National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Biodiversity of Fish in Everglades National Park

An Updated Species List with Habitat Associations

Natural Resource Report NPS/EVER/NRR—2015/1065

ON THIS PAGE
Photograph of a permit (*Trachinotus falcatus*) over seagrass in Florida Bay at Everglades National Park. Photograph courtesy of the National Park Service.

ON THE COVER
Photograph of a diverse group of freshwater fish taken from a monitoring trap in Everglades National Park.
Photograph courtesy of R. Cammauf and the National Park Service.

Biodiversity of Fish in Everglades National Park

An Updated Species List with Habitat Associations

Natural Resource Report NPS/EVER/NRR—2015/1065

Tonya M. Howington[1]

[1]Everglades National Park
950 North Krome Avenue
3rd Floor
Homestead, Florida 33030

October 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

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 both informal and formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Everglades National Park website (http://nps.gov/ever), and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Howington, T. M. 2015. Biodiversity of fish in Everglades National Park: An updated species list with habitat associations. Natural Resource Report NPS/EVER/NRR—2015/1065. National Park Service, Fort Collins, Colorado.

NPS 160/130112, October 2015

Contents

Figures

Page

Tables

Page

Photographs

Abstract

Protecting biodiversity is important for Everglades National Park (EVER). EVER was the first park to have its biodiversity recognized in its enabling legislation enacted in 1934. Field monitoring in EVER is challenging, and consequently, elucidating details of the park's biodiversity is a slow and complicated effort. In order to progress more rapidly, EVER updated the dataset of species and habitat associations developed under a project funded by the Critical Ecosystems Studies Initiative (CESI) using a comprehensive literature review that included citizen science databases. EVER is recommending that the South Florida and Caribbean Inventory and Monitoring Network (SFCN) use the CESI dataset to update the internet accessible species lists on https://irma.nps.gov/NPSpecies/ (NPSpecies). The SFCN provided a quality assurance and quality control (QAQC) analysis of the updated CESI species lists. Predictions were made of the spatial distribution of species by comparing their preferred habitats to vegetative communities found within EVER's physiographic regions.

Photo 1. Goliath grouper (*Epinephelus itajara*) in Florida Bay at Everglades National Park. Photo courtesy of F. Francis.

This report addresses the fish species found within EVER. This analysis refined our understanding of how native, threatened and endangered, and non-native species may affect overall biodiversity. Recommendations are included regarding next steps for refining the list of fish species and potential initiation of long-term monitoring of fish biodiversity in EVER. Other reports will address birds, mammals, reptiles and amphibians. Additional taxonomic groups will be addressed in separate reports as the information is collected and vetted as appropriate.

.

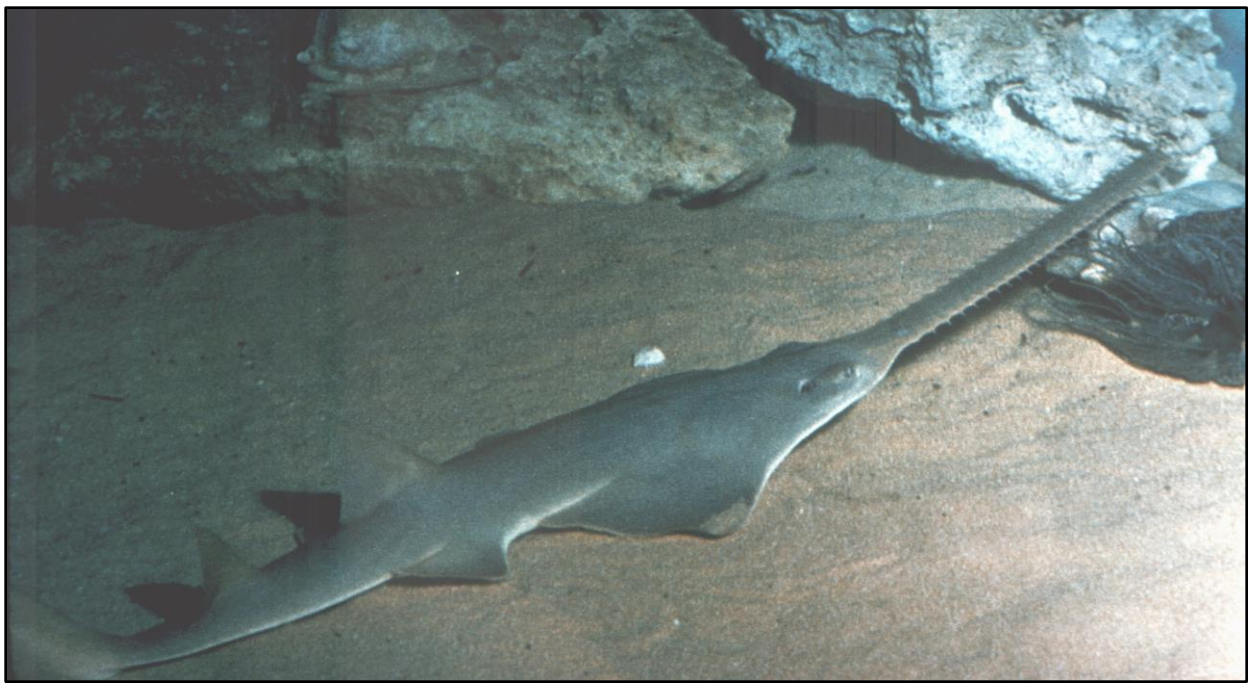

Photo 2. Federally endangered smalltooth sawfish (*Pristis pectinate*) in Everglades National Park. Photo courtesy of National Park Service.

Acknowledgments

I want to thank A. Arteaga, a graduate student at Florida International University, and A. Atkinson, South Florida Caribbean Network, for their assistance in performing the quality assurance and quality control analysis for the South Florida Caribbean Network. J. Redwine provided the maps of physiographic regions and contributed to the exchange of ideas for analysis of the data during this process. Also, we want to thank B. Gamble, Everglades National Park, and F. Haberkorn, a student at the University of Florida, for their help in formatting the data and layout of the document.

Photo 3. Sports fishermen in Florida Bay, Everglades National Park. Photo courtesy of National Park Service.

Introduction

Calculating the native biodiversity of fish in Everglades National Park (EVER) is a critical component of understanding, protecting, and enjoying the park's natural resources. Biodiversity is generally associated with the health of an ecosystem, and therefore it is an important indicator for park management to track. This is particularly true for areas that are expected to have few impacts of human development, such as large tracts of designated wilderness. The diversity of native species should be managed to remain stable over time and contribute to the resilience of the park's ecosystems (Ceausu, 2015; Hobbs et al., 2009; Walker, 2002). With 87% of EVER designated as the Marjory Stoneman Douglas Wilderness, actual resilience will be dependent on internal and external impacts to the large habitat buffers provided by the managed wilderness area. As scientific knowledge of the Everglades grows, we can continue to explore questions such as "How is biodiversity distributed across the Everglades landscape?"

