note that it is challenging to tell a simple story about a large variety of resources over a large area. Nonetheless, telling the story is necessary, so we proceed to tell the story of natural resources in Everglades National Park with requisite caution.

Six categories of resources are assessed as improving across the park, ten categories are stable, eight are declining, and ten are not assessed. A more careful inspection of trends indicates that for the eight natural resource categories that warrant significant concern, none are improving, while five are stable, and two are declining. The clearly declining natural resources in the category of warranting significant concerns are the ridge-slough-tree island patterned landscape and exotic herpetofauna. Luckily, the challenges associated with both of these resource categories are clearly understood by natural resource managers in the region, and attempts to systematically correct these concerns are underway. Everglades National Park has a long history of developing partnerships in the region, and the Comprehensive Everglades Restoration Plan is focused on the most severely challenged areas of the ridge-slough-tree island patterned landscape. Exotic herpetofauna are being actively managed. The majority of management actions are occurring east of the park boundary, with some effort to find and remove pythons on access routes (levees and roads) inside the park. The DOI South Florida

Ecosystem Restoration Task Force is coordinating a strategic action plan for all types of exotic organisms in southern Florida.

A summary of results aggregated at the highest level - identified as Heinz (2002) ecological attributes - provides some interesting insights about the type/quantity of information that is available to EVER resource managers. Chemical/physical resources and agents of change are two categories where every resource was assessed. Five of the eleven categories of animals/invertebrates are assessed in this report, while only two of the five categories of plants are assessed. This result seems to occur for a few different reasons. First, chemical/physical attributes are often measured by other agencies using national or global datasets. Second, the level of complexity required to effectively assess biological systems is significant. Complexity certainly played a role in preventing the NRCA ecologist from analyzing the extent and distribution of vegetation communities and the status of wetland and marsh-mangrove ecotones. Even with a significant amount of information about vegetation communities across EVER, there is no standard set of methods that have been applied in many different areas and which can be used to systematically assess the status of vegetation across the park. If the use of efficient landscape-scale monitoring designs continues to progress, these gaps in information may be closed this decade. However, it is not clear that all of the stakeholders who operate monitoring efforts in the region have a clear and shared vision of how to structure vegetation monitoring in a way that would support a systematic assessment. The implementation of vegetation monitoring for tracking exotic plant species is progressing, but the link to whole-system vegetation monitoring remains tenuous. A similar challenge occurs with monitoring of animals/invertebrates. The best long term biological monitoring in southern Florida has been focused on wading birds, freshwater fish and invertebrates, and estuarine sport fish. Exploited marine invertebrates and marine fish communities are the natural resource groups where monitoring information is furthest from the condition where an effective and comprehensive assessment could be delivered.

Overall, the assessment of natural resources throughout Everglades National Park covers a very large area with many types of valuable natural resources, most of which are not as healthy as they were a century ago. Considerable quantities of natural resources remain, and some are clearly improving, but there are clear signs that further deterioration is likely unless there is an effective and timely effort to address the challenges that exist. Given the large spatial scale across which challenges occur, it is essential that solutions are developed with and understood by a broad set of stakeholders in cooperation with the National Park Service. This overarching conclusion is consistent with the perspective that has been used to manage EVER for at least three decades. The story of the natural resource management in EVER starts with this broad conclusion, yet there is much more to be learned by comparing/contrasting resource conditions among the six distinct watersheds that are present in the park (depicted in Figures 3.2 and 5.1).

5.2. Status by watershed: comparing/contrasting stressor combinations and resulting effects on managed areas

Assessing the status and trends of natural resources among the distinct watersheds that occur in EVER allows us to sharpen the general perspective of a vast ecosystem that has been experiencing the escalating effects of human activities for most of the last century. The major challenges that occur

in EVER are most severe in the areas where the current condition is furthest from the historical condition – the East Everglades Addition Lands in particular, and the eastern third of EVER in general (northeastern Shark Slough, Taylor Slough, Eastern Marl Prairies and the northeastern basins in Florida Bay). The intention is to address the ecological challenges in these areas with projects designed through the partnerships established in the Comprehensive Everglades Restoration Plan.