Studying the biodiversity of fish is critical to understanding and predicting habitat community structure and disturbance (Hiddink 2008, Helfman 2007). Tracking species richness (the number of different species of each taxonomic category, in this case fish) is especially important in EVER where the habitats available for fish include a uniquely diverse combination of freshwater wetlands and deep water sloughs, estuarine, and marine open water environments. The inventory of fish populations, including the identification of species, provides important information needed for their protection and persistence (Fischer, 2013). Evaluating biodiversity of fish is part of an overall biodiversity assessment for the park, but is probably not predictive of biodiversity of other groups. Including fish as part of a biodiversity assessment is important as analysis using only one taxonomic group, such as bird biodiversity, as a predictor of high overall biodiversity of a region has been shown to have limited utility (Larsen et al., 2012).

Fish that are part of the Everglades ecosystem include native residents and local and oceanic fish that roam in and out of park boundaries looking for food or temporary refuge. There is also a growing population of non-native fish species. Non-native fish are considered to be those that were introduced by human activity either deliberately or by accident. Although little is known about the ecological impacts of many non-native fish in the Everglades, some non-native fish species potentially induce more harm to EVER's natural resources than others (NWF, 2014), e.g., Indo-Pacific lionfish (*Pterois volitans*). Those that cause the greatest impact are most likely to be targeted for management action.

Park-wide information on species diversity is found on the National Park Service website National Park Service website for their Integrated Resource Management Application https://irma.nps.gov/NPSpecies/ (NPSpecies). NPSpecies is an online database created to track the occurrence of species in park units across the nation (NPS, 2014). NPSpecies is used by land managers that need to have a general picture of species diversity within national park units. It is also available for public use. The NPSpecies dataset for EVER is managed by the South Florida Caribbean Inventory and Monitoring Network (SCFN). Creation of the current list of fish in NPSpecies for EVER has relied on the limited primary sources of information available, which are

primarily park species lists and individual observations. The majority of the fish species in NPSpecies were last confirmed in 2006 (NPS, 2014). There is currently no park list of all native and non-native, freshwater and marine fish species other than what is available in the NPSpecies.

Keeping NPSpecies up-to-date is a time-consuming process. It is believed that EVER can provide information intended to updated NPSpecies by reviewing the references used for the existing information, adding information from relevant literature previously not applied, and then maintaining the dataset using new information from recent field studies that may include citizen science databases.

The usefulness of the information provided by NPSpecies is reliant upon the application of consistent quality assurance (QA) and quality control (QC) methods to the data from inventories, including data entered from all-taxa inventories and bio-blitzes (Budde and Kingston, 2014, Selleck, 2014). Data managers who maintain NPSpecies as a source of information for the species that can be found in EVER can then also be prepared in the event of large-scale updates such as a bio-blitz or other small scale field inventories intended to verify the current species lists. Keeping NPSpecies current may also include more reliance on the use of on-line citizen science databases in the future with appropriate QAQC checks (NPS, 2013b). By implementing as much as possible a QAQC process and peer reviewed Natural Resource Reports of species lists prior to the data from any source being entered into NPSpecies, the accuracy of the information available in NPSpecies for EVER can be improved. For example, each species should be validated by associating it to a voucher specimen, photograph, report or paper.

This first objective of this project was to create a single current park fish species list using the information available from a study funded by the Critical Ecosystems Studies Initiative (CESI) and the NPSpecies with the assistance of the SFCN, EDDmaps.org (EDDmaps (2014) and other sources. The second objective was to provide habitat associations for each species, and to examine the distribution of fish species across broad physiographic regions in EVER. This work was done in cooperation with the SFCN. It should be noted that for this study neither species richness nor its spatial distribution is considered as a surrogate for the abundance of species.

Methods

The CESI dataset was created during 2001-2003 (Howington, 2008), initially using the EVER CREEL survey, which is described by Osborne (2006), Kushlan (1972), and Loftus and Kushlan (1987). Initially, the preferred habitat of fish species was determined by reviewing various literature references that describe observations of fish within EVER and south Florida that included Gilbert (2002), USFWS (1999), Smith (1997), and Myers and Ewel (1990). Updates to the preferred habitats and species list were made using descriptions of where fish are being found using Kline and Fratto (2013), and Trexler (2011).

The dataset was created in Excel in a format required to facilitate a GIS application that would visually display the potential occurrence of vegetation and animal species under the hydrologic conditions of a given simulation model run over a selected year; however, the dataset can be used independently of the GIS application. The final list of species, which has breeding, seasonal occurrence, and a general description of the preferred habitats, is provided in Howington (2015).

Habitat associations were made separately for each individual fish species by comparing the species' preferred habitat in Florida using USFWS (1999), Myers and Ewel (1990), and personal knowledge and experience of the principle investigator, to the habitats within EVER as identified by the Florida GAP program (F-Gap) (Pearlstine et al., 2002). The hydroperiod associated with the habitat was also taken into account as developed by Wetzel (2001). Table 1 provides the list of F-Gap vegetative communities used in this study. Qualitative abundance and occurrence information that is reported in NPSpecies was not included in the CESI dataset.

Table 1. The list of F-Gap vegetative communities used in this study and F-Gap codes.

F-Gap Vegetative Community Types	F-Gap Code
Open Saltwater/Seagrass/Sandy Bottom	1
Tropical Hardwood Hammock Formation	2
Semi-Deciduous Ecological Complex Tropical/Subtropical Swamp Forest	3
Xeric-Mesic Live Oak Ecological Complex	4
Mesic-Hydric Live Oak, Sabal Palm Ecological Complex	5
Bay/Gum/Cypress Ecological Complex	6
Lobolly Bay Forest	7
Cajeput Forest	8
Mixed Mangrove Forest Formation	9
Black Mangrove Forest	10
Red Mangrove Forest	11
Casuarina Compositional Complex	12
South Florida Slash Pine Forest	13
Mesic-Hydric Pine Forest	16
Swamp Forest Ecological Complex	17

Table 1. The list of F-Gap vegetative communities used in this study and F-Gap codes (continued0