The type, number, and intensity of ecological threats are different among the ecological regions in EVER (Table 2.4). The average condition is seven (of 11 possible) threats per region and only one watershed area is obviously different from the rest - the marine/estuarine areas along the west coast of the peninsula. These marine/estuarine areas have about half of the number of stressors observed among the other regions. This result should be interpreted cautiously, since a comprehensive assessment of marine stressors is not present in this report (this was a practical consideration, since the marine system is such a small portion of EVER). It is likely that there are stressors associated with the marine system, which are not identified. The ecological threats that were assessed appear to group as pervasive/widespread (climate change, exotic species, and regional water management infrastructure), thematic (altered fire conditions, nutrient pollution, mercury pollution, historical land use, historical or current roads, recreational fishing), or location-driven/sparse (storm surges, pesticides/environmental contaminants, and reduced spatial extent of habitats surrounding park).

A tabular summary of resource status/trends among the six watersheds (Table 5.2, Figure 5.1) in EVER is consistent with the general impression of park managers. The Taylor Slough and Eastern Prairies watershed has a higher proportion of natural resources that warrant significant concern (red) than any other of the park's watersheds. Two watersheds have a higher proportion of natural resources that warrant concern (yellow) – the Shark Slough and Rivers and Florida Bay Basins that should be enhanced by CERP – than the rest of the regions. Together, these three "worse than average" regions cover 61% of the area of the park.

Table 5.2. Summary of indicator scores by watershed and park-wide. The top row indicates the proportion of the park each watershed covers. The remaining cells indicate the proportion of assessed indicators with a certain status in each watershed. Colored cells are outside the 95% confidence interval of the mean proportion in each category. The park-wide status column is a summary of scores from Table 5.1, while the "watershed" columns are a summary of scores from Table 5.3. The boxes are shaded with superscripts and table notes as a result of an analysis process that is statistically based Caution should be used when using this table to draw inferences about management decisions.

Ten Thousand Islands (10.6% of park area)	Broad/Lostman's River (14.5% of park area)	Shark Slough and Rivers (28.2% of park area)	Taylor Slough and Eastern Prairies (19.3% of park area)	Florida Bay – CERP influenced (13.6% of park area)	Florida Bay and Marine areas not influenced by CERP (13.5% of park area)	Park-wide Status and Trend (100% of park area)
19.0%[a]	9.1%	0.0%[b]	4.3%	5.3%	10.5%	**2.9%**
23.8%[a]	31.8%	45.5%	34.8%	47.4%[b]	42.1%	**47.1%**
19.0%	22.7%	27.3%	34.8%[b]	15.8%	15.8%	**20.6%**
38.1%	36.4%	27.3%	26.1%	31.6%	31.6%	**29.4%**

[a] Indicates that the proportion of natural resources in this category is "better" than the average across the park (also shaded green).

[b] Indicates that the proportion of natural resources are "worse than the average condition across the park" (also shaded red).

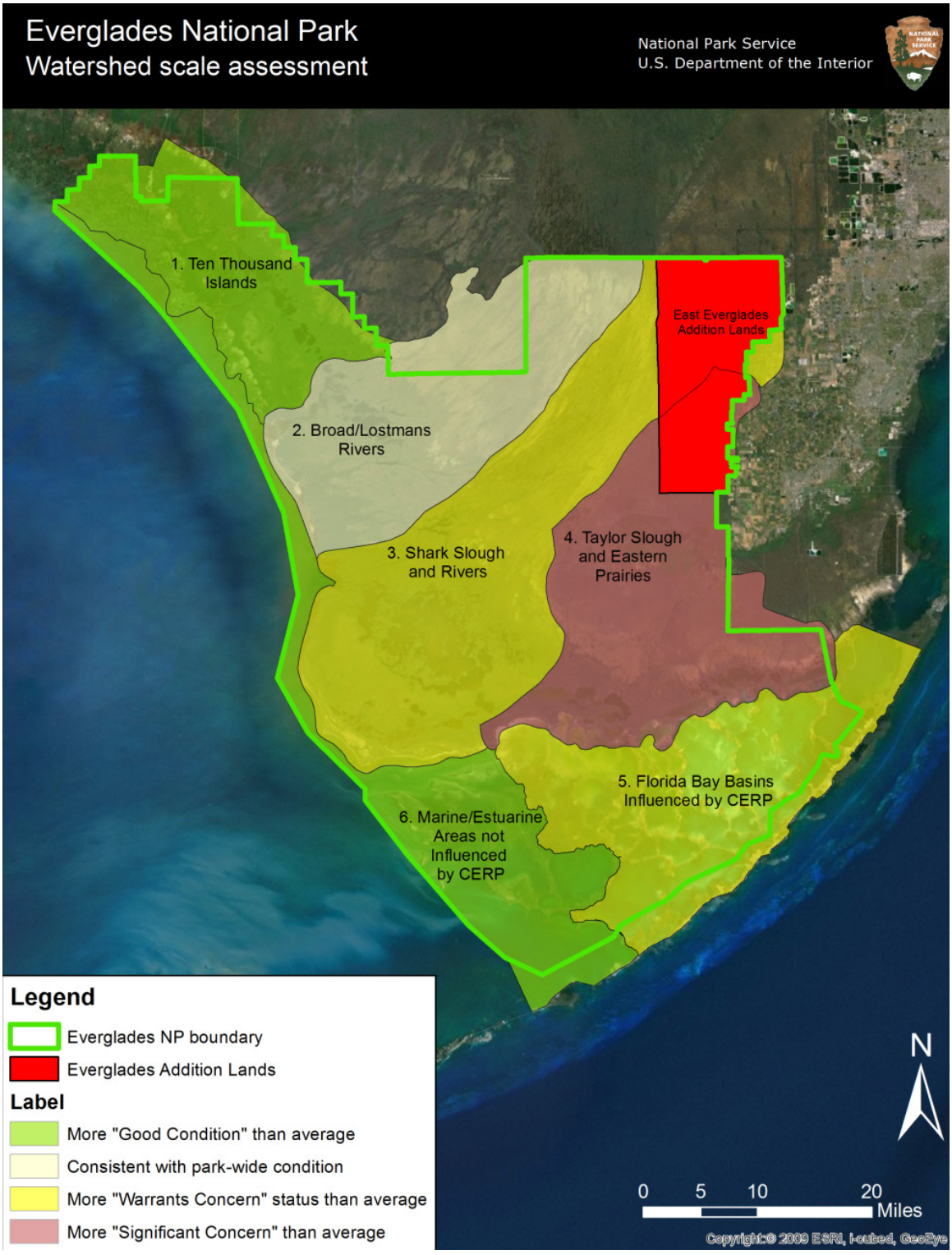


Figure 5.1. A synthesis of resource conditions in Everglades National Park across all assessed categories at the watershed scale. The mismatch between desired and observed hydrologic conditions in the East Everglades Addition lands appears to be the overarching causal driver for the most widespread ecological challenges across the park.

Conversely, the Ten Thousand Islands watershed contains the highest proportion of natural resource categories that were rated as good (green), and relatively fewer natural resources that warrant concern (yellow) compared to the average watershed region. Both areas of Florida Bay have fewer resources that warrant significant concern (red) than the average region, although the eastern portion of Florida Bay that should be enhanced by CERP has a higher proportion of resources that warrant concern (yellow) than the average region of the park. The correspondence between this result and the perspective of natural resource managers suggests that even though this assessment is not entirely comprehensive (10 of 34 indicators are not assessed), there is enough information to differentiate resource conditions across the park, and identify areas where high priority management actions should be taken. This summary validates decades of natural resource management effort that has been focused on restoring water flows to the East Everglades Addition Lands, to modify the eastern boundary of the park, and to elevate the water table in the coastal marshes that are just upstream of northeastern Florida Bay. While progress has occurred, the results of this assessment are clear - **much progress remains to be accomplished before the most severely negative ecological impacts in the region are corrected**. Nearly all of the most challenging stressors are a direct consequence upstream water diversions and the consequent chronic dehydration of the watershed. The effects of dehydration include soil loss, large-scale dry-season peat soil consuming fires, and hypersaline conditions in central Florida Bay.