F-Gap Vegetative Community Types	F-Gap Code
Cypress Forest	18
Buttonwood Woodland	20
Mixed Mangrove Woodland	21
Black Mangrove Woodland	22
Red Mangrove Woodland	23
South Florida Slash Pine Woodland	25
Dry Prairie Ecological Complex	29
Gallberry/Saw Palmetto	30
Brazilian Pepper Shrubland	31
Dwarf Mangrove Ecological Complex	32
Coastal Strand	33
Groundsel-tree/Marsh Elder Tidal Shrubland	34
Saturated-Flooded Cold Ecological Complex Shrubland	37
Saltwort/Glasswort Ecological Complex	38
Graminoid Emergent Marsh	42
Sawgrass Marsh	43
Spikerush Marsh	44
Muhly Grass Marsh	45
Cattail Marsh	46
Salt Marsh Ecological Complex	47
Sand Cordgrass Grassland	48
Black Needle Rush Marsh	49
Saltmarsh Cordgrass Marsh	50
Saltmeadow Cordgrass/Salt Grass Marsh	51
Sparsely Wooded Wet Prairie	52
Dwarf Cypress Prairie	53
Temperate Wet Prairie	54
Maidencane Marsh	55
Forb Emergent Marsh	56
Water Lily or Floating Leaved Vegetation	57
Periphyton	58
Sand, Beach	59

This comprehensive fish-habitat dataset was first reviewed to identify species that are listed by the federal and/or state government as threatened or endangered (T&E) following the guidelines in the Endangered Species Act of 1973 with amendments (Title 16 of the United States Code). Updates were obtained from information available on the US Fish and Wildlife Service website (USFWS, 2014) and the Florida Fish and Wildlife Conservation Commission website (FFWCC, 2014).

Listings of species vulnerability were added for migratory species (USFWS, 2014) and those species considered as potentially in need of greater management protection by the Florida Natural Areas Inventory (FNAI) website (FNAI, 2014). Species considered as vulnerable and not threatened or endangered were not included as part of the T&E category in this study.

The list of non-native species in the dataset was updated using the Early Detection and Distribution Mapping System (EDDmaps) on-line citizen science database (EDDmaps, 2014). Habitat associations were made for non-native species by interpreting the preferred habitats of non-native species in Florida provided by the Florida Fish and Wildlife Conservation Commission (FFWCC, 2014b and FFWCC, 2014c) into the F-Gap vegetative communities.

For the purpose of examining patterns of fish diversity, and to facilitate the presentation of species lists, much of this analysis uses these three categories of fish species within EVER. 1) native, non-T&E species (no special status), 2) T&E species (special status species), and 3) non-native species. Howington (2015), which contains the data and graphics associated with this report, is organized accordingly.

The second step of this study was to determine distribution of the species among EVER physiographic regions. As part of the Natural Resource Condition Assessment (NRCA) for EVER, the SFCN analyzed available vegetation and landscape information and created a map of 17 physiographic regions based on dominant physical and biological features of the landscape (NPS, 2015). Figure 1 shows the map resulting from the analysis. This map was overlaid on the map of the F-Gap vegetative communities so that the fish species in the CESI dataset could be associated with the physiographic regions.

A full description of each physiographic region can be found in the EVER NRCA (NPS, *in press*). The distribution of F-Gap vegetative communities within the physiographic regions is provided in Table 2. The detailed results of this step and metadata are provided in the dataset associated with this report (Howington, 2015).

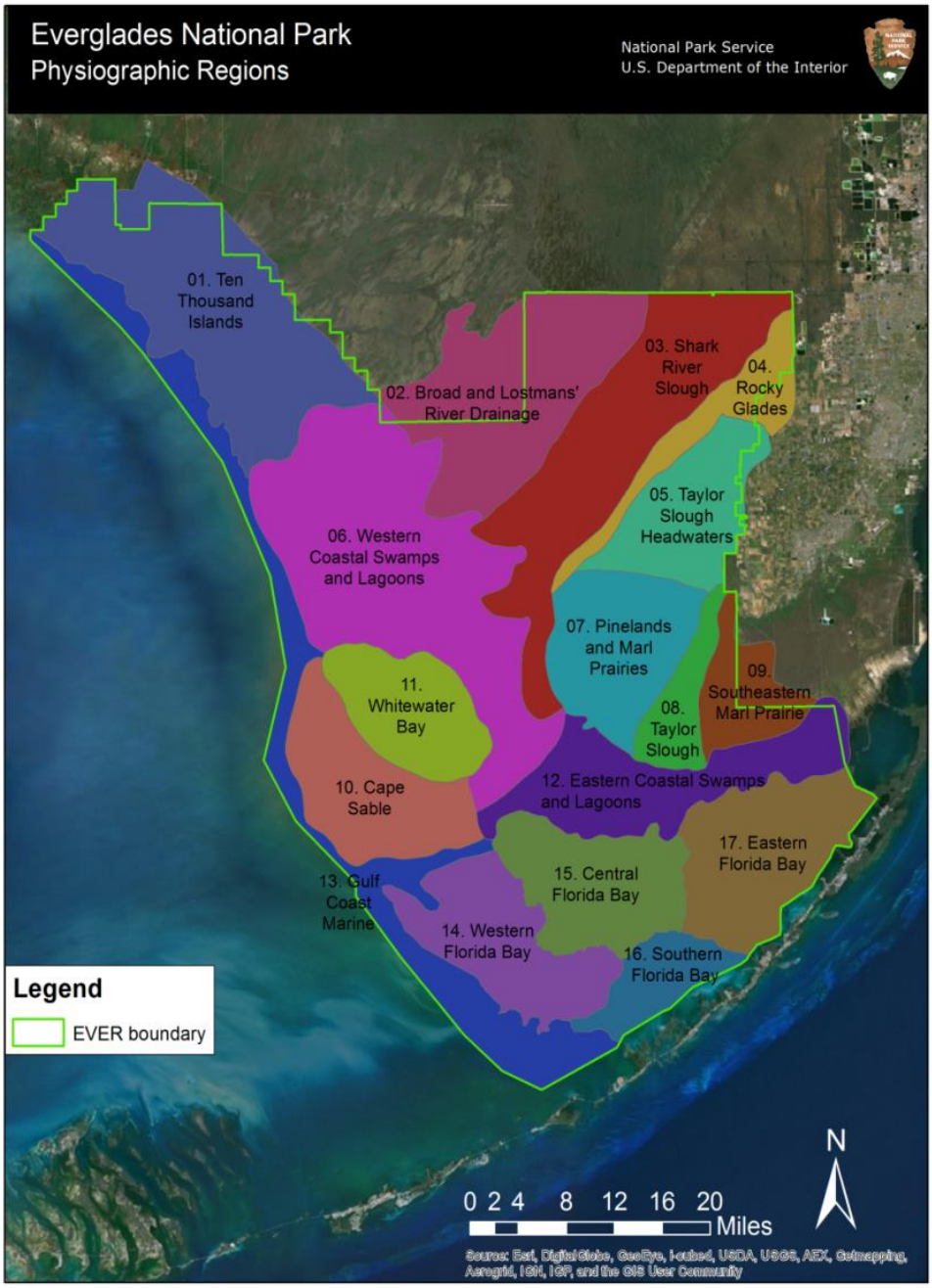

Figure 1. The map of EVER's 17 physiographic regions created as part of the NRCA.

Table 2. Assignments of F-Gap codes to EVER NRCA regions.