A systematic summary of the status of the six watersheds present in EVER is presented in Table 5.3. This approach to summary is probably most useful as a reference, since there are so many condition/location combinations to consider, and it is challenging to remember the rationale for all 204 possible subject/watershed combinations (thirty-four resource categories across six watersheds in EVER = 204 combinations). This synthesis across categories is a qualitative summary that preserves the opportunity to provide a comprehensive assessment, without the need to deliver a quantitative summary score. The decision to use a tabular summary to compare the regions of the park is made due to the stark differences in the degree of development of individual resource assessments. Combining different assessment processes into an overall status is necessary. The Sequoia/Kings Canyon NRCA developed composite condition scores for each region of their park, and then presented a list of reasons why the quality of the condition scores might be compromised (NPS 2013, page 271). A score for each region is not the outcome of this summary of natural resources in EVER, but a difference in the proportion of status categories is an outcome that is an effective and defensible method of synthesis.

Table 5.3. Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

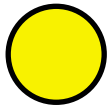
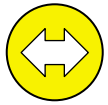
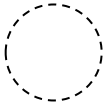
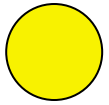
Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
System Dimension	Landscape Context	NA	NA	NA	NA	NA	NA	
Chemical and Physical	Air Quality							
	Surface Water Hydrology					NA	NA	
	Salinity Patterns in Florida Bay		NA	NA	NA			
	Total Phosphorus in Freshwater Wetlands us							
	Nutrients in Freshwater Wetlands and Periphyton					NA	NA	

Table 5.3 (continued). Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

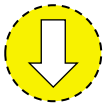
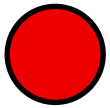
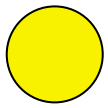
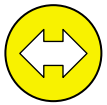
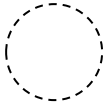
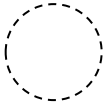
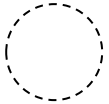
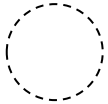
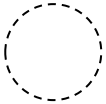
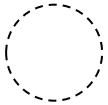
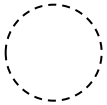
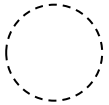
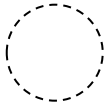
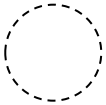
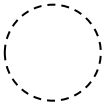
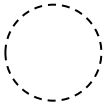
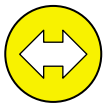
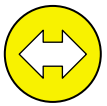
Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
Chemical and Physical (continued)	Nutrients & Florida Bay Algal Blooms	NA	NA	NA	NA			
	Soils					NA	NA	
	Mercury and Other Contaminants							
Biological - Plants	Vegetation Communities Extent & Distribution							
	Seagrass Communities	NA	NA	NA	NA			
	Ridge, Slough, and Tree Island (RSTI) Landscape	NA				NA	NA	

Table 5.3 (continued). Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

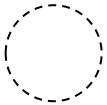
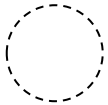
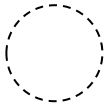
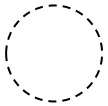
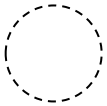
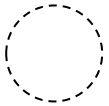
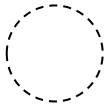
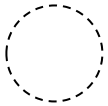
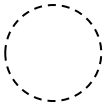
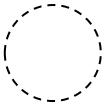
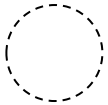
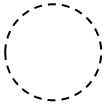
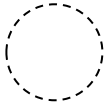
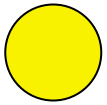
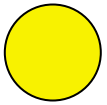
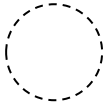
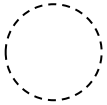
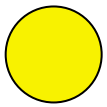
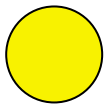
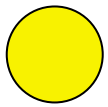
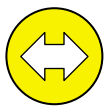
Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
Biological – Plants (continued)	Wetland Ecotones and Community Structure					NA	NA	
	Mangrove-Marsh Ecotone					NA	NA	
Biological – Animals and invertebrates	Marine Exploited Invertebrates	NA	NA	NA	NA			
	Marine Fish Communities	NA	NA	NA	NA			
	Estuarine Sport Fish and Invertebrates	NA	NA	NA	NA			
	Freshwater Fish and Aquatic Invertebrates					NA	NA	
	American Alligator	NA				NA	NA	