Physiographic Regions	F-Gap vegetative communities found within physiographic regions
Region 1 - Ten Thousand Islands	1, 9, 10, 11, 21, 22, 23, 33
Region 2 - Broad and Lostmans River Drainage	2, 3, 5, 21, 22, 23, 30, 43, 44, 46, 55, 56, 57, 58, 59
Region 3 - Shark River Slough	2, 3, 5, 17, 43, 44, 55, 56, 57
Region 4 - Rocky Glades	5, 8, 12, 43, 44, 45, 46, 55, 56, 58
Region 5 - Taylor Slough Headwaters	2, 3, 4, 5, 8, 25, 30, 43, 44, 45, 46, 52, 55, 56, 58
Region 6 - Western Coastal Swamps and Lagoons	9, 10, 11, 17, 18, 21, 22, 23, 33, 59
Region 7 - Pineland and Southwestern Marl Prairies	2, 3, 4, 5, 6, 7, 13, 16, 18, 25, 29, 30, 31, 32, 42, 45, 46, 52, 53, 55, 56, 58
Region 8 - Taylor Slough	6, 32, 42, 43, 44, 45, 53, 54, 55, 56, 57, 58
Region 9 - Southeastern Marl Prairies	3, 8, 6, 17, 18, 42, 43, 44, 45, 46, 54, 55, 56, 58
Region 10 - Cape Sable	1, 9, 10, 11, 21, 22, 23, 34, 38, 42, 47, 48, 49, 50, 51, 59
Region 11 - Whitewater Bay	1, 9, 10, 11, 21, 22, 23
Region 12 - Eastern Coastal Swamps and Lagoons	9, 10, 6, 11, 20, 21, 22, 23, 32, 33, 34, 37, 38, 47, 48, 49, 50, 51, 59
Region 13 - Gulf Coast Marine	1
Region 14 - Western Florida Bay	1, 11, 17, 20, 23, 59
Region 15 - Central Florida Bay	1, 9, 11, 23, 33, 50, 51, 59
Region 16 - Southern Florida Bay	1, 11, 23
Region 17 - Eastern Florida Bay	1, 9, 11, 20, 21, 23, 33, 50, 51, 59

The third step of this study was performed by the SFCN. They provided an independent QAQC of the final species list of fish in the CESI dataset when compared to the species list provided in NPSpecies. This QAQC was intended to facilitate the process of transferring the CESI dataset to the SFCN to use as their first step toward updating NPSpecies, which was the first objective of this study. The QAQC considered the various attributes describing the species and their populations that are documented in NPSpecies and include nativeness, qualitative abundance, general occurrence or frequency of presence in the park, and threatened and endangered status as listed by the federal and state governments. The QAQC reviewer's recommendations as to which species should not be considered to be in the park and which might be added to the NPSpecies list were incorporated as an

update to the CESI dataset. The QAQC also included whether species in NPSpecies and the CESI dataset were equally identified in terms of the common and scientific names being used.

As a fourth step to this study, a final review was conducted of the SFCN QAQC recommendations, the EVER fish list in NPSpecies, and the most recent park fish list. Decisions were made as to what would remain and what might be changed in the updated CESI species list based on the following criteria:

- If SFCN recommended the species not be considered in the park, it was removed from the dataset.
- If SFCN recommended that the species should be considered at species level only and not variety, the dataset was updated to reflect only species level identification.
- Some species listed in NPSpecies but not in most recent park check list were not added to the CESI dataset. The species in this category are all considered vagrants, occur not more than occasionally, and have only 1 or no observation references listed in the dataset in the NPSpecies dataset. The rationale is to ensure that all species occurrig in the final list are the result of more than one documented observation. This should help to eliminate errors of inclusion, and is conservative when estimating biodiversity.
- EDDMaps was used as the current authority for the occurrence of non-native species in the park. This eliminated some species that are currently in NPSpecies. Use of the EDDmaps.org website is recommended in the future to determine the status of a species as “native” or “non-native”. Species that are native but not residents in EVER are identified as “vagrants” under the NPSpecies field called “NPS Tags” that includes a description of the seasonality of the species occurrence.
- Species listed as having unknown nativeness in NPSpecies are listed as non-native in the CESI dataset if the species appears in EDDmaps.org as non-native. Otherwise, the species is listed as native in the CESI dataset.

Results and Discussion

The EVER NPSpecies dataset includes 425 fish species (NPS, 2014). This list includes 311 native fish species, 18 non-native fish species, and 1 species of fish documented in NPSpecies as having "unknown" nativeness. There are an additional 95 species of fish in NPSpecies that have no information regarding their nativeness. Of these 95 species, 66 are listed as false reports. One species of fish, the smalltooth sawfish (*Pristis pectinata*), is listed as federally endangered.

After the QAQC provided by the SFCN, the CESI dataset includes a total of 372 fish species (Howington, 2015). The dataset includes 360 native fish species and 12 non-native fish species. The CESI dataset includes only the 1 native fish species that is listed as a T&E species, the smalltooth sawfish.

The QAQC provided by the SFCN recommended that the CESI dataset maintain 119 species of marine fish as approved additions to the NPSpecies dataset. The presence of the majority of these species was confirmed in the EVER CREEL survey. The SFCN QAQC recommended the removal of 17 fish species from the CESI dataset that were determined not likely to be found within park boundaries. Examples of the fish that are recommended to be added to and the species recommended to be removed from NPSpecies are provided in Table 3.

Table 3. Selected fish species recommended to be added to NPSpecies and removed from NPSpecies as a result of the SFCN QAQC.

Selected fish species to be added to NPSpecies from the CESI Dataset	Selected fish species to be removed from NPSpecies
Largetooth sawfish (*Pristis perotteti*)	Freshwater drum (*Aplodinotus grunniens*)
Remora (*Remora remora*)	Striped bonito (*Sarda Orientalis*)
Chalk bass (*Serranus tortugarum*)	Rough silverside (*Membras martinica*)
Blackfin snapper (*Lutjanus buccanella*)	Key silverside (*Menidia conchorum*)
American eel (*Anguilla rostrata*)	Pirate perch (*Aphrododerus sayanus*)
Rough triggerfish (*Canthidermis maculata*)	Bridle cardinalfish (*Apogon aurolineatus*)
Yellow jack (*Caranx bartholomaei*)	Barred cardinalfish (*Apogon binotatus*)
Shoal flounder (*Syacium gunteri*)	Conchfish (*Astrapogon stellatus*)

The second review of the QAQC found 43 species that are in NPSpecies, but are not in the CESI dataset. A total of 9 of these species were found in the CREEL survey; however, the CREEL survey is not provided as a reference in NPSpecies. Twenty-two (22) of these species are listed in NPSpecies as false reports. For these reasons, these species are not recommended to be added to the CESI dataset until more verification is provided. These results are provided in Howington (2015).