Table 5.3 (continued). Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

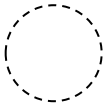
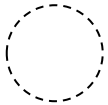
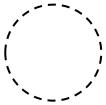
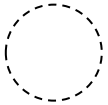
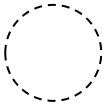
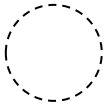
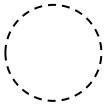
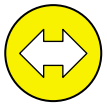
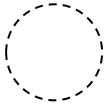
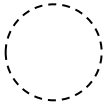
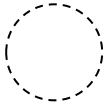
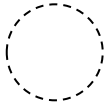
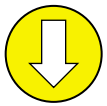
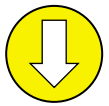
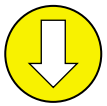
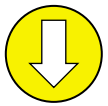
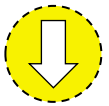
Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
Biological – Animals and invertebrates (continued)	Amphibians					NA	NA	
	Wading Birds							
	Threatened or Endangered Marine Invertebrates	NA	NA	NA	NA			
	Sea Turtles	NA	NA	NA	NA			
	American Crocodile	NA	NA	NA	NA			
	Florida Panther					NA	NA	
Biological - Comprehensive	Biodiversity							

Table 5.3 (continued). Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

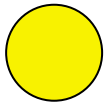
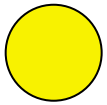
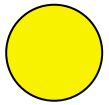
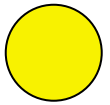
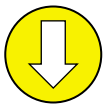
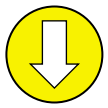
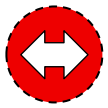
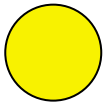
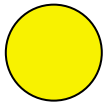
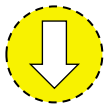
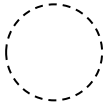
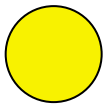
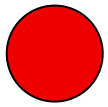
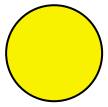
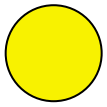
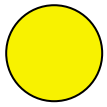
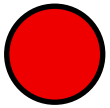
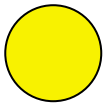
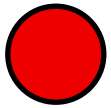
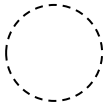
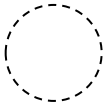
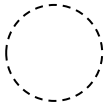
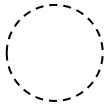
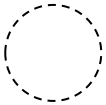
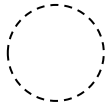
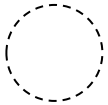
Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
Agents of Change (Stressors that are not captured elsewhere)	Altered fire regime					NA	NA	
	Climate change							
	Terrestrial Invasive Exotic Plants					NA	NA	
	Invasive marine species	NA	NA	NA	NA			
	Exotic Fish in Freshwater Marshes					NA	NA	
	Exotic Herpetofauna	NA	NA	NA		NA	NA	

Table 5.3 (continued). Each category of natural resource is rated for each of the six watersheds found in EVER. Cells with "NA" occur when assessment is not appropriate for a specific region.

Heinz (2002) Ecological Attributes	Focal Resources	Watersheds						
		Ten Thousand Islands	Broad River	Shark River	Taylor Slough and Eastern Prairies	Florida Bay – CERP Influenced	Florida Bay and Marine Areas not Influenced by CERP	Overall Status and Trend
Human Experience	Night Skies							
	Soundscape							