The species list in the CESI dataset identifies 83 different freshwater and marine fish guilds in EVER (see Table 4). Guilds are defined as grouping of species having similar traits of behavior, such as feeding strategy, or habitat preferences.

Table 4. List of freshwater and marine fish guilds identified in this study. Guilds with one asterisk [*] contain non-native species and those with two asterisks [**] only contain non-native species.

Airbreathing catfish**	Clingfishes	Gars	Molas	Sawfishes	Sunfishes
Anchovies	Clinids	Gobies	Mullets	Sea catfishes	Swordfish
Angelfishes	Cobias	Grunts	Perches	Scorpionfish**	Threadfins
Barracudas	Combthooth blennies	Guitarfishes	Pikes	Silversides	Toadfishes
Batfishes	Conger eels	Hammerhead sharks	Pipefishes	Skates	Triggerfish
Bigeyes	Cusk eels	Herrings*	Pipefishes	Sleepers	Tripletails
Blenny	Damselfishes	Jacks	Porcupinefishes	Snake eels	Trumpetfishes
Bonefishes	Dolphins	Killifishes	Porgies	Snake Eels	Wrasses
Bowfins	Dragonets	Lefteye flounders	Puffers	Snappers	
Boxfishes	Drums	Livebearers*	Remoras	Snooks	
Bullhead catfishes	Eagle rays	Mackerels	Requiem sharks	Soles	
Butterfishes	Electric rays	Mantas	Rivulins	Spadefishes	
Carpet sharks	Flying fishes	Mojarras	Sand stargazers	Stingrays	
Carps and minnows	Freshwater eels*	Morays	Seabasses	Surgeonfishes	
Cichlids*	Frogfishes	Parrotfishes	Searobins	Tarpons	

An average of 195 native, non-T&E fish species is predicted to be found in any one of EVER's physiographic regions (see Figure 2). Seven physiographic regions each include more than 300 species fish species found in EVER including Region 1 – Ten Thousand Islands, Region 10 – Cape Sable, Region 11 – Whitewater Bay, Region 14 – Western Florida Bay, Region 15 – Central Florida Bay, Region 16 – Southern Florida Bay, and Region 17 – Eastern Florida Bay. One explanation for why these regions have the highest number of native fish species relates back to these environments being predominately estuarine environments with mangrove forests and open water. The location of these regions relative to each other may also account for the high number of species. The physiographic regions that contain the highest number of fish species in EVER are where freshwater empties into the estuarine and marine environments of Florida Bay and the Atlantic coast.

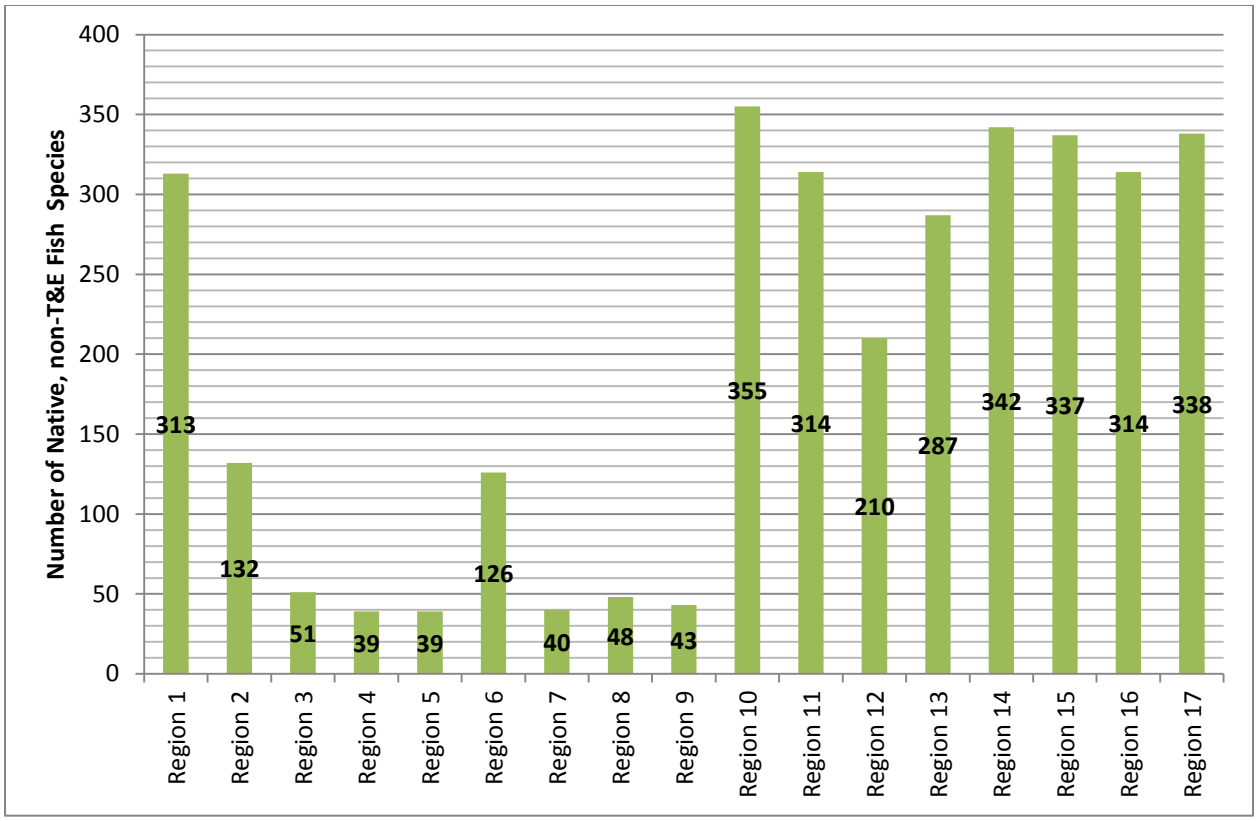

Figure 2. Graph of the total number of native fish species predicted to be found in each physiographic region of EVER.

Estuarine areas are well known as areas of high biological productivity. High productivity in the estuarine areas of EVER has been commonly attributed to the alternating pulse of surface water flowing downstream following the wet and dry seasons of South Florida's climate toward the coast. Many studies have attributed high species richness to climate and high productivity at large scales (Field et al. 2008). It is, however, not well understood how the biodiversity of fish communities responds to changes in floodplains that are irregularly forested with tree islands that may have high species richness and large expanses of flooded grasses such as that of Shark River Slough; however, it is well known that fish tend to thrive where there is plentiful food and constantly moving waters, even if slow flowing.

To better understand general patterns of fish species distributions in EVER, the number of physiographic regions associated with a particular species was analyzed, starting with the subset of native, non-T&E species. The native, non-T&E fish species with the most broad distribution are those that may be found in at least 14 of EVER's physiographic regions. Four species of fish fit this description.

Fish species that are distributed in no more than 3 regions are considered to be those that are most narrowly distributed. There were 12 fish that were found to fit this description. The fish species with the broadest and narrowest distribution are provided in Table 5.

Table 5. Native, non-T&E species with broadest distribution and most narrow distribution across EVER's physiographic regions.

Native non-T&E species with broadest distributions	Native non-T&E species with narrowest distributions
Fat sleeper (*Dormitator maculatus*)	Bigmouth sleeper (*Gobiomorus dormitor*)
Channel catfish (*Ictalurus punctatus*)	Atlantic threadfin (*Polydactylus octonemus*)
Diamond killifish (*Adinia xenica*	Highfin goby (*Gobionellus oceanicus*)
Snook (*Centropomus undecimalis*)	Green goby (*Microgobius thalassinus*)
	Native non-T&E species with narrowest distributions
	Striped anchovy (*Anchoa hepsetus*)
	Hardhead silversides (whitebait) (*Atherinomorus stipes*)
	Silver croaker (Silver perch) (*Bairdiella chrysoura*)
	Largemouth bass (*Micropterus salmoides*)
	Bigeye stargazer (*Dactyloscopus crossotus*)
	Sand stargazer (*Dactyloscopus tridigitatus*)
	Southern stingray (*Dasyatis Americana*)
	Hogfish (*Lachnolaimus maximus*)

The only T&E fish, in the CESI and NPSpecies database, the smalltooth sawfish (*Pristis pectinate*), is associated as potentially occurring in all eleven of EVER's physiographic regions that either have open water, mangrove forests, or both (see Figure 3). It is not assumed that the smalltooth sawfish is found at all times in any of these physiographic regions. There are monitoring projects, including Carlson et al. (2013) and Carlson and Osborne (2012), which analyzed the EVER CREEL survey and found the Smalltooth sawfish predominately in areas with extensive mangrove forests along the western coast, such as the Ten Thousand Islands, and deeper waters of the western areas of Florida Bay.

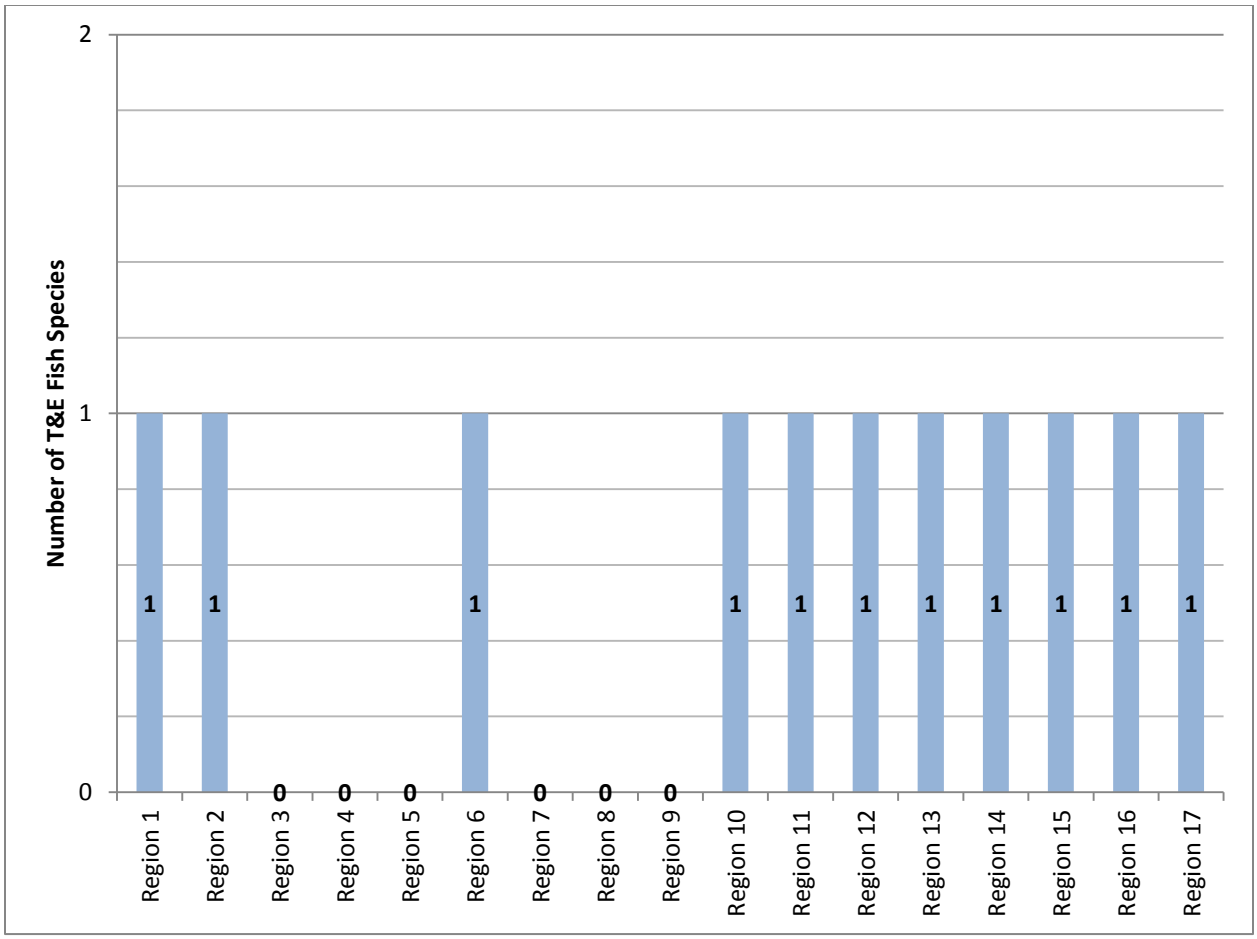

Figure 3. Graph of the total number of T&E fish species predicted to be found in each physiographic region of EVER.

In contrast to having comparatively lower species richness than the physiographic regions with estuarine environments, the regions with the highest number of non-native species are those with mostly freshwater areas (see Figure 4). For example, Regions 2 – Broad and Lostmans River Drainage, Region 3 – Shark River Slough, and Region 8 – Taylor Slough, all have 10 non-native fish. The physiographic regions along the coast or Florida Bay have 4 or fewer non-native fish species.