In the interest of taking the discussion about comprehensive assessment that was developed for the SEKI NRCA one step further, it helps to recognize the reasons for differences in approach to natural resource assessment among different parks. Physical processes and stressors are reasonably similar across the many different units of the National Park System. The biota, however, are not. Of course, different parks are going to monitor different biota with different methods and different goals in mind, and of course management is going to focus on threatened/endangered species (all of which have a status that warrants some level of concern). The natural heritage of North America is so magnificent precisely because of the rich mosaic of thousands of habitats composed of tens of thousands of plant species occurring on tens of thousands of soil types, that are habitat to thousands species of birds, and hundreds of species of reptiles, amphibians, mammals, and fish. The as-yet-uncounted number of invertebrates, fungi, lichens, soil microbes, and other living things are part of this natural heritage too. It is completely appropriate for natural resource managers to focus scientific monitoring on the organisms, habitats, or themes that are the foundational aspects of the National Park land that they manage. Everglades National Park has done an effective job of focusing the public and scientists on the key biological themes that are the predominant reason why the park was established. The challenge that remains is to structure comprehensive natural resource monitoring in a manner that simplifies the assessment process so that status and trends can be updated on a regular basis and assessment systems can continue to be refined.

The qualitative approach to summary conducted here simplifies the interpretation process, and allows the discussion about the condition of the whole park to remain intuitive, even while the assessment of individual resource conditions and the causal linkages between resource conditions can be quite complex and non-intuitive. Effectively managing this information paradox is essential. The one million people who visit EVER each year consistently identify the value that they place on natural resources, as well as their interest in learning more about the park (see section 2.61). Concise communication with visitors is essential. In contrast, the scope and interactions between distinct challenges facing EVER are complex, and management strategies for addressing challenges are often quite sophisticated. EVER is confronted with geographically nested threats that range from shifts in global climate, to continental scale patterns of air pollutants, to trade/migration assisted movement of exotic organisms, to regional scale alterations to the watershed, to highly localized challenges like illegal harvesting and arson. Effective monitoring and focused research will continue to play an important role in recognizing developing threats and prioritizing management actions. While priorities may shift over time, management strategies will always need to be coordinated with a broadly inclusive set of stakeholders and cooperating legal authorities. Therefore, the process of developing sophisticated, objective, and performance-based assessments for individual resources will continue to exist in parallel with periodic, concise, and comprehensive summaries across resource categories. The qualitative approach to synthesis provided here treats every assessment category as an independent opportunity to identify a condition status of “Good,” “Warrants Concern,” or “Warrants Significant Concern.” The relative proportions of these cases across the regions of the park correspond to the degree of challenge. This qualitative approach can be used until a collection of fully quantifiable assessment strategies exist for each resource of interest. Opportunities for simplifying and enhancing the synthesis process are presented as a part of the analysis of the gaps in the assessment of EVER.

A brief inspection of the assessment of threats (Table 2.4) and the assessment of natural resource status (Tables 5.2 and 5.3) suggest that differences in the severity of individual threats is the most important issue that "Warrants Significant Concern" in the Taylor Slough and Eastern Marl Prairies watershed. A second conclusion is that the terrestrial areas of EVER are currently experiencing a larger number of challenges than the estuaries of Florida Bay or the marine areas along the west coast.

5.3. Gaps

Everglades National Park is part of one of the most vigorous environmental monitoring efforts in the United States – the Comprehensive Everglades Restoration Plan Monitoring and Assessment Plan (the CERP - MAP). This monitoring plan is administered through an interagency process, and even though it is large, it does not cover all of the areas of EVER, nor does it address all of the monitoring needs of Everglades National Park. Given the practical challenges associated with managing and implementing comprehensive monitoring, it is essential to continue to develop and/or revise approaches to tracking changes in the number or location of organisms across EVER.

There are a few types of gaps in this report:

1. Gaps in assessment due to lack of information.
2. Gaps in assessment due to time/effort limitations.
3. Significant differences between assessments associated with the degree of development of indicators, metrics, threshold designations, or desired state of conservation.