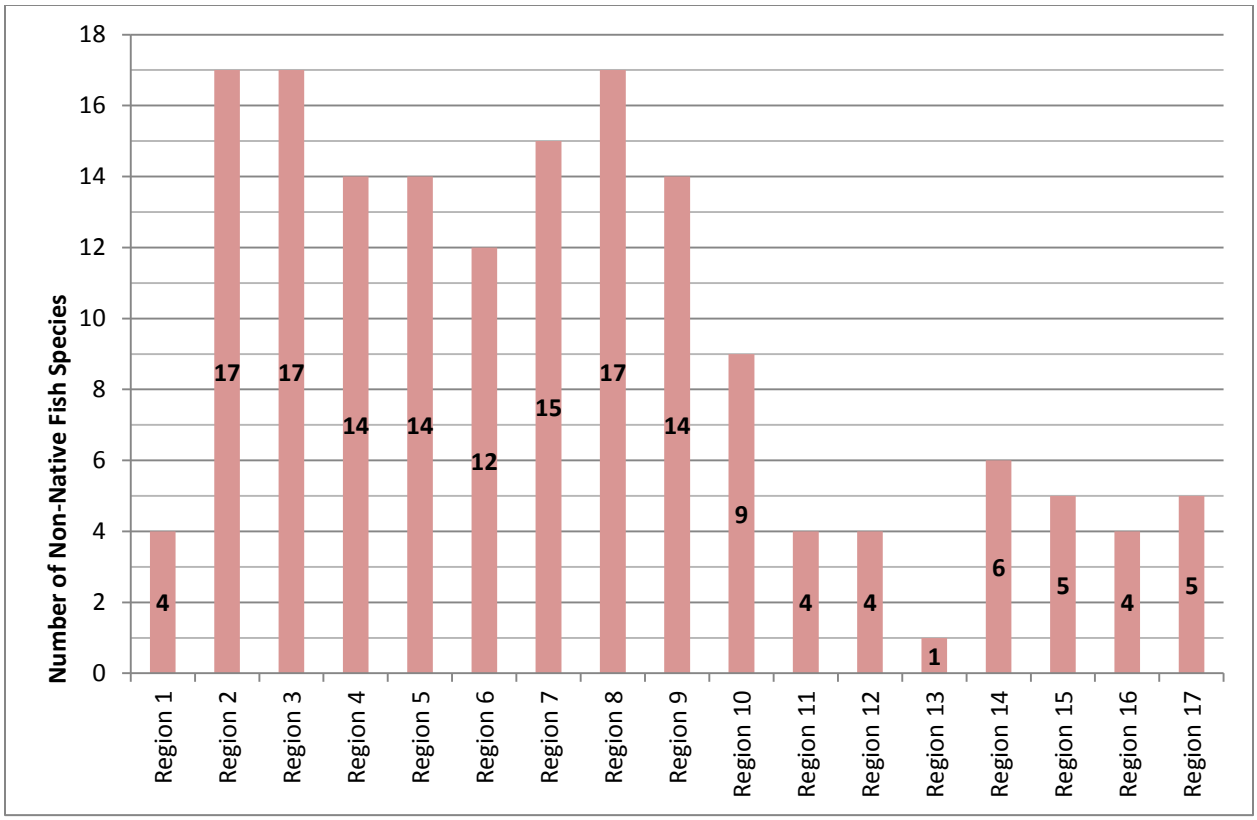

Figure 4. Graph of the total number of non-native fish species predicted to be found in each physiographic region of EVER.

The non-native fish species with the broadest distribution based on habitat preferences are those that may be found in 10-13 physiographic regions of EVER. These species include the following: oscar (*Astronotus ocellatus*), pike killifish (*Beloneso x belizanus*), blue tilapia (*Oreochromis aureus*), threadfin shad (*Dorosoma petenense*), and gizzard shad (*Dorosoma cepedianum*).

The peacock cichlid, also known as the butterfly peacock bass (*Cichla ocellaris*) has potentially the narrowest distribution and may be found in only 6 physiographic regions that includes all those with open saltwater with a seagrass or sandy bottom.

The majority of non-native fish in EVER originated from the urbanized areas in South Florida because the fish were either formerly domesticated and released deliberately or accidently by commercial businesses. EVER has a long-term fish monitoring program that has tracked non-native fish species and performed studies to determined how the non-native fish are entering EVER (Kline and Fratto, 2013; Trexler, 2012). This program contributes important information for natural resource management and regional restoration efforts.

Photo 4. Close up of an Atlantic tarpon (*Megalops atlanticus*) in Florida Bay. Photo courtesy of National Park Service.

Conclusions

The CESI dataset provided here is currently the most updated park-wide species list of fish found in EVER. It is useful as a source of fully-referenced information about native, T&E, and non-native species found in EVER, and associates these species with habitats in EVER as well as with the broader physiographic regions defined in the EVER NRCA.

The CESI dataset is provided for the purposes of creating an updated EVER fish list for NPSpecies. It is recommended that the information on preferred habitats and seasonal occurrence of species be incorporated into NPSpecies as additional data fields. Inclusion of species-habitat associations in NPSpecies can provide a wealth of information for further analysis, from comparison of different taxonomic groups in park habitats, to examination of long-term changes that can occur throughout park landscapes with time.

Additional studies of interest in the future include tracking biodiversity over time in EVER and looking at the ecosystem-wide effects of climate change and regional ecosystem restoration. As the data in NPSpecies is updated using new information such as the data included in this report, these comparative studies become more feasible, providing pertinent information to resource managers about the status of biodiversity in the park.

Photo5. Open water habitat surrounding Duck Key in Florida Bay illustrates expansive habitat available for marine fish. Photo courtesy of National Park Service.

Literature Cited

Carlson, J. K., S. J. B. Gulak, C. A. Simpfendorfer, R. D. Grubbs, J. G. Romine, and G. H. Burgess. 2013. Movement patterns and habitat use of Smalltooth sawfish, Pristis pectinata, determined using pop-up satellite archival tags. Aquatic Conservation: Marine and Freshwater Ecosystems 24: 104-117.

Carlson, J. K. and J. Osborne. 2012. Relative Abundance of smalltooth sawfish (Pristis pectinata) based on The Everglades National Park CREEL Study. NOAA Technical Memorandum NMFS-SEFSC-626.

Ceausu, S., I. Gomes and H. M. Pereira. 2015. Conservation planning for biodiversity and wilderness: A real-world example. Environmental Management 55:1168-1180. DOI 10.1007/s00267-015-0453-9

Early Detection and Distribution Maps (EDDMaps). 2014. Early Detection and Distribution Mapping System. The University of Georgia. Center for Invasive Species and Ecosystem Health. website. Available from https://www.eddmaps.org (accessed: multiple times in 2014).

Field, R., B. A. Hawkins, H. V. Cornell, D. J. Currie, J. Alexandre F. Diniz-Filho, J. Guegan, D. M. Kaufman, J. T. Kerr, G. G. Mittelbach, T. Oberdorff, E. M. O'Brien, and J. R. G. Turner. 2009. Spatial species-richness gradients across scales: a meta-analysis. Journal of Biogeography. 36:(1) 132-147.

Fischer, J. (editor). 2013. Fish identification tools for biodiversity and fisheries assessments: review and guidance for decision-makers. Food and Agriculture Oganization of the United Nations (FAO) Fisheries and Aquaculture Technical Paper No. 585. Rome, FAO. 107 pages.