Ten of the thirty-four indicators of natural resource conditions were not assessed. These are the most obvious gaps in this report. Three of these ten unassessed indicators are marine organisms of some kind (marine exploited invertebrates, marine fish communities, Threatened or endangered marine invertebrates, and sea turtles). Gaps in assessment of the marine community are a consequence of lack of information and time/effort limitations. There is information available on most of these subjects, but no recent status and trend reports were available. Less frequently, the NRCA ecologist was not able to locate any information on the subject (beyond a general impression of a NPS staff person). The next largest group of unassessed indicators is the three vegetation resource categories (vegetation communities' extent/distribution, wetland ecotones and community structure, and mangrove-marsh ecotone). These three categories are gaps due to time/effort limitations, since information is being actively developed through the creation of a vegetation map for EVER, the implementation of mangrove-marsh ecotone project, and the prospect of continued wetland monitoring through the CERP monitoring and assessment program (MAP). The four remaining unassessed resource categories are amphibians, the Florida panther, and soundscapes. The absence of amphibian monitoring is a concern as amphibians are experiencing global declines, and this is truly a gap in information. Assessment of the Florida panther will be present in the NRCA for Big Cypress. Information to support an assessment of soundscapes is available, but time constraints prevented the NRCA ecologist from delivering an assessment.

Quantitative assessments are clearly preferred for the NRCA. Significant gaps in assessment are present in the majority of assessment categories, and these are generally characterized as gaps in development of indicators. Continuing to pursue the goal of quantitative assessment for all categories of natural resources is essential, since management actions are location-specific and are often prioritized based on the scale of the concerns that an action can address. One significant challenge to nearly all of the biological assessments in this NRCA is that they are not fully quantitative. Only the assessment of wading birds contains an estimate of the total population size each year for a long time-series. Well-developed assessments of freshwater fish, alligators, crocodiles, and the top four exotic plant species report quantities of organisms within sampled areas, and none of these subjects estimates park-wide biomass, total acreage, or number of organisms throughout the park. Park-wide estimates are only delivered when a census of the entire park is conducted (often using aircraft). A census approach is not feasible for most organisms. Ideal monitoring efforts are structured to identify observed changes and to relate these to estimated changes at unmeasured locations. The absence of estimates of status at unmeasured locations is perhaps the most glaring, systematic gap that is shared by most of the biological monitoring efforts. The behavior of observed sites can be used as a model to make predictions at unobserved locations. This approach to analysis is an essential aspect of Adaptive Management (Williams et al. 2007), which encourages the use of model-based predictions to affirm or refute the effectiveness of management actions. A robust coupling of long-term monitoring efforts with short-term monitoring of specific locations that are affected by individual management actions is only possible if long-term observations are collected and analyzed in a manner that supports estimates of resource status (with explicitly estimated ranges of certainty) at unmeasured locations. The long time-series of estimates of condition prior to management actions can then be compared to a shorter time series of pre/post management action to identify the effects of management actions and determine whether actions should be changed to enhance environmental benefits.

A second type of gap that is conspicuous across most of the biological resource assessments is the absence of explicit use of species community composition information to assess status and trends. Once again, some of the more mature resource monitoring programs (like exotic plants, wading birds, and freshwater fish) assess the status of a few of the more common species (the top four exotic species, the five most common wading bird species, and the four most common freshwater fish species), but none explicitly address species composition patterns with discernable metrics. The best version of species composition analysis occurs in the “Nutrients in Freshwater Wetlands and Periphyton” (section 4.3.3) and “Seagrass/softbottom communities in Florida Bay” (section 4.7.2) assessments. One of the most important aspects of habitat patches in EVER is how many organisms are packed into acre-sized patches of habitat. Many more species occur per acre in EVER than the surrounding human-altered environments, and the resistance/resilience of patches following disturbances is a function of the number of species. It is also likely that species composition is linked to biomass patterns, and that the interaction of species composition and biomass predicts the likelihood that exotic species will colonize a habitat patch. This discussion is developed in the assessment of biodiversity (section 4.6.6), and addressed indirectly in the assessments of exotic plants, wading birds, and freshwater fish. Effective analysis of species composition patterns is a unique analytical skill, and coordination of monitoring efforts is necessary for resource managers to

be able to document how trends in composition patterns across different organism groups - which are monitored with different methods. Delivering this type of monitoring assessment can be challenging, but much like the NRCA, telling the story is essential, even if it is a challenging story to tell. Effective conservation of biodiversity is inextricably linked to patterns in species community composition at the level of individual patches. Loss of rare species in a habitat patch is an early indicator of biological decline, and assessment of expected and observed biodiversity patterns is likely to be an effective approach to early detection of biological decline.

5.4. The Eastern Everglades Addition Lands

Even though the NRCA is designed to identify status and trends among naturally occurring watershed units within EVER, the assessment would be incomplete if the East Everglades Addition Lands were not explicitly discussed. A summary of the content of this report indicates that the 109,600 ac area known as the "East Everglades Addition Lands" are:

1. The most recently added portion of EVER (added in 1989, section 2.1).
2. The largest non-wilderness area of EVER (Figure 2.23).
3. An area of EVER that contains large numbers of established roads and installed canals, most of which have been abandoned (Figure 4.2, section 4.1.1).
4. Immediately downstream of the region of Tamiami Trail where flows have been altered the most (section 4.2.1).
5. The area where the largest quantity of peat soils have been lost since 1948 (section 4.5).
6. The area where the Ridge-Slough-Tree Island habitat is most severely degraded (section 4.6.2).
7. The most extensively invaded inland marsh area in EVER (only coastal marshes are as extensively invaded by the top four exotic plant species, Figure 4.51).
8. The region of Shark Slough that has experienced the highest number of dry season fires since park establishment (Figure 4.52)
9. Directly upstream of the most severely challenged watershed found in EVER (Figure 5.1).

The compilation of threats to EVER (Table 2.4) indicates that the number of threats to natural resources are similar across regions, but subsequent assessment indicates that the intensity of threats is different. The East Everglades Addition Lands contain the most upstream component of the Shark River Slough, and is the most altered portion of Shark River Slough. The East Everglades Addition Lands have received very small quantities of water from the upstream basins, in stark contrast to the pre-drainage condition where very large volumes of water flowed through the region. The combination of historical roads and canals, severe dehydration as a result of regional hydrologic infrastructure, extensive infestation by exotic plants, large numbers of dry season fires, peat soils loss, degraded ridge-slough-tree island landscapes, and the presence of this area in the most severely

challenged watershed area of EVER indicate that the East Everglades Addition Lands are among the areas that warrant the most concern in EVER.

5.5. Long Pine Key – a special habitat in the Pinelands and marl prairies unit

A second area in EVER that deserves special attention is Long Pine Key. The pine rocklands of Long Pine Key contain numerous roads, and several historical homes were located in this upland portion of EVER. This area has the highest combined number of species of special concern and invasive exotic species (section 4.6.6) of any area in EVER. Long Pine Key is the largest remaining pine rockland habitat in Florida and is designated as globally imperiled. The rock ridge, given its relative elevation, is the preferred area of development in Miami-Dade County, and over 95% of the pine rocklands in the region have been converted for human uses.

The status of pine rocklands outside of EVER is starkly different from nearly all other habitats in EVER. There are a large number of organisms that are adapted to use what was once a regionally dominant upland habitat type. Now, there are very few options for these species outside of EVER. The land use history in the region has resulted in a small island of remaining pine rockland habitat. Ecological theory predicts that isolated islands of habitat are more susceptible to loss of species than connected patches of the same size, and this "island biogeography" phenomenon presents a significant risk to species that reside in pine rocklands. The deliberate installation of rare, threatened, endangered, or commercially exploited species in pine rocklands may be an important strategy for land managers to ensure that the remaining pine rockland habitat patches continue to exhibit the high numbers of native organisms that are characteristic of this globally imperiled habitat type.

The hole-in-the-donut restoration area is adjacent to Long Pine Key, and contains restored lands at an elevation that is suitable for habitats ranging from long hydroperiod sloughs up to pine rocklands (section 4.6.1.1). These sites are excellent candidates for deliberate installation of special status species. Soil scraping activities in this portion of EVER presents an opportunity to enhance the spatial extent of pine rocklands by a few square miles.

5.6. References

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Photo of spider webs collecting dew in the sawgrass of Taylor Slough. Photo by Judd Patterson.

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

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A photo of a few of the “ten thousand islands” in the Gulf Coast region of Everglades National Park by Judd Patterson.