Florida Fish and Wildlfie Conservation Committee (FFFWC). 2014a. Imperiled Species. Available from http://myfwc.com/imperiledspecies/ (accessed multiple times in 2014).

Florida Fish and Wildlife Conservation Committee (FFWCC). 2014b. Species Profiles: Non-native fish website. Available from http://myfwc.com/wildlifehabitats/nonnatives/freshwaterfish and http://myfwc.com/wildlifehabitats/nonnatives/marinespecies (accessed June 3, 2014).

Florida Fish and Wildlife Conservation Committee (FFWCC). 2014c. Species Profiles: Non-native fish website. Available from http://myfwc.com/wildlifehabitats/nonnatives/marinespecies (accessed June 3, 2014).

Florida Fish and Wildlife Conservation Committee (FFWCC). 2014d. Wildlife and Habitats: Nonnative species. How Do They Get Here? website. Available from http://myfwc.com/wildlifehabitats/nonnatives/how-do-they-get-here (accessed December 16, 2014).

Florida Natural Areas Inventory (FNAI). 2014. Tracking List. Available from http://www.fnai.org/trackinglist.cfm (accessed multiple times in 2014).

Gilbert, R. C. 2002. National Audubon Society Field Guide to Fishes: North America. Knopf Doubleday Publishing Group.

Helfman, Gene S. 2007. Fish Conservation: A Guide to Understanding and Restoring Global Aquatic Biodiversity and Fishery Resources. Island Press. Washington, D.C.

Hiddink, J. G., B. R. MacKenzie, A. Rijnsdorp, N. K. Dulvy, E. E. Nielsen, D. Bekkevold, M. Heino, P. Lorance, H. Ojaveer. 2008. Viewpoint: Importance of fish biodiversity for the management of fisheries and ecosystems. Fisheries Research 90: 6-8. Available online at www.sciencedirect.com.

Hobbs, R. J., D. N. Cole, L. Yung, E. S. Zavaleta, G. H. Aplet, f. S. Chapin III, P. B. Landers, D. J. Parsons, N. L. Stephenson, P. S. White, D. M. Graber, E. S. Higgs, C. I. Millar, J. M. Randall, K. A. Tonnessen, and S. Woodley. 2009. Guiding concepts for park and wilderness stewardship in an era of global environmental change. Frontiers Ecological Environments 8(8):483-490. DOI: 10.1890/090089 (accessed September 23, 2015).

Howington, T. 2008. Final Report: Methodologies and Tools to Support Decision Making. Critical Ecosystems Studies Initiative program funded project (ASS01-8.) Everglades National Park, South Florida Natural Resources Center. Homestead, Florida.

Howington, T. 2015. Biodiversity of EVER Biodiversity of Fish and Habitat Associations in Everglades National Park: an Updated Species List. [data file and metadata]. National Park Service National Park Service Integrated Resource Management System Data Store Available at https://irma.nps.gov/App/Reference/Welcome [distributor].

Kline, J. L. and Z. W. Fratto. 2013. Development of comprehensive fish and macroinvertebrate monitoring programs in Everglades National Park for evaluation of effects of hydrological restoration projects. In-house project of Critical Ecosystems Studies Initiative. Everglades National Park, Homestead, Florida.

Kushlan, J. A. 1972. An ecological study of an alligator pond in the Big Cypress Swamp of southern Florida. Coral Gables, FL: Univ. Miami

Larsen, F. Wugt, J. Bladt, A.Balmford, and C. Rahbek. 2012. Birds as biodiversity surrogates: will supplementing birds with other taxa improve effectivess? Journal of Applied Ecology. 49:349-356.

Loftus, W.F., and Kushlan, J.A., 1987. Freshwater fishes of southern Florida: Bulletin of the Florida State Museum, Biological Sciences. 31(147-344).

Myers, R. L. and J.J. Ewel, Eds. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

National Park Service (NPS). *In press*. A Natural Resource Condition Assessment for Everglades National Park. Natural Resource Report NPS/EVER/NRR—2016/XXX. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2013a. Biodiversity Discovery. NPS/Explore Nature/Biologic Resources website. National Park Service. Available from http://www.nature.nps.gov/biology/biodiversity/biodiversitydiscovery.cfm (accessed January 6, 2014).

National Park Service (NPS). 2013b. Get Involved in Biodiversity Discovery. NPS/Explore Nature/Biologic Resources website. National Park Service. Available from http://www.nature.nps.gov/biology/biodiversity/getinvolved.cfm (accessed January 6, 2014).

National Park Service (NPS). 2014. NPSpecies - The National Park Service Biodiversity Database. IRMA Portal version. Available at https://irma.nps.gov/App/Species/Search (park-species list - evidence counts. (accessed multiple times in 2014).

National Wildlife Federation (NFW). 2014. Invasive Species website. http://www.nwf.org/Wildlife/Threats-to-Wildlife/Invasive-Species.aspx (accessed December 12, 2014).

Osborne, J. K., 2006. The status, protocols, and history of the Marine Fisheries Monitoring Program at Everglades National Park (1958-2005). Report to Everglades National Park submitted for Independent Study Course EVR 5907, Florida International University, Miami, Florida.

Pearlstine, L. G., S. E. Smith, L. A. Brandt, C. R. Allend, W. M. Kitchens and J. Stenberg. 2002. Assessing state-wide biodiversity in the Florida Gap analysis project. Journal of Environmental Management. 66:2 (127-144.)

Selleck, J. 2014. Perspectives on the ATBI. Park Science. 31:1 (50-57).

Smith, C. Lavett. 1997. National Audubon Society Field Guide to Tropical Marine Fishes: Caribbean, Gulf of Mexico, Florida, Bahamas, Bermuda. Knopf Doubleday Publishing Group.

Trexler, J. 2011. Monitoring Fish and Decapod Crustaceans in Everglades National Park. Final Report. Cooperative Agreement H5000060104, Task Agreement P11AT50481/P11AC91149. Modified Waters Delivery program, Everglades National Park, Homestead, Florida.

US Fish and Wildlife Service (USFWS) 1999. South Florida Multi-species Recovery Plan. US Fish and Wildlife Service. Southeast Region. Myers, R.L. and J.J. Ewel, Eds. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

US Fish and Wildlife Service (USFWS). Endangered Species. Available at http://www.fws.gov/endangered/ (accessed multiple times in 2014).

Walker, B. 2002. Conserving biological diversity through ecosystem resilience. Conservation Biology 9(4):747-752. D OI: 10.1046/j.1523-1739.1995.09040747.x (accessed September 23, 2015).

Wetzel, P. 2001. Plant Community Parameter Estimates and Documentation for the Across Trophic Level System Simulation (ATLSS.) Data Report Prepared for the ATLSS Project Team.

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.

NPS 160/130112, October 2015

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov