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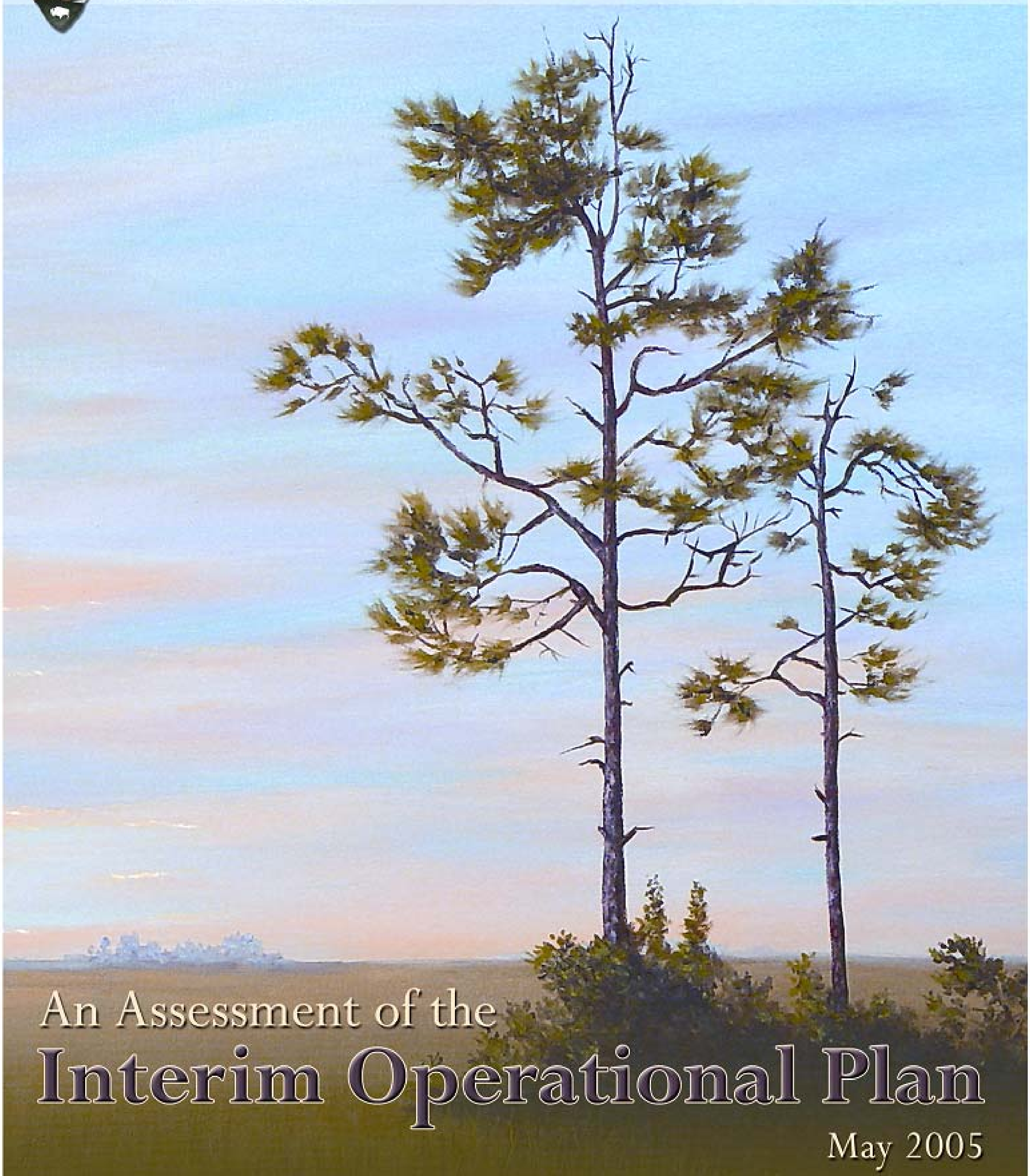

An Assessment of the Interim Operational Plan

May 2005

South Florida Natural Resources Center
Everglades National Park

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List of Abbreviations

BACI- Before After Control Impact

BO- Biological Opinion

CERP- Comprehensive Everglades Restoration Plan

C&SF- Central and Southern Florida Project

CSOP- Combined Structural and Operational Plan

ENP- Everglades National Park

FWS- U.S. Fish and Wildlife Service

IOP- Interim Operational Plan

ISOP- Interim Structural and Operational Plan

MWD- Modified Water Deliveries Project

NESS- Northeast Shark Slough

P- Phosphorous

RPA- Reasonable and Prudent Alternative

SDCS- South Dade Conveyance System

SFWMD- South Florida Water Management District

SFWMM- South Florida Water Management Model

TP- Total phosphorous

USACOE- U.S. Army Corps of Engineers

WCA- Water Conservation Area

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> **"The Committee is concerned about recent efforts to alter significantly the Interim Operational Plan (IOP) for the protection of the Cape Sable Seaside Sparrow. The proposed new plan appears to pose significant threats to the park, in the form of water pollution and disruption of natural water flows, and may compromise the ability to move forward with true restoration. The Committee is concerned that the proposed IOP may not be operated in a way that is consistent with the authorized purposes of the modified water deliveries and C-111 projects. The Committee directs the Everglades National Park to prepare a comprehensive report concerning possible impacts of the proposed IOP on water quality in the park, and the preservation and restoration of natural hydrologic regimes."**
>
> ***House Appropriations Committee Report 107-564, July 11, 2002***

The Interim Operational Plan, or IOP, for water deliveries to Everglades National Park (ENP) is the most recent in a long series of water management plans designed to provide water supply to the park. The specific purpose of this operational plan, however, is to create more favorable hydrological conditions within ENP for the protection of the endangered Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) and its designated critical habitat. Control and manipulation of water deliveries to ENP have been practiced for approximately four decades. Throughout this long period, the often-conflicting needs of the natural environment and the needs of the built environment have complicated decisions regarding water deliveries to the park; often resulting in neither set of needs being fully met. IOP presents a new version of this challenge: how to avoid jeopardizing the existence of a species endemic to a portion of the ecosystem in the short term before restoration of the greater ecosystem can be effected in the longer term.

The operations associated with the IOP, initiated in mid-2002, are anticipated to be in place until completion of all structural features associated with two broader ecosystem restoration projects, the Modified Water Deliveries (MWD) and C-111 Projects. Once these projects have been completed, the operations of the combined project features will be in accordance with a new plan, currently under development. This new plan, referred to as the Combined Structural and Operational Plan (CSOP), is scheduled for implementation in 2006.

This report provides a compilation of the analyses conducted in support of the congressional directive to evaluate the hydrological and ecological effects of IOP. The specific objectives of the document are as follows:

1. Assess the impacts of the IOP structural and operational features on water quality in ENP.

2. Assess the impacts of the IOP structural and operational features on the preservation and restoration of natural ecologic and hydrologic regimes.

3. Recommend any needed modifications to the IOP structural and operational features, including proposed plans for marsh-driven operations, based on hydrological, ecological and water quality analyses. Marsh driven operational criteria would reduce the seepage gradient between ENP and the IOP detention areas, which will reduce the potential for nutrient enrichment.

4. Recommend a monitoring program to assess the long-term impacts of the IOP structural and operational features.

Specific conclusions regarding the operational plan are provided along with recommendations for future improvements. Given the short time period for IOP data collection, for some analyses we lack either the quantity or quality of information needed to draw firm conclusions. For this reason, one of the more important components of this report is the recommendation for continued monitoring and research. It is the opinion of ENP that any operational plan, including IOP and subsequent plans for water deliveries to ENP, can only be properly evaluated with information of sufficient quantity, quality, and duration. These standards must be met in order to assess the impacts in a manner that provides meaningful recommendations for the successful management of this very complex ecosystem.

I. Background

1. Study Area / Physiographic Regions

The subtropical climate of south Florida, with its distinct wet and dry seasons, high rates of evapotranspiration, and extreme events, including floods, droughts and hurricanes, represents a major physical driving force that shapes and sustains the Everglades while creating water supply and flood control challenges in the agricultural and urban segments. South Florida's climate, in combination with low topographic relief, delayed the development of south Florida until the Twentieth Century, motivated the creation of the Central and Southern Florida (C&SF) water management project fifty years ago, and continues to necessitate water management planning today.

Seasonal rainfall patterns in south Florida resemble the wet and dry season patterns of the humid tropics more than the winter and summer patterns of temperate latitudes. South Florida receives on average 53 inches of rain annually, with 75 percent falling during the wet season months of May through October. Wet season rainfall follows a bimodal pattern with peaks during May-June and September-October. Tropical storms and hurricanes provide major contributions to wet season rainfall. Interannual variation in rainfall, ranging from 37 to 106 inches, is high and unpredictable. Both flood and drought years occur frequently. The location of south Florida between temperate and subtropical latitudes, its proximity to the West Indies, the expansive wetland system of the greater Everglades, and the low levels of nutrient inputs under which the Everglades evolved all combine to create a unique and species rich vegetative mosaic. Today nearly all elements of south Florida's native vegetative community have been either altered or eliminated by development, altered hydrology, increased nutrient inputs, and spread of non-natives that have resulted directly or indirectly from a century of water management. This is true even in seemingly remote areas of the remaining Everglades found within the Water Conservation Areas (WCAs) and ENP.

The problems of the Everglades extend to the mangrove estuary and coastal basins of Florida Bay, where the forest mosaics and submerged aquatic vegetation show the effects of diminished freshwater heads and flows upstream. The upland pine and hardwood hammock communities of the Atlantic Coastal Ridge, once interspersed with wet prairies and cypress domes and dissected by "finger glade" water courses that flowed from the Everglades to the coast, remain only in small and isolated patches that have been protected from urban development. The importance of south Florida's vegetation, its unique and diverse composition as well as its critical linkage to the region's fauna, makes its current state of degradation a major concern and its restoration a primary objective in any water management project in this area. In depth vegetative studies have focused on those wetland systems that are the most seriously degraded and that stand to benefit most from restoration efforts. Those systems include the Everglades peatlands, the Everglades marl prairies and Rocky Glades, and the mangrove estuaries and coastal basins of Florida Bay.

For purposes of this report, investigations focused on assessing the hydrologic, water quality, and ecological conditions within five major physiographic regions within the southern Everglades. These regions are WCA-3A and WCA-3B, Shark Slough, Taylor Slough and the Rocky Glades, the Eastern Panhandle, and Florida Bay (Figure 1).

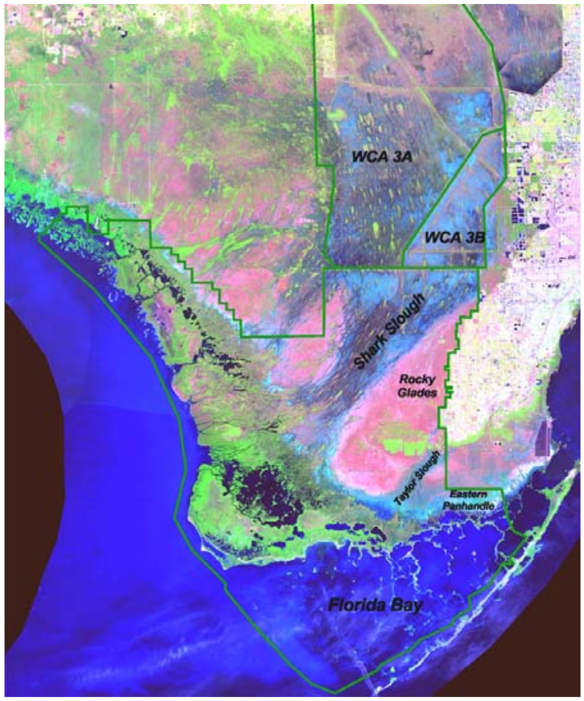

Figure 1. Five major physiographic regions of the south Florida Everglades.

a. Water Conservation Area 3 (WCA-3A and WCA-3B)

Three state and federally managed WCAs serve to provide water to the remaining Everglades and to provide water control functions (water storage, aquifer recharge, and flood control) for the region. WCA-3, the largest of the water conservation areas, covers 915 square miles. WCA-3 was historically linked to the other water conservation areas to the north and ENP, as part of the system of overland flow that extended from Lake Okeechobee to Florida Bay.

The Everglades peatland that remains in the WCAs consists of a mosaic of sawgrass (*Cladium jamaicense*) strands, wet prairies, sloughs, and tree islands that are oriented in the direction of flow patterns in the pre-drainage system. Sawgrass commonly forms monospecific strands throughout these areas. Cattail (*Typha* sp.) has replaced sawgrass in phosphorus (P) enriched areas, and the non-native melaleuca (*Melaleuca quinquenervia*) has invaded sawgrass in peripheral and overdrained areas. A less dense wet prairie community characterized by spikerush (*Eleocharis* spp.), maidencane (*Panicum hemitomon*), and other emergent macrophytes grows at slightly lower elevations than sawgrass. The wet prairie blends into a more open-water floating and aquatic community characterized by white water lily (*Nymphaea odorata*) and bladderwort (*Utricularia* spp.) in the lowest elevation water courses between the sawgrass ridges.

Wet prairies and sloughs support a luxuriant growth of attached algal communities known as periphyton, the important base of aquatic food webs and a diagnostic indicator of water quality and hydrologic conditions in the Everglades. Wet prairies and sloughs also provide habitat for aquatic fauna and for foraging wading birds. Sawgrass is filling in wet prairies and sloughs in much of the remaining Everglades peatlands, probably as a result of lowered water levels. Tree islands dot the landscape in the form of either teardrop-shaped larger islands or round smaller islands. The heads of larger teardrop-shaped islands support swamp forest trees such as red bay (*Persea borbonia*) in the WCAs and tropical hardwood trees such as gumbo limbo (*Bursera simaruba*) in ENP. The tails of the islands often support willow (*Salix caroliniana*) and other more water-tolerant species. The smaller round islands are referred to as battery islands or bay heads and support willows or swamp forest species. Often many hundreds of years old, tree islands provide essential habitat not only for their unique forest plant assemblages but also for vertebrate species that depend upon them, particularly during high water. Tree islands have been destroyed or damaged both by lowered water levels, that have resulted in tree island and underlying soil burnout, and by unnaturally high water levels that have killed the less water tolerant tree species.

b. Shark Slough (West Shark Slough and Northeast Shark Slough)

Shark Slough is the main flow-way within ENP, immediately south and, until recently, contiguous with the wetlands comprising the WCAs. The slough is a broad bedrock depression confined on the east and west by transitional areas of slightly higher elevations and shorter hydroperiods. The vegetative community in Shark Slough is similar to that in the WCAs but represents a more natural state. The slough gently arcs from northeast to southwest as a continuous unit composed of various plant communities well suited to micro-variations within the slough. Within Shark Slough the predominant soils are comprised of Loxahatchee peat and tall sawgrass Everglades peat; deeper water favors Loxahatachee peat formation while shallower depths favor Everglades peat, the former predominates in southern Shark Slough. In areas of Northeast Shark Slough (NESS), formerly a peat-forming environment, marl forms the surface layer (Tropical BioIndustries 1990; Winkler et al. 1996; Loftus, unpubl. data). Reductions of inflows from the north and northeast, the routing of water to the west side of Shark Slough, and the barrier to eastward flows by the L-67 extension canal appear to have produced conditions leading to peat loss. The restoration of hydroperiods and water depths supporting the long-term predominance of slough vegetation (i.e., average annual hydroperiods of 9 months or more and water depths of at least 0.6 m), would promote formation of Loxahatchee peat throughout the main channel of the slough (Tropical BioIndustries 1990; Noble et al. 1996).

c. Taylor Slough and the Rocky Glades

Taylor Slough is a 158 square mile freshwater wetland located within ENP. The slough consists of a relatively narrow, sediment-filled channel that broadens southward, flanked by areas 10-30 cm higher in elevation that are much broader than the slough itself. The headwaters are poorly defined, originating north of the slough in the Rocky Glades, a slightly elevated area west of the Miami Rockridge, a low outcropping of oolitic limestone. Under natural conditions, Taylor Slough regularly channeled water drained off adjacent uplands and marl prairies southward to the mangrove forests along the north shore of Florida Bay. During wet years, additional water flowed from the much larger Shark Slough to the northwest across the slightly elevated Rocky Glades into the northern portions of the Slough. The resultant sheet flow persisted in the early dry season, maintaining high marsh ground-water levels and freshwater flows to northern Florida Bay.

Three vascular plant species are characteristic of the Slough and appear to have some value as indicators of hydrological conditions. Sawgrass is the freshwater marsh species dominant throughout most of the Everglades including large portions of Taylor Slough. It occurs in marshes that range in hydroperiod (annual duration of surface flooding) from two to nine months. Muhly grass (*Muhlenbergia filipes*) is a characteristic species of marl prairies that annually are flooded for approximately one to three months a year but sometimes up to six months (Olmsted et al. 1980). Spike-rush (*Eleocharis cellulosa*) often is found in wet prairies that are annually flooded on average about six to nine months (Gunderson and Loftus 1993; Olmsted and Armentano 1997).

The higher elevation wetlands that flank Taylor Slough support the highly diverse landscape of the marl prairie and Rocky Glades. This mosaic of short stature sawgrass, wet prairie, muhly prairie, and tropical hammock tree islands grows on marl and exposed limestone substrate in areas where the marsh naturally would dry for two to four months during most years. The wet prairie community of the marl prairie and Rocky Glades shares some species with the wet prairies described in Shark Slough, above, for Everglades peatlands, but it grows under drier conditions and includes the most species rich wetland plant assemblage in the Everglades. The wetland communities of the marl prairie and Rocky Glades support a distinct calcareous periphyton mat from which the marl substrate is formed. The muhly prairie community is particularly important as critical habitat for the endangered Cape Sable Seaside Sparrow.

The tree islands found in this landscape support a diverse assemblage of tropical hardwood species mixed with temperate species. Shortened annual duration of flooding in the marl prairie and Rocky Glades landscape presently supports a primarily terrestrial community that is flooded briefly each year rather than a primarily aquatic community that dries briefly each year. Impacts to vegetation include the loss of species richness in wet prairie communities, the conversion of muhly prairie and mixed species prairie to sawgrass, the invasion of woody and non-native trees and shrubs into prairie communities, and tree island burnout. Eastern Panhandle and the Coastal Mangroves

d. Eastern Panhandle

The Eastern panhandle is a flat coastal plain that ascends from sea level to approximately one meter above sea level at the base of the uplands. Soil substrates are mostly marls produced under fresh water conditions, or peats, or some combination of the two (Leighty et al. 1965). The lower half of the eastern panhandle is dissected by ephemeral creeklets, which range in depth from several inches in the upper reaches to several feet near the coast. Much of the variation in vegetation structure, including a profusion of tree islands, appears to be associated with these and smaller local undulations in topography. Water levels at sites in the lower panhandle respond primarily to fluctuations in the adjacent marine waters, while levels in the interior marshes are highly correlated with artificially maintained stages in the C-111 canal (see Section 2 below). Immediately downstream of this area is the mangrove estuary between the freshwater Everglades and Florida Bay. This region supports a mosaic of mangrove forests, tidal creeks, salt marshes, coastal lakes, tropical hardwood hammocks, and Florida Bay coastal basins. Red mangrove (*Rhizophora mangle*) swamp dominates the landscape along with stands of buttonwood (*Conocarpus erectus*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*). Tidal creeks dissect the mangrove forests and are often bordered by salt marsh communities of black rush (*Juncus roemarianus*) and cord grass (*Spartina* spp.). Tropical hardwood hammocks with canopy trees such as West Indian mahogany, Jamaica dogwood (*Piscidia piscipula*), and strangler fig (*Ficus aurea*) grow on elevated coastal embankments. Coastal lakes and basins support seasonally variable beds of submerged aquatic macrophytes that range from low-salinity to marine communities). Reduction in freshwater heads and flows from the Everglades, in concert with sea level rise, has caused community shifts in the submerged aquatic vegetation of the coastal lakes and basins and apparently has contributed to the filling in of tidal creeks. A salinity regime favoring an increased frequency of high salinity events and a decreased frequency of low salinity events in the coastal lakes and basins has resulted in the loss of the low-to-moderate salinity macrophyte communities that seasonal populations of migratory waterfowl once utilized Florida Bay.

e. Florida Bay

Florida Bay is located at the southern tip of the Florida peninsula and covers about 850 square miles, including 700 square miles within ENP. The Bay is relatively shallow with average depths less than three feet. The Bay is bounded by ENP on the north and the Florida Keys on the southeast and includes over 200 small islands or “keys”. The shorelines of most of the keys are vegetated with mangroves and have interior irregularly flooded “flats” with calcareous algal mats. Extensive meadows of seagrass cover the bottom of Florida Bay and together with the Florida Keys, form one of the world’s largest seagrass beds. The meadows are prime habitat for many fish species and for pink shrimp.

Overland surface water flow across marl prairies of the southern Everglades, as well as creeks fed by Taylor Slough and the C-111 canal, provide fresh surface water inflows into northern Florida Bay. Surface water from the Shark Slough system flows into Whitewater Bay and may also move south around Cape Sable to western Florida Bay.

Water discharged from Shark Slough, in the form of direct surface water contributions as well as from groundwater flow also contribute significant quantities of freshwater to the northern portions of central Florida Bay. Water level in the central and eastern Bay is often driven more by wind than tidal forces. Central Florida Bay becomes hypersaline during the late dry season and this physiologically stressful condition becomes more severe (approaching 70 parts per thousand) and widespread in times of drought or reduced freshwater input.

Florida Bay is known as the principal inshore nursery for the offshore Tortugas shrimp fishery and also provides critical habitat for juvenile spiny lobsters, stone crabs, and many important finfish species. The Bay supports numerous protected species including the bottle-nosed dolphin, the American crocodile, the West Indian manatee, and several species of sea turtles.

2. Structural Features for the Delivery of Water to Everglades National Park

Water deliveries to ENP are largely determined by a series of water control structures constructed along the northern and eastern boundaries of the Park. These project features determine the quantity, timing, and distribution of flow to the major drainage basins of the park, Shark Slough, Taylor Slough, and the Eastern Panhandle. All of the current structural components of the C&SF Project, which are used in the management of ENP water deliveries, are depicted in Figure 2. A detailed explanation of the important features for each of the three major drainage basins follows.

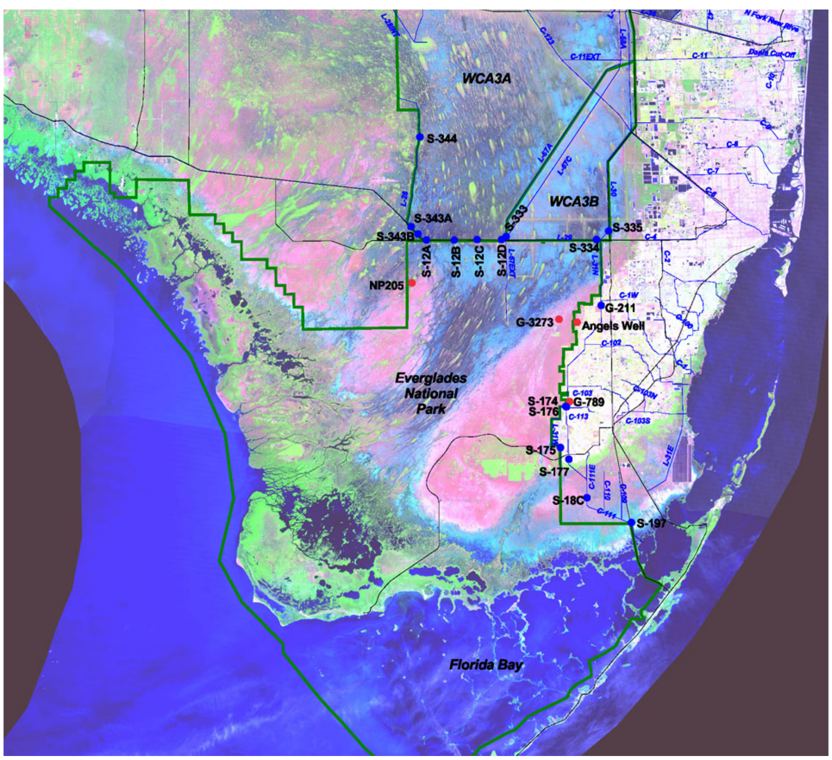

Figure 2. Components of the C&SF Project that affect water deliveries to ENP and some important monitoring sites (red) for controlling deliveries and evaluating potential impacts.

Shark Slough. Much of the surface water delivered to the Shark Slough basin of ENP originates in either WCA-3A or WCA-3B, located immediately north of Tamiami Trail (US 41) and ENP. The WCAs were deliberately created through the construction of the C&SF Project components; the most notable of these features are the L-67A and L-67C canals and associated levees, which were constructed across the natural surface water flow path through the area. This location of L-67A and C was selected to effectively isolate the western half of WCA-3 (WCA-3A) from the highly transmissive eastern half (WCA-3B) in order to be able to contain these waters for water supply purposes for the expanding urban and agricultural development of Miami-Dade and Broward counties. Coupled with these features, four large-capacity structures (S-12 A-D) were constructed in the 1960's under the re-aligned Tamiami Trail to control discharges to the park from WCA-3A. The L-67 extension canal and levee was constructed during the extreme drought of the mid-1960s to assist in the delivery of water from the conservation areas to the park, but the original design purpose was to prevent the flow of surface water from west Shark Slough into NESS, the lands of which were in private ownership at the time and could not be intentionally flooded. The combination of the L-67A canal, L-67 extension, and the S-12 structures resulted in much of the water discharged to Shark Slough being confined to an area referred to as west Shark Slough. These same C&SF features, coupled with the construction of the L-29 and L-30 levees, effectively isolated the wetlands within WCA-3B. As a result the wetlands immediately south of WCA-3B in NESS were largely deprived of significant surface water flow upon completion of these features. The net result of the construction of these C&SF Project features and subsequent operation was to direct large quantities of water into west Shark Slough and relatively little water to NESS.

Several important downstream hydrological monitoring sites within Shark Slough serve important functions in assessing the discharge of water to the basin. As will be detailed in subsequent sections of this report, station NP-205 is currently used to determine the dry season discharges through the S-12 structures for protection of the Cape Sable Seaside Sparrow. In a similar manner, station G-3273 and Angel's Well serve important functions in determining the timing of water releases to NESS through structure S-333 and the protection of the 8.5 Square Mile Area from higher water levels in NESS due to these releases.

Taylor Slough**.** Many of the early features (Figure 3) responsible for the delivery of water to Taylor Slough and the rest of south Miami-Dade County resulted from the modifications to the C&SF Project associated with the construction of the South Dade Conveyance System. The primary purpose of these features was to provide agricultural water supply to south Miami-Dade County and to meet the Congressionally mandated minimum water deliveries to Taylor Slough. To achieve the latter purpose, the L-31W canal was constructed immediately adjacent to the park boundary thereby providing a conduit for delivery of water from the L-31N canal to pump station S-332. This pump station was constructed for the primary purpose of meeting the minimum quantity of water to Taylor Slough as mandated by Congress (see section II. 1. below). Depending on the time of year and prevailing hydrologic conditions, this could require the transfer of water from the regional system down the two major South Dade Conveyance System canals on the east side of the park, the L-31N and C-111 canals.

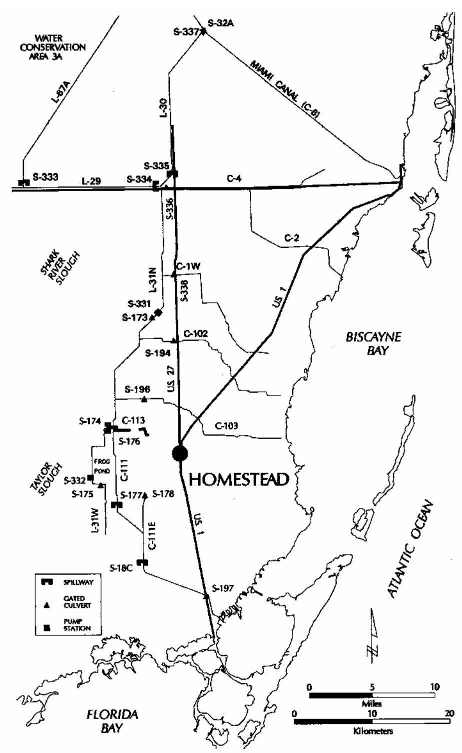

Figure 3. South Dade Conveyance System (reproduced from Davis and Ogden 1994)

Immediately downstream of the S-332 pump station is a gravity flow spillway, S-175, which allows for the discharge of water to the southern portion of the L-31W canal, eventually discharging into central Taylor Slough. These operations were often conducted during flood events and allowed for the rapid routing of water from the northern portions of the basin, effectively "short-circuiting" northern Taylor Slough wetlands in order to remove additional water from the basin.

***Eastern Panhandle*.** Most of the congressionally mandated minimum water deliveries to the eastern panhandle region of ENP are made through a single structure, S-18C. However, the actual quantity of water discharged to the eastern panhandle is dependent on the net discharge in the reach of the C-111 canal between S-18C and S-197. Since S-197 discharges directly into Manatee Bay, the quantity of water actually discharged to the eastern panhandle region is the amount released through S-18C reduced by the amount released from S-197. This net discharge flows from the C-111 canal through over bank flow along the entire reach of the southeast alignment of the C-111 canal immediately north of the park boundary. Upon leaving the canal, these waters flow through the marsh and into tidal creeks of the mangrove communities of the eastern panhandle before ultimately discharging into Northeast Florida Bay.

II. Early Water Delivery Plans for Everglades National Park

1. The Minimum Schedule of Water Deliveries Plan (1970-1983)

In response to the drought conditions of the 1960's, Congress authorized a set minimum allocation of water from the C&SF Project for Shark Slough, as well as Taylor Slough and the Eastern Panhandle drainage basins. This management approach, often referred to as the minimum water delivery schedule, was active from 1970-1983. The minimum allocations were based on average monthly flow volumes from 1939-1960 that existed prior to the construction of the WCAs. However, these minimum volumes were routinely exceeded due to regulatory discharges designed to ensure that water levels in the upstream reservoirs were maintained within the range necessary to meet water supply and flood control requirements. Large regulatory water releases, in great excess of the prescribed minimum, resulted and caused rapid changes in hydrologic conditions within the downstream park and disastrous ecological consequences, including the flooding of eggs within alligator nests and the abandonment of nestlings within wading bird colonies. It should be noted that all of the releases, including the large regulatory discharges, from WCA-3A during this period were in accordance with the prescription for water deliveries to the park in effect during this time. With the construction of the South Dade Conveyance System, the methods of water delivery to ENP evolved into an increasingly more complex set of rules that also served to highlight the increasingly divergent needs of the natural environment and the built environment.

2. The Experimental Program of Water Deliveries to Everglades National Park (1984 -1999)

Since many of the problems associated with the management of water deliveries to ENP reflected the fact that the jurisdictional boundaries of the park were not coincident with the historic drainage patterns in south Florida, Congress authorized the establishment of an experimental water delivery program. Initiated in the early 1980's, the goal of the experimental program was to modify the schedule for delivery of water to ENP and conduct experimental deliveries for the purpose of determining an improved schedule of water deliveries. Much of the ecological and hydrological information existing prior to the program indicated a need to reestablish historic flow patterns within the entire Shark Slough drainage basin. However, much of the historic basin area was located outside and east of the park, referred to as NESS, this area includes lands having undergone agricultural and residential development. In order to reestablish flows within this portion of Shark Slough, several compensatory measures were implemented that allowed for the lowering of the canals east of and adjacent to ENP in order to introduce additional water into NESS. These changes in water management had consequences of their own. The lowering of canals, particularly in the vicinity of Taylor Slough and the Rocky Glades, is thought to have contributed to an alteration of the landscape mosaic through an associated expansion of non-native vegetation and increased fire frequency within this area. Due to extremely porous underlying limestone, lower water levels in the canals adjacent to ENP also lowers water levels throughout the region and may contribute to decreased discharges to the downstream estuary and subsequent increases in Florida Bay salinity.

Throughout the Experimental Program, the U.S. Fish and Wildlife Service (FWS) consulted with the U.S. Army Corps of Engineers (USACOE) on the implementation of each phase of the Program pursuant to the requirements of the Endangered Species Act. One of the primary reasons for the consultation was concern for the endangered Cape Sable Seaside Sparrow. Much of the FWS concern emanated from actual census data collected by ENP from the period 1981 to the present. The results of the monitoring of the species indicate that several sub-populations exist, whose distribution, size, and importance have changed dramatically with time. Bass and Kushlan (1982) described sub-population A in Shark Slough and another, sub-population B, in Taylor Slough. Studies that followed identified a total of six sub-populations (Curnott and Pimm 1993). These corresponded to the original A and B sub-populations described in 1982 and four others (C through F). Pimm (1998) further suggested that three breeding sub-populations are needed to sustain the survival of the endemic species. The range for these sub-populations is depicted in Figure 4.

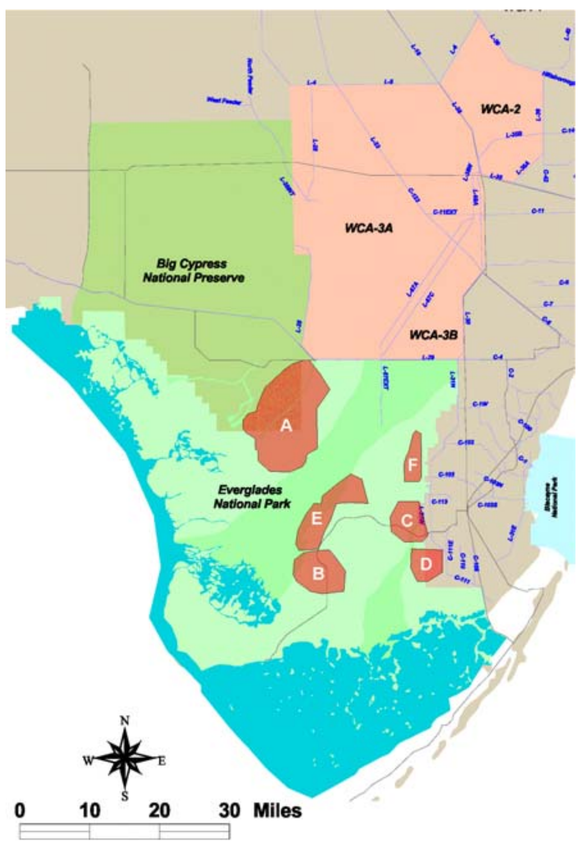

Figure 4. Cape Sable Seaside Sparrow sub-populations.

Based on its review of census data, the FWS became concerned about the impacts of the Experimental Program on the continued existence of the sparrow and its designated critical habitat. The population census data from up to and including 1995 and other available scientific information led the FWS to conclude in its Biological Opinion (BO) of October 27, 1995 that Test Iteration 7 was likely to jeopardize the continued existence of the sparrow. The BO also instructed the USACOE to develop a Remedial Action Plan as part of the Reasonable and Prudent Alternative (RPA) to avoid jeopardy. Due to disagreements on the content of the Remedial Action Plan, consultation was reinitiated in November 1997.

III. Interim Water Delivery Plans

In February 1999 the FWS issued the Final BO for the Modified Water Deliveries Project, the C-111 Project (see sub-sections that follows), and the Experimental Program of water deliveries to ENP. The FWS found that the hydrological impacts associated with the Experimental Program if continued, would likely jeopardize the continued existence of the Cape Sable Seaside Sparrow and adversely modify its critical habitat. In response to a FWS concern of imminent peril in December 1999, the USACOE initiated two plans designated Interim Structural and Operational Plan (ISOP) 2000 and 2001, followed by the Interim Operational Plan (IOP), designed to protect the endangered Cape Sable Seaside Sparrow until completion of the Modified Water Deliveries and C-111 projects, which have been delayed for a variety of reasons.

Both ISOP and IOP were formulated to address specifically the concerns for the Cape Sable Seaside Sparrow as stated in the original and subsequent versions of the FWS BO. The intended purpose of these plans was to implement water management actions consistent with the specific provisions of the RPA to avoid jeopardy to the Cape Sable Seaside Sparrow and not destroy or adversely modify designated critical habitat.

1. The Interim Structural and Operational Plan (ISOP)

ISOP was developed in response to concerns expressed by the USACOE for the potential to aggravate flooding in the East Everglades, particularly the 8.5 Square Mile Area, should the USACOE be required to introduce additional water into the NESS according to the 1999 RPA. To resolve the potential conflicts between the FWS RPA and these concerns, numerous meetings were held in 1999 to discuss RPA implementation. In December 1999, the President's Council on Environmental Quality assembled representatives from the Department of the Interior and the USACOE to facilitate the negotiations on the elements of a water delivery plan agreeable to the participating agencies. This resulted in the development of the first generation of the Interim Structural and Operational Plan or ISOP 2000. This plan was in effect from December 1999 until January 2001 when the plan was replaced with ISOP 2001 that was in effect from January 2001 until July 2002. The ISOP 2001 plan supported the same objectives as ISOP 2000 but attempted to resolve some of the shortcomings of ISOP 2000. The major operational features of the ISOP are depicted in Figure 5.

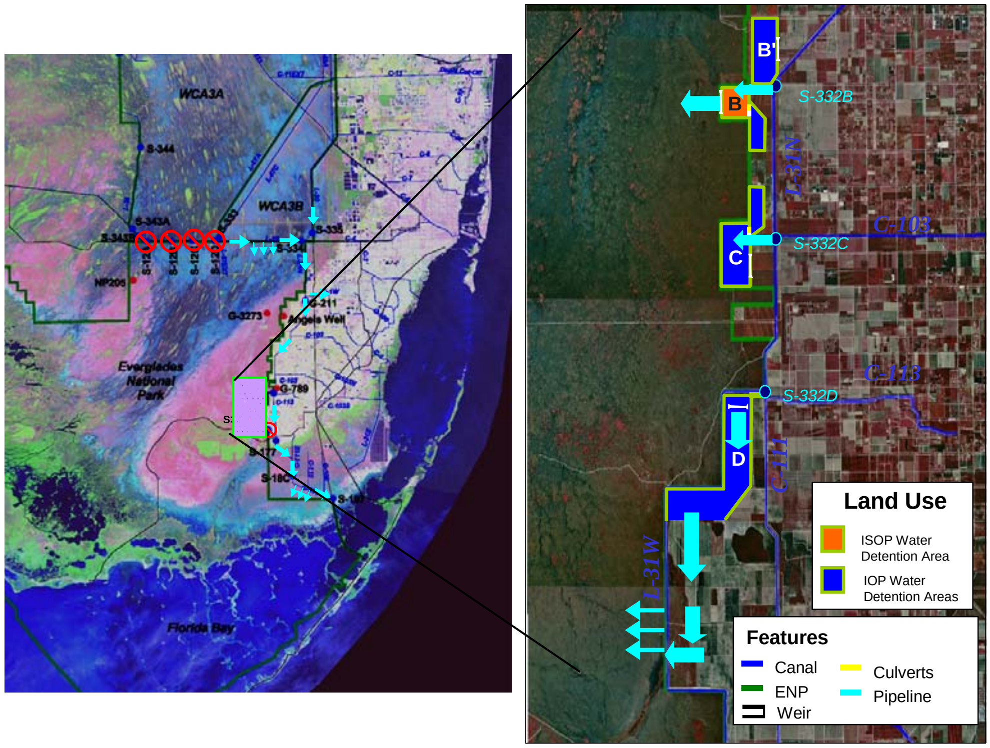

Figure 5. Depiction of the structural and operational components of the ISOP and IOP. The S-332B-C connector detention area has yet to be completed. Problems with the acquisition of the land between the north and south segments prevent complete connection of these two detention areas.

The most fundamental change that occurred in the implementation of ISOP was the institution of limitations on the quantity of water discharged through the S-12 structures. This action allowed for better control of water level conditions in the vicinity of sub-population A of the Cape Sable Seaside Sparrow and thereby created hydrologic conditions more favorable to sparrow nesting success. In addition, ISOP also allowed for the routing of water from WCA-3A through structure S-333 and S-334 and subsequently into south Miami-Dade County through G-211 and S-331 to improve conditions for sub-populations C, D and F. To assist in the management of potentially higher water levels in WCA-3A, the ISOP operations also specified an additional management zone for the regulation of water levels within the conservation area. Referred to as Zone E1, this regulatory zone allowed for the lowering of water levels within WCA-3A to levels 0.5 feet lower than the regulations prior to the implementation of ISOP. Water from WCA-3A was then transferred to south Miami-Dade County through S-333 and S-334 into the L-31N canal. These waters were then subsequently discharged through a new pump station (S-332B) into a newly constructed detention area of the C-111 Project. This detention area is located immediately east of ENP and in the vicinity of sub-population F of the Cape Sable Seaside Sparrow. The S-332B detention area also has a weir located on the west side for discharge of surface water under emergency conditions into ENP, including the sparrow habitat.

The net effect of these ISOP structural and operation modifications was to move water away from western Shark Slough, which was too wet for the sparrow nesting, to regions of the Rocky Glades and Taylor Slough on the east side of ENP, which were too dry for maintenance of sparrow habitat. Collectively, these modifications would meet conditions of the RPA, according to the USACOE.

The ISOP was revised in the March 2000 (Environmental Assessment, USACOE 2000) to include flood control operations and pre-storm operations. The ISOP operations in the March 2000

Environmental Assessment "seek to lower canal levels during the wet season and allow for higher water levels during the dry season. These operations also take into account real-time field conditions as measured in groundwater wells and forecasted storm events" to lower water levels in the L-31N and C-111 canals in order to improve flood protection capability in southern Miami-Dade County. The increased flood protection capability is made possible by pumping additional water from the canals into the new detention area on the east side of ENP. The target water levels in the C-111 Canal were adjusted downward to accommodate the higher levels of flood protection desired as well as the need to effect operations in advance of a major storm event.

2. The Interim Operational Plan (IOP)

The ISOP was discussed and adjusted throughout much of 2001 until the USACOE issued the June 2002 Final Environmental Impact Statement for IOP "to create favorable hydroperiods in sparrow habitat in ENP while providing flood protection capability for developed lands east of the L-31N Canal". The IOP makes use of the ISOP features as well as additional structural features from both the Modified Water Deliveries and C-111 projects and is intended to be only an interim plan that will be replaced with an operational plan for these two projects, upon their completion.

Monitoring of conditions within the sparrow sub-populations within ENP continued and resulted in additional refinements to the plan of operations for the Cape Sable Seaside Sparrow. Through an interagency collaborative process, the following structural and operational components were identified as part of IOP (IOP-Alt 7R), in addition to the continued use of the features constructed as part of ISOP:

- Degradation of the lower four miles of the L-67 extension canal and levee.
- Raising of the western levee of the S-332B detention area to reduce the frequency of surface water flows from the detention cell into ENP. This feature is predicated on the completion of an additional detention area (S-332B north) adjacent to the original ISOP-implemented S-332B west detention area.
- Construction of the temporary S-332C 500 cubic ft/second (cfs) pump station associated with the C-111 Project.
- Construction of four new reservoirs within the C-111 Project area:
    - S-332B north detention area to augment storage capability of the existing ISOP S-332B west detention area.
    - S-332C detention area
    - Connector detention area between the S-332B and S-332C detention areas.
    - S-332D detention area including a high head cell located immediately west of the S-332D pump station to distribute the water discharged from the pump along the full width of the northern portion of this detention area
- Construction of a temporary S-356 pump station to discharge from the L-31N canal into the L-29 canal
- A marsh-driven operational plan, to be implemented through a collaborative interagency process, to address concerns expressed by ENP regarding potential impacts of direct surface water discharges as well as high water levels in the detention areas.

At the time of this writing, four of the above mentioned features of the IOP remain unimplemented: (1) the S-332B detention area weir remains at the original crest elevation, (2) ENP lands have not been exchanged for similar lands from the South Florida Water Management District to complete the direct north-south S332B and C connector, (3) S-356 operations have not been adopted and (4) the marsh-driven operations also remain unimplemented. However, the land exchange legislation is pending in Congress and proposals for the S-356 and marsh-driven operations are undergoing interagency technical review.

Based on USACOE initial assessments of IOP-Alt 7R, the USACOE requested the FWS amend the Final BO of 1999 to include IOP-Alt 7R as a second RPA to address jeopardy to the Cape Sable Seaside Sparrow. In March 2002, the FWS amended the BO stating, “the Service has determined that IOP-Alt 7R represents an additional RPA for water-management actions to avoid jeopardy to the Cape Sable Seaside Sparrow and would not destroy or adversely modify designated critical habitat.” The USACOE subsequently released the Final Environmental Impact Statement in May 2002 identifying IOP-Alt 7R as the recommended plan. The structural and operational features of both the ISOP and IOP are depicted in Figure 5.

IV. Towards Restoration of Everglades National Park: Implementation of the Modified Water Deliveries and C-111 Projects

1. The Modified Water Deliveries Project

While some successes were realized through iterations of the experimental program, it soon became apparent that only limited changes to the water deliveries to ENP were possible when much of the Shark Slough basin was outside the management jurisdiction of the National Park Service. This limitation was acknowledged in 1989 when Congress passed the ENP Protection and Expansion Act. The purpose of the Act was twofold: (1) incorporate the 109,000 acres of NESS into ENP and (2) implement structural modifications to the C&SF Project to restore the natural hydrologic conditions within the park. Congress also authorized the use of information from the experimental program as the basis for the structural and operational features of what would become the Modified Water Deliveries Project.

2. The C-111 Project

In 1994 Congress authorized modifications to the C&SF Project features within the C-111 basin (the C-111 Project) to address problems associated with water deliveries on the east side of the park. The primary purpose of the C-111 Project, according to the 1994 General Reevaluation Report, is restoration of the ecosystem in Taylor Slough and the Eastern Panhandle of ENP while maintaining the level of flood protection existing prior to construction of the features associated with the C-111 Project recommended plan. The concept was to build features in the C-111 canal and adjacent areas to contain the seepage losses from ENP in a manner that would also maintain the level of flood protection prior to the proposed modifications.

3. Restoration Objectives of the Modified Water Deliveries and C-111 Projects

Initial phases of the restoration of ENP will require the implementation of components from both the Modified Water Deliveries and C-111 Projects. The Modified Water Deliveries components are designed to restore the Shark Slough basin while the C-111 Project features are directed towards restoration of the Taylor Slough, Rocky Glades, and Eastern Panhandle regions of ENP. Unfortunately, the implementation of both of these projects has been delayed due to problems of flood control and flood mitigation, land acquisition, as well as design refinements needed to provide the level of performance to produce the conditions which will result in restoration. The current implementation schedules for these projects will not have them both operational until late 2007. Until completion, operations must continue in a manner that is consistent with the restoration intent of these projects while also meeting other project purposes and legal mandates.

Significant restoration is anticipated through the implementation of the MWD and C-111 Projects. The authorized restoration objectives for these projects include the following:

Restoration Objective 1: Improve the timing of water deliveries to ENP; change the schedule of water deliveries so that it fluctuates in consonance with local meteorological conditions, including providing for long term and annual variation in hydrologic conditions in the Everglades.

Restoration Objective 2: Improve the location of water deliveries to ENP; restore WCA 3B and Northeast Shark Slough as a functioning component of the Everglades hydrologic system.

Restoration Objective 3: Improve the quantities of water deliveries to ENP; adjust the volumes of water discharged to ENP to minimize the effects of too much or too little water.

Restoration Objective 4: Restore historic hydrologic conditions in the Taylor Slough, Rocky Glades, and eastern Panhandle of ENP.

Restoration Objective 5: Protect the natural values associated with the Everglades National Park.

Restoration Objective 6: Eliminate the damaging freshwater flows to Manatee Bay/Barnes Sound and increase flows to northeast Florida Bay from the lower C-111.

Restoration Objective 7: Ensure that project waters delivered to ENP, an Outstanding Florida Water (OFW) body, meet all applicable water quality criteria.

While it is not the expectation of the park to meet these objectives through the implementation of the ISOP or IOP, it is expected that the operations be consistent and compatible with the MWD and C-111 Project objectives. For this reason, each of the assessments that follow will evaluate the ISOP/IOP operations based on certain stated expectations. The ability of the ISOP/IOP operations to meet these expectations serves as the basis for the conclusions and recommendations.

V. An Assessment of the Interim Plans

Biologic resources are very sensitive to changes in the physical environments upon which they depend. However, assessing biologic change is not easy, in part because the physical conditions governing biological processes are often complex and poorly understood. Physical modeling approaches are not applicable in such cases. Alternatively, statistical methods are often used to assess change. A Before-After and Control and Impact (BACI) approach is one such statistical method for assessing change and has been proven to be very powerful in detecting even small changes (Stewart-Oaten et al. 1986). At the beginning of the assessment of ISOP/IOP impacts, hydrologists and biologists working on ENP research met to discuss the approach to be used in evaluating IOP impacts. This group determined the parameters to be analyzed and selected the BACI approach as the primary analytic method to be employed in the IOP assessment.

Therefore, the BACI approach was applied to hydrologic and biologic data whenever possible. Some water quality and biological data that were not readily fitted to the BACI approach, due to limited duration and frequency of sampling, were analyzed by alternative statistical approaches. The period of the BACI analysis extends from 1995 to 2002.

1. Physical Environment

The Department of the Interior has been monitoring of the physical environment within and adjacent to lands now comprising Everglades National Park since before the park was authorized. The collection of discharge data under the Tamiami Trail, along the northern boundary of the park, was initiated in 1939 and continues through a collaborative effort of the ENP, the U.S. Geological Survey, the USACOE, and the South Florida Water Management District. Since the initiation of this monitoring, hundreds of additional sites have been added to the network for the collection of hydrological, climatological and water quality parameters. This information has proven vital to understanding the natural resource requirements of the park as well as to establishing the important characteristics needed for its restoration. The assessments of the ISOP/IOP that follow were a result of analyses of data from this extensive network. The purpose of these assessments was to provide a summary of the consequences of the alterations in the management of discharges to ENP as well as to provide complementary information needed to understand how these changes might affect the biological resources of the park.

a. Hydrology

ISOP and IOP will have their most direct and observable effects in the hydrology, and the purpose of ISOP and IOP was to use the C&SF Project structures to manipulate hydrologic responses of groundwater and surface water to rainfall. This is a summary of the major findings, grouped by location.

Rainfall: The study period includes the years 1995 to 2002, where 1996 to 1999 define the Test 7 years while 2000 to 2002 define the ISOP/IOP years. The ENP basin average rainfalls were computed by historical rainfalls measured from 25 gauging stations in and around the park. The annual average rainfall during the study period is about 3% higher than the long-term average, which is about 56 inches, mainly due to higher wet season totals. The ISOP/IOP period is close to the long-term annual ENP average, but rainfall differs by approximately 8 inches annually and by about 6 inches during the dry period. During the study's time period the rainfall totals between ENP and WCA-3 differed, principally in that the wet season totals in WCA-3 were lower than the ENP totals; the most significant variation occurred during 2001 when the difference was 11 inches.

Water Budget Synopsis: Canal water budgets were analyzed to provide insights concerning the response of the managed system to the operational rules and rainfall events. These water budgets were constructed based on controlling flow at major hydrologic structures in the form of total annual flow volumes. The water budgets are summarized as follows; first, there are large changes in the magnitude of the S-12 discharges, as the ISOP/IOP flows appear to be considerably reduced. Another point of interest is S-335, which is the outlet of L-30, the canal along the eastern side of WCA-3B and the western side of the Pennsuco wetlands. Flows appear to increase during ISOP/IOP when compared to prior years, even as rainfall decreases. Similarly, outflow at S-338 appears to increase significantly in the above average ISOP/IOP rainfall years when compared to prior operations. S-331 and G-211 flow volumes are similar in both periods, but do exhibit inter-annual variability. The Test 7 and ISOP/IOP canal water budgets also show a marked difference in the operations around S-332D. S-332 use is minimal since ISOP implementation, and S-176 flows were also significantly reduced. This change of operations led to close scrutiny of marsh impacts in upper Taylor Slough. Although operations affecting upper Taylor Slough appear to be different after ISOP implementation, the structures in C-111 do not appear significantly different in terms of annual flow volumes. S-177 and S-18C flows seem very similar. This was not entirely desirable, as the hope was that modification of S-332D operations would result in more flow down lower Taylor Slough. This suggests that C-111 is capturing a significant amount of S-332D outflow as well as water from Taylor Slough.

i. Water Conservation Area 3A

According to the Environmental Impact Statement (EIS) (USACOE 2002), Water Conservation Area 3A was predicted to increase in depth; this conclusion was a major factor in the "Finding of Significant Impact" in that EIS. This increase was expected because of the periodic closure of the S-12 structures, which release water from Water Conservation Area 3A into ENP.

The analysis of hydrologic data for Conservation Area 3A seems to indicate that the area was likely lower under ISOP/IOP than it would have been under Experimental Water Deliveries operations. The addition of Zone E1 appears to have over compensated for the partial closures of the S-12 structures. Moreover, aggressive releases of flood water from Water Conservation Area 3A during the wet season into the South Dade Conveyance System also had the effect of keeping water levels lower than anticipated.

ii. Water Conservation Area 3B

There is no issue related to the Cape Sable seaside sparrow directly tied to Water Conservation Area 3B. For this reason, the impacts from ISOP/IOP were expected to be small, although the EIS did anticipate the possibility of higher water levels related to increased seepage from Water Conservation Area 3A.

An analysis of the available hydrologic record for Water Conservation Area 3B indicates that operations associated with ISOP/IOP resulted in lower water levels in WCA3B. Gage 3BSE, located in the southeast corner of WCA3B showed the greatest reduction in water levels. This appears to be related to a change in the operational philosophy for S-335 and S-338, and not an explicit and intentional element of ISOP/IOP. The S-335 operations have resulted in undesirable and unintended consequences related to the ability of the C&SF Project to provide dry season water supply.

iii. Central and Western Shark Slough

The primary objective in implementing the ISOP and IOP was to reduce damaging high water levels in the Cape Sable Seaside Sparrow habitat along the western flank of Shark Slough. The purpose was not only to provide an improved opportunity for nesting, which is directly related to water levels during the breeding season, but also to allow the habitat to recover from prolonged unnatural flooding.

According to an analysis of the ISOP/IOP operations, the plan achieved the fundamental goal of reducing water levels in western Shark Slough and Cape Sable Seaside Sparrow habitat. However, because this was accomplished by reducing the total volume of water crossing Tamiami Trail, the result was also significant reductions in water levels and hydroperiods in central and lower Shark Slough.

iv. Northeast Shark Slough

In a restored, functional Everglades, Northeast Shark Slough would receive the major portion of flow, would experience peak water depths exceeding 2 feet, and would dry out only during severe droughts. Although the RPA called for diverting water from western Shark Slough into Northeast Shark Slough, this was deemed impractical under ISOP and IOP, primarily because of the potential effects on the 8.5 Square Mile Area. The expectation in ISOP was that Northeast Shark

Slough would experience no significant changes, and that, with the removal of the lower end of L-67 extension, there was a possibility of some improvements in water levels and hydroperiods in IOP.

In examining the available hydrologic data, there is virtually no change in NESS attributed to ISOP/IOP operations. As was the case prior to ISOP/IOP, NESS receives very little of the wet season water deliveries. Lower water levels recorded during the ISOP/IOP period were likely related to rainfall. The removal of the lower 4 miles of the L-67 Ext. canal and levee was expected to provide some benefit to NESS, however, the existing hydrologic monitoring network is inadequate to determine the effects of the canal/levee removal. The conclusion is that ISOP/IOP impacts were consistent with the expectation, i.e., that ISOP/ IOP would not provide the needed benefits to NESS. Implementation of the Modified Water Deliveries project will be needed to realize any benefits in this important region.

v. The Rocky Glades

The major difference between ISOP and IOP was the construction of additional buffer reservoirs between L-31N and ENP. The expectation was that these reservoirs would compensate for the reduction in L-31N water levels, which had resulted in over drainage and a general decline in habitat quality in the Rocky Glades. These reservoirs would serve was a hydraulic barrier, decreasing seepage losses from ENP, and improving water levels, hydroperiods, and making the response of the wetlands to rainfall more natural.

The analysis of the effects of ISOP/IOP in the Rocky Glades proved very difficult. The network was not adequate to get a complete picture of the response. Moreover, the data smoothing required to look at general trends did not allow for a quantitative investigation of the effects of pre-storm operations. However, the network that was in place was situated to pick up the most likely expected benefits.

The analysis of the available information showed that ISOP/IOP operations did result in a slight increase in water depths and small reduction in seepage losses. It does not appear that the significantly decreased water levels in the lower L-31N canal translated into significant reductions in marsh water levels, as had been the result when canal stages were lowered in the Experimental Water Deliveries Program. That is, the ISOP/IOP structures probably were sufficient to offset reductions in L-31N canal stages, but not sufficient to result in significantly improved water depths and hydroperiods, as anticipated in IOP.

vi. Upper Taylor Slough

In this report, upper Taylor Slough is considered to be the region just west of the Frog Pond, where the C&SF Project has historically delivered water to Taylor Slough. Water deliveries to Taylor Slough underwent significant changes from Test 7 Phase I to ISOP, and again from ISOP to IOP. In IOP, the Corps constructed significant engineering works in the Frog Pond to improve the water deliveries from the new pump station, S-332D. The expectation for IOP was that volume, timing, and distribution of inflows to Taylor Slough would become more natural.

Results of IOP operations in upper Taylor Slough were unique in comparison to the other regions examined in this report. A prior analysis of the ISOP operations indicated that the ISOP resulted in wholly unnatural and very undesirable impacts in upper Taylor Slough. However, IOP appears to have substantially corrected those problems. The new operational scheme and structures represent a significant improvement. More natural wet season recession patterns were observed including a greater spatial extent of surface water during the wet season and a possible decrease in seepage losses. All these suggest that IOP resulted in more natural timing and distribution of inflows to upper Taylor Slough.

vii. Lower Taylor Slough and the Eastern Panhandle

The construction of S-332D made it possible to divert flood discharges drained from the Rocky Glades back into Taylor Slough rather than passing those flows down C-111 and into the Eastern Panhandle of ENP. In both the ISOP and IOP, operations were designed to do exactly this. The expectation was that by putting the flows into Taylor Slough, they would flow down Taylor Slough and enter Florida Bay much further west than if they were routed down C-111. This would also reduce the frequency of direct freshwater discharges into Barnes Sound.

From the analysis of the hydrologic information, it is clear that direct surface water discharges from L-31N into C-111 have been significantly reduced. However, this reduction in surface water discharges has been almost exactly offset by an increase in groundwater seepage into C-111. No significant improvement in flow characteristics into lower C-111 and the Eastern Panhandle was found. In addition, there was no strong evidence of improvements in flow into lower Taylor Slough. Apparently, the significant benefits observed in upper Taylor Slough do not propagate very far downstream. The most likely obstacles are the lower L-31W and Aerojet canals that capture groundwater and surface water and rapidly convey it back towards C-111. Moreover, low wet season operational levels in C-111 result in strong gradients and large seepage rates from Taylor Slough back toward the C-111 canal.

b. Water Quality

Water quality is a major concern in the restoration of the Everglades. Direct impacts (e.g. nutrient loading, and the introduction of contaminants such as heavy metals and pesticide), as well as indirect impacts such as elevated salinity associated with the decreases in freshwater flow all contribute to factors affecting the successful restoration of the ecosystem. Evaluation of the quality of water requires an examination of the physical properties and chemical constituents of both surface and groundwater. The water quality at any given location depends on many interrelated factors. One of the most important factors affecting water quality in the Greater Everglades is the water source. The delivery and routing of water through the canals, pumps and other structures of the C&SF Project to ENP is controlled and regulated. With the changes in the water deliveries imposed by the ISOP/IOP, Congress specifically expressed concern for how the altered water delivery schemes might impact the quality of water delivered to ENP.

Historically, the macronutrient, phosphorous (P) is the water quality variable that has drawn the most attention. This nutrient limits Everglades ecosystem productivity and biomass accumulation. The Everglades ecosystem has developed under extreme low levels of phosphorus. Excessive levels of phosphorus causes anthropogenic eutrophication that is characterized by increased productivity, reduced dissolved oxygen, changes in species composition, and reduced biodiversity. Stormwater discharges from Everglades Agriculture Area and urban areas have elevated levels of TP and when the stormwater is discharged into the Everglades, it impacts the Everglades ecosystems. The severity and extent of these impacts on A.R.M. Loxahatchee National Wildlife Refuge and ENP caused the Federal government to sue the State of Florida in 1988 for not enforcing its water quality laws. The lawsuit was settled in 1991; and the resulting Consent Decree established TP interim and long-term limits for inflows to the Refuge and Park. Numerous sampling sites were established throughout south Florida and the Everglades to monitor TP in rainfall, in the marshes and at water management structures (Figure 6).

ENP expectations of water quality changes during ISOP/IOP include decreases in TP concentrations at the Shark Slough inflow structures (during ISOP/IOP, 4 Stormwater Treatment Areas (STAs) located between the Everglades Agricultural Area and the WCAs began functioning), slight increases of TP concentrations at the L-31N/C-111 structures (historically Shark Slough flows have had higher TP concentrations than L-31N/C-111 flows), uptake of TP in soils of detention areas, and no increases of TP concentrations in surface water, groundwater, and soils of ENP (detention areas remove excess TP before discharging into ENP marshes).

Because of possible ecological impacts changes in TP loads and concentrations at structures and sites located in and around ENP following implementation of ISOP/IOP have been evaluated. A relatively simple statistical procedure was applied to identify monitoring sites where changes in average flows, concentrations, or loads were likely to have occurred following ISOP/IOP implementation in late 1999. The procedure accounted for background variations associated with rainfall. More detailed analyses and interpretations of the results were performed on a regional basis (WCA-3A, Shark Slough, and Taylor Slough/Eastern Panhandle) to further describe the changes and assess the causal linkages to the ISOP/IOP, as opposed to other anthropogenic or natural factors. The performance of the C-111 detention areas is evaluated in terms of TP removal using both the actual data and the Dynamic Model of Stormwater Treatment Areas (Walker and Kadlec 2002). Monitoring of TP concentrations in soil and surface water in ENP marshes is reported.

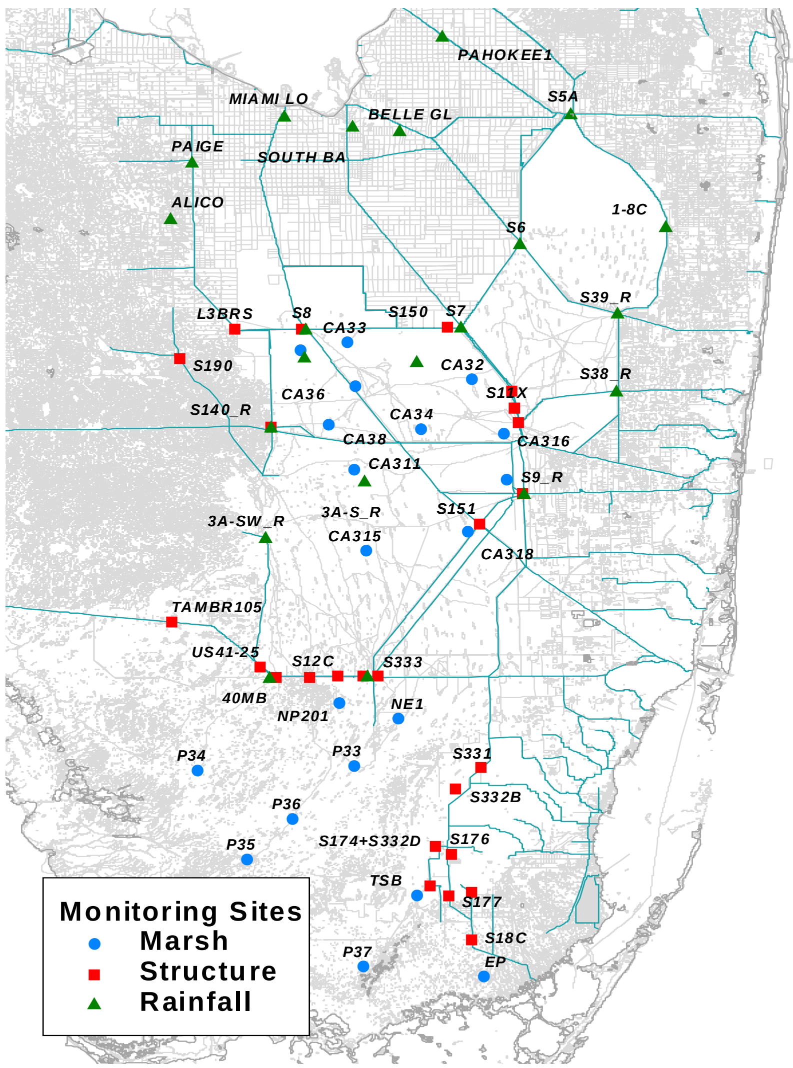

Figure 6. Water quality monitoring sites.

Shifts in mean flow, TP concentration or TP load have been identified by comparing yearly data before and after ISOP/IOP using graphical and statistical techniques. Identifying water quality changes specifically related to IOP/ISOP is difficult in the presence of background variability attributed to variety of natural and anthropogenic factors, as well as to sampling variability. Background variance in structure flows and TP loads is correlated with basin rainfall at most structures. A regression model was used as the screening procedure to test for shifts in the long-term mean between the two time periods in the presence of natural variations associated with rainfall and other random factors. Table 1 summarizes the screening results of this analysis in the three main geographic areas and Figure 7 shows the changes in TP concentration (Pre-ISOP/IOP- 1994 to 1999 vs. ISOP/IOP – 2000 to 2003 in the three geographic areas. The detailed technical analyses can be found in a series of supporting documents listed in Section VII of this report (also available at http://www.sfnrc.ever.nps.gov/iop_data/).

Table 1. Results of the Screening Analysis of flow, TP load and mean TP concentration at inflow structures (see Figure 6, Monitoring sites) by region. pre-ISOP/IOP = 1994-1999 mean,. Increase = ISOP/IOP (2000-2003) mean – pre-IOP mean. % Incr = Increase as percent of pre-ISOP/IOP mean. p = significance level, two-tailed test (light shading/* p < .15 (significant), dark shading/ ** p < .05(very significant)). Values adjusted to average rainfall.

	Flow (kac-ft/yr)					Total P Load (kg/yr)					Mean Concentration (ppb)				
Structure	pre-IOP	Increase	% Incr	p		pre-IOP	Increase	% Incr	p		pre-IOP	Increase	% Incr	p	
WCA-3A Inflows															
S150	52	-11	-23%	0.48		3467	-588	-17%	0.63		56.6	-1.3	-2%	0.90	
S140	124	12	9%	0.50		6034	4730	78%	0.02	**	42.5	28.1	66%	0.06	*
G155	102	-50	-61%	0.03	**	22696	-9085	-40%	0.07	*	183.9	14.1	8%	0.77	
S190	80	11	13%	0.57		11647	217	2%	0.96		112.7	-3.6	-3%	0.86	
S8+G404	347	-23	-7%	0.69		39795	-1086	-3%	0.91		91.9	-3.5	-4%	0.83	
S11X	574	-130	-25%	0.12	*	18443	-5784	-31%	0.02	**	27.9	-6.0	-22%	0.21	
S9	235	32	13%	0.11	*	4091	2885	71%	0.01	**	14.3	7.4	52%	0.03	**
WCA-3A IN	1512	-160	-11%	0.20		106173	-8712	-8%	0.60		56.3	-0.3	-1%	0.97	
ENP Shark River Slough															
S12A	156	-11	-7%	0.78		1190	406	34%	0.24		7.0	2.8	40%	0.01	**
S12B	134	7	5%	0.81		1049	221	21%	0.47		6.6	1.1	17%	0.19	
S12C	281	-21	-8%	0.56		2467	-21	-1%	0.94		7.6	0.7	10%	0.35	
S12D	354	-50	-15%	0.25		3685	17	0%	0.98		9.0	1.8	20%	0.06	*
S12X	925	-76	-8%	0.54		8391	623	7%	0.63		7.9	1.5	19%	0.08	*
S333	166	20	11%	0.72		2345	748	32%	0.43		11.3	2.3	20%	0.02	**
S12X+S333	1090	-56	-5%	0.62		10736	1371	13%	0.39		8.6	1.9	22%	0.02	**
NESRS	157	-15	-10%	0.77		2127	392	18%	0.67		10.8	3.4	31%	0.01	**
SRS_ENP	1081	-91	-9%	0.46		10517	1015	10%	0.54		8.4	2.0	24%	0.02	**
ENP Taylor Slough/Eastern Panhandle															
L31N_IN	63	72	79%	0.01	**	1133	959	85%	0.05	*	13.1	-0.9	-7%	0.71	
S174+S332D	87	51	48%	0.04	**	1027	548	53%	0.31		9.1	-0.2	-2%	0.93	
S332+S175	203	-104	-64%	0.12	*	1858	-947	-51%	0.26		7.2	-0.6	-8%	0.68	
S176	89	-30	-39%	0.11	*	1125	-511	-45%	0.32		9.8	-1.7	-18%	0.58	
S177	131	4	3%	0.86		1140	513	45%	0.25		7.2	2.6	36%	0.20	
S18C	190	-10	-5%	0.69		2616	-691	-26%	0.46		10.5	-2.4	-23%	0.39	
S18C-S197	158	-6	-4%	0.84		1958	-447	-23%	0.60		9.4	-1.8	-20%	0.47	

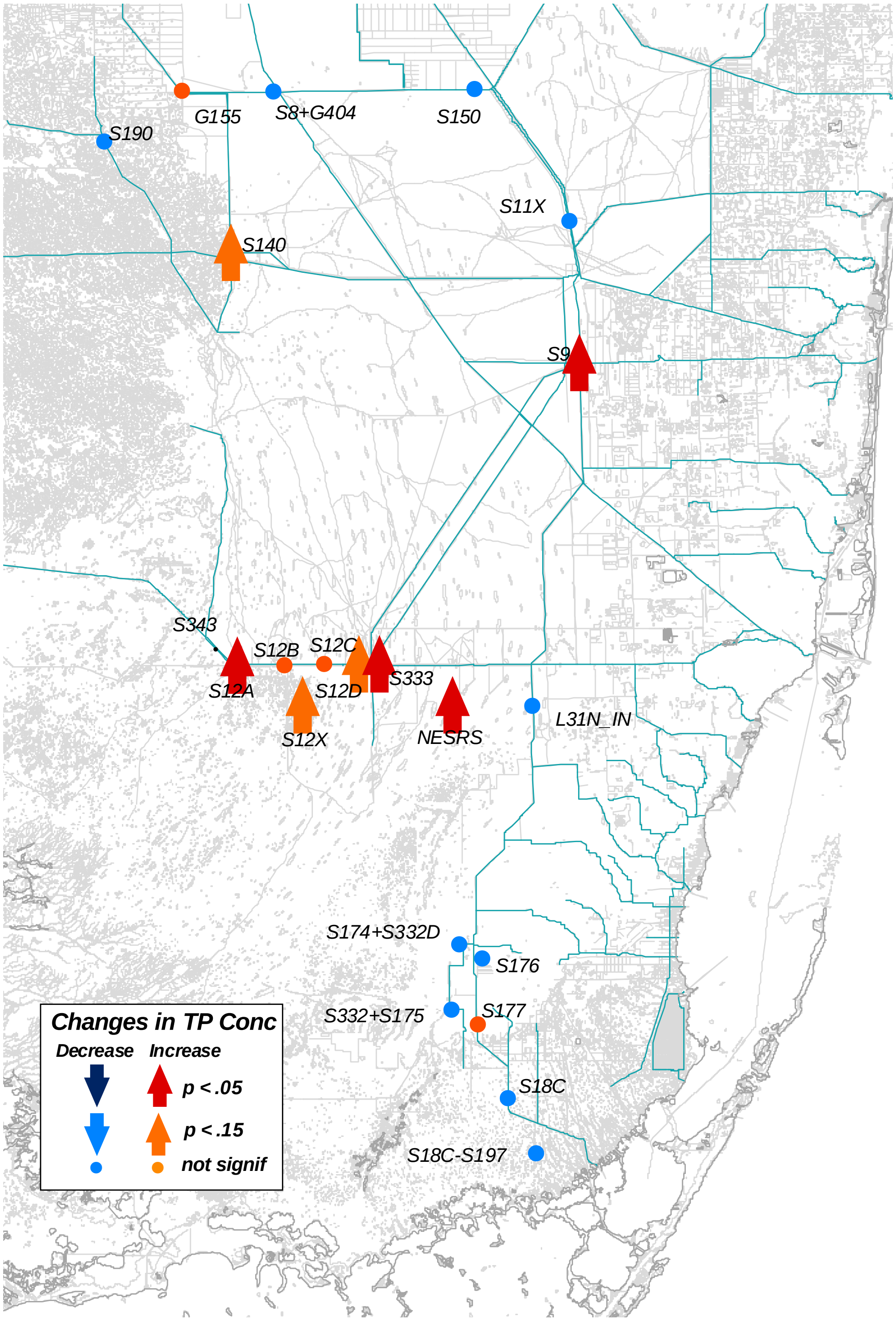

Figure 7. Map of changes in TP concentration. Pre-IOP (1994-1999) vs. IOP (2000-2003) periods. Up arrow = significant increase (red p<0.05, orange p <0.15). Down arrow = significant decrease (dark blue p < .05, light blue p < 0.15). Orange circle = increase, not statistically significant (p > 0.15). Blue circle = decrease, not significant (p > 0.15). p/2 estimates the probability that the actual change was in the opposite direction from that indicated.

i. WCA-3A

This analysis (see Table 1 and Figure 7) identified two significant changes in WCA-3A inflows during the ISOP/IOP time period. First, there were increases in TP concentrations and loads discharged from S-140. S-140 is a SFWMD pump station that discharges partially treated stormwater (STA-5) from the agriculture-dominated basins southwest of Lake Okeechobee. Flows from the L-28 canal and the western L-28 basin are pumped east into WCA-3A at S-140. Apparent increasing trends over the 1994-2003 period are not explained by rainfall or flow. It is unlikely that the trends were related to ISOP/IOP. They maybe related to changes in the drainage basin and/or diversion of L-28 canal inflows to the northwest corner of WCA-3A. Second, there were increases in outflows, TP concentrations, and loads from S-9. S-9 is a SFWMD pump station that discharges untreated stormwater from urbanized central Broward County. Runoff from the C-11 West basin is pumped into eastern WCA-3A at S-9. A portion of the flow is recycled seepage from adjacent WCA-3A and WCA-3B. Apparent increasing trends in TP loads and concentrations are not explained by rainfall or flow, but probably related to urban development in the western C-11 basin.

While apparently unrelated to ISOP/IOP, increases in TP load to the central portion of WCA-3A via S-140 (78%) and S-9 (71%) are of potential water quality concern because these inflows are closest to ENP inflow structures. The lower WCA-3A stages required by ISOP/IOP reduces overland flow of S-140 and S-9 discharges into the marshes of WCA-3A that would remove TP from the water column. This often results in direct discharge of S-140 and S-9 flows into ENP. The percentage of the total load to WCA-3A attributed to these sources increased from 9% in the pre-ISOP/IOP years to 21% in the ISOP/IOP years.

ii. Shark Slough

This analysis found two significant changes due to ISOP/IOP at Shark Slough inflow structures. First, the combined flow-weighted mean concentration at the S-12's and S-333 increased by 1.9 ppb or 22%. There are numerous potential mechanisms for the observed increase in WCA-3A outflow TP concentrations to Shark Slough between 1994-1999 and 2000-2003. First, there were increases in external TP loads to the central portion of WCA-3A via S-9 and S-140. A second mechanism is an increase in TP recycling from marsh soils and vegetation promoted by WCA-3A drawdown under ISOP/IOP. ISOP/IOP changed the WCA-3A regulation schedule (ISOP/IOP Zone E1) by allowing a decrease in water levels of 0.5 feet between February and July, relative to the pre-ISOP/IOP period. Further analysis (referenced in Section VII) of the data showed an inverse relationship between TP concentration and WCA-3A stage at many structure and monitoring sites in WCA-3A and Shark Slough. TP concentrations increase when stage drops below ~9.5 feet at all outflow sites (S-12's, S-333, US41-25), flows under the Tamiami Trail into Big Cypress (TAMBR-105), interior sites in the central and southern portions of WCA-3A (CA311, CA315), and marsh sites in Shark Slough (P-33, P-35, P-36, NE-1, NP-201). Another mechanism is the increase in the proportion of the flow through S-333 vs. S-12's.

The final mechanism responsible for this increase in TP concentrations is the enhancement of TP transport from external sources through WCA-3A as a consequence of drawdown and its associated hydraulic effects. This caused decreases in the residence time required for assimilation of external loads by the WCA-3A marsh and caused increases in the proportion of canal flow vs. marsh sheet flow at low stage, particularly down the Miami Canal and along L-67A canal.

Second, there was a shift in WCA-3A outflows from the S-12 structures to S-333. This shift is a consequence of the diversion of dry season flows away from western Shark Slough through S-333 to NESS and the L-31N/C-111 basin. The overall pattern is consistent with the ISOP/IOP strategy.

iii. Taylor Slough and the Eastern Panhandle

Screening of the L-31N/C-111 data identified no significant changes in TP concentrations after IOP implementation. The following factors and data limitations most of which are less important in or absent from the Shark Slough data, contribute to the variability in the data from this basin and reduce probabilities of detecting changes. The recent data may not adequately reflect long-term water quality conditions likely to result from continuation of the ISOP/IOP, particularly with future evolution of the C-111 Project and potential urban development in the region.

One factor is greater year-to-year variation in flow-weighted-mean TP concentration at L-31N/C-111 structures (CV = 0.25 – 0.45), compared with Shark Slough structures (CV = 0.15 – 0.25). This is partially attributed to lower analytical precision at the lower TP concentration range. Greater variation decreases the probability of detecting change in a dataset of fixed length (Snedecor & Cochran 1989).

A second factor is that adjustments for rainfall generally removed less variance from data at sites in this basin, as compared with sites in Shark Slough and WCA-3A. This may reflect the fact that hydrologic variability in this system is controlled more by seepage, canal stages, and local inflows, as opposed to WCA rainfall. Screening results do not change significantly using rainfall measured at S-18C instead of the WCA/Everglades Agricultural Area basin average.

The 2000-2003 ISOP/IOP period did not include wet years, which would be critical to evaluating long-term water quality impacts of operating the system (via the S-332B, C, and D pumps and lower canal elevations) to provide flood control for areas east of the canals. Wet year data are needed to assess critical conditions and long-term-average loads at S-18C, which is influenced by direct agriculture runoff via the C-111E canal via S-178. While flow data are insufficient to evaluate loading at S-178, geometric mean TP concentrations at this site increased from 21 ppb in the 1994-1999 to 32 ppb in 2000-2003. Unlike most other sites in the ENP region, TP concentrations at S-18C tend to increase at high flows, a pattern typical of sites influenced by runoff (e.g., S-9 or S-8). For example, monthly flow-weighted TP concentrations at the S-12's generally decrease from ~15 ppb at low flows to ~6 ppb at high flows, whereas TP concentrations at S-18C increases from ~6 ppb at low flows to ~20 ppb at high flows. Canal water budgets indicate that under the dry to average rainfall conditions typical of the 2000-2003, flow and TP concentrations at S-18C are likely to be dominated by seepage from ENP and the L-31N/C-111 buffer cells, as opposed to watershed runoff.

Another possible factor is the sampling methodology. With the exception of S-332D, the screening analysis is based extensively upon biweekly grab samples. This type of sampling is generally inadequate for detecting infrequent spikes in TP concentration and loading associated with runoff events and flood-control operations. TP spikes may account for a large fraction of the TP load at a given site. Grab samples may be adequate to measure the TP loads at the S-12's, but continuous flow-weighted composite sampling is needed to measure TP loads at S-18C and other sites in this basin possibly affected by runoff events and flood control operations. A comparison was made of South Florida Water Management District (SFWMD) grab and weekly composite samples at S-332D and S-18C that showed TP levels of composite samples were higher than grab samples during periods when flows are high. Because composite sampling was not initiated at S-18C until 2003 the above screening analysis for S-18C was based exclusively upon grab samples. While it is possible that some of the differences between grabs and composites can be attributed to initial "shake-down" of the automatic sampling devices or other artifacts, there is a significant risk that grab samples under-estimate flow-weighted-mean TP concentrations and loads at these and other structures in the basin.

The final responsible factor is that the initial phases of the C-111 buffer project (including S-332B, S-332C, S-332D, and their associated detention areas, and other components) were not in fullscale operation for the entire 2000-2003 IOP period analyzed. Local inputs to the L-31N/C-111 canals are diluted by seepage losses from ENP (Walker 1997). An increase in TP concentration would be expected when the buffer project is in full operation and seepage losses are reduced; particularly, if the system is operated to provide additional flood control for developed areas east of the canals. Occasional TP spikes (20 to 90 ppb vs. baseline of less than 10 ppb) in the C-102 and C-103 data from 2001-2003 (Anamar Inc. et al. 2003) provide evidence of inputs from eastern developed areas that are inadequately characterized by grab sampling. TP concentrations from these areas will increase with future land use changes and/or system operation to provide additional flood protection (Harper 1994).

iv. Water Quality at C-111 Detention Areas

A review of the operation of the C-111 detention areas in terms of water quality showed little improvement in terms of TP removal. Infiltration rates in the various basins ranged from 75 cm/day at S-332B (Hendron 2000) to 30 – 50 cm/day at the S-332D detention area. These rates are in the expected range for this area. As a result, water detention times in the detention areas are very short, typically less than a day. Water quality modeling was conducted on flow and TP concentration data from the S-332B detention area using the Dynamic Model of Stormwater Treatment Areas (Walker and Kadlec 2002). A good correspondence between model and observed performance was found, with both measured and modeled removal of 25% of the inflow TP load was being discharged as surface overflow, 70% was lost to seepage, and 5% was retained in the system. However, the TP concentration reduction achieved for overland discharges to ENP was less than one ppb, and is forecast to be on the order of 5 – 15% for incoming TP concentrations of 6 – 20 ppb. Because of the high infiltration rates and high hydraulic loadings during pumping events, water residence time was less than 1 day, which is insufficient to allow for significant biological uptake of inflowing TP loads. The direction and rate of TP transport to seepage and affects of antecedent soil TP are generally unknown. Unless specific and predictable removal mechanisms are identified, the detention areas should not be relied upon to provide significant water quality treatment.

v. Everglades National Park Marshes

In upper Taylor Slough marshes during IOP, there were regular events in which TP concentrations exceeded 15 ppb. Furthermore, there were a number of times in late 2003 where the water entering this marsh from L-31W canal via the levee scrape-down area just north of S-332 had TP concentrations above 30 ppb. The nitrogen data are even more dramatic from the upper Taylor Slough marsh site. Total nitrogen concentrations during IOP have nearly always exceeded 700 ppb and at times have exceeded 1.4 ppm. Soil sampling west of the S-332B detention area in ENP found soil TP values under 210 ugP/g dw (12 of 24 sites, Figure 8). However, there was a southwest-northeast pattern of soil TP values above 210 ugP/g dw that begins at the south-central portion of the S-332B detention area weir (Figure 8). This pattern appears to follow the generalized slope of this area and it appears that this is the primary flow path of the discharge from the S-332B detention area overflow weir. Most of the soil TP concentrations in this “flow path” are not markedly higher than the surrounding marsh, however, there are a few that are much higher. This includes a value greater than 330 ugP/g dw at the site closest to the weir (A5) and about 400 ugP/g dw at the site furthest from the weir (D2). The D2 site is a deep, slough-like environment where one would expect high soil TP concentrations. However, the “flow path” of moderately high TP concentrations is not a kriging/statistical artifact because this pattern is supported by soil TP concentrations above 210 ugP/g dw from 10 of the 24 sites. There is evidence of periodic, even regular water quality pulses in ENP wetlands associated with IOP water management. While this was not a chronic problem, there is evidence of water quality problems.

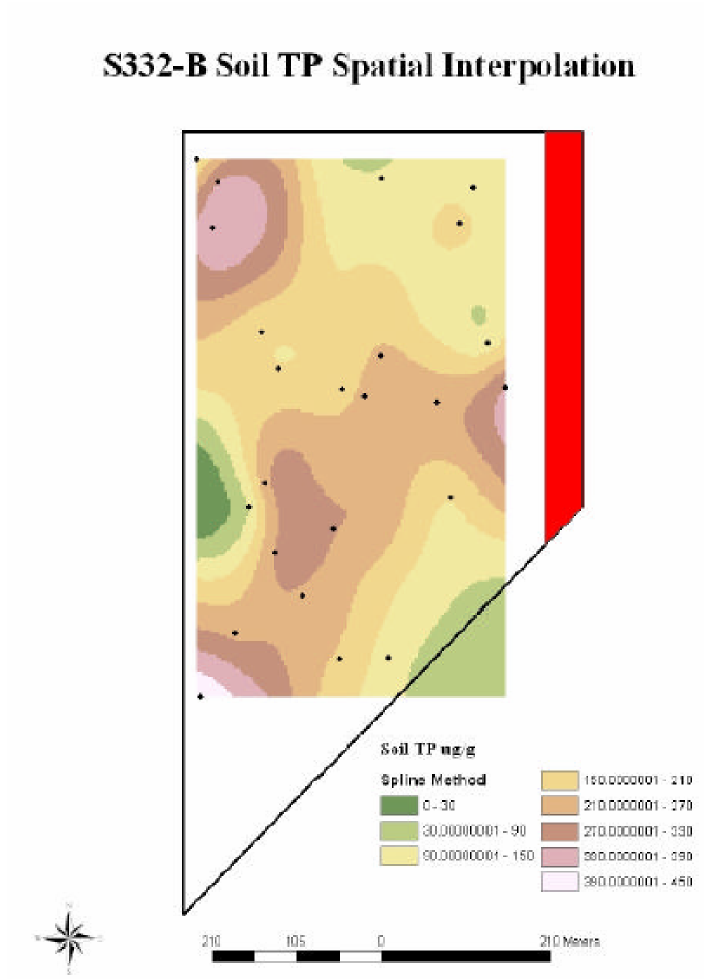

Figure 8. Soil bulk TP content (ug P/g dw) map for the S-332B sampling area. Detention area spillway is immediately east of the No Sample A Zone (shown in red)

In composite samples collected in C-111 marshes since 1998, TP has seldom exceeded 10 ppb, and with the exception of certain events there is some evidence of a 6-year downward trend of TP in the water entering C-111 marshes. Total nitrogen concentrations are considerably lower than Taylor Slough marshes (350 to 420 ppb), and the data show a clear downward trend in total nitrogen concentrations. At this time, there is no evidence of water quality impacts on C-111 wetlands and since these wetlands are well north of ENP wetlands there can be no evidence of IOP water quality problems on Eastern Panhandle wetlands.

vi. Summary

The resulting increases in TP concentration at the Shark Slough inflows as a result of ISOP/IOP were unexpected and are a major concern. Management changes should be made in the WCA-3A regulation schedule and plugs placed in the L-67A canal that will presumably reduce TP concentrations of Shark Slough inflows to ENP. The finding of no increases and low TP concentrations at L-31N/C-111 structures was a positive outcome of ISOP/IOP. However, the observation of pulses of nutrients in the surface waters and high soil TP in ENP marshes is a source of concern. The inability of the detention areas adjacent to ENP to provide significant water quality treatment should be thoroughly evaluated in future operational evaluations.

c. Salinity

Salinity may be affected by changes in water management and may directly impact the function of downstream estuarine systems, making it one of the most important water quality variables to be considered when evaluating operational changes. Increased salinity in Florida Bay or Gulf Coast estuaries as a result of changes in water management is generally considered to run counter to the goals of restoration. The salinity expectations of the CERP, Modified Water Deliveries, and C-111 projects are for decreases in the salinity concentration level and reductions in the occurrence of hyper-salinity conditions for the health of estuarine ecosystem. Both ISOP and IOP were designed to influence the timing and allocation of surface water flowing into the Park across Tamiami Trail from the north and through the L-31W and C-111 canals from the east. Evaluation of ISOP/IOP impacts on salinity regimes in downstream estuaries involved two tasks. The first was to investigate if any changes in salinity could be detected and the second was to test whether the changes were significant after accounting for climate differences. Smith (2003) analyzed ISOP/IOP impacts using historical salinity data and a Before-After-Control-Impact (BACI) approach. Marshall (2003) developed salinity prediction models, using a statistical approach. The latter study tested the models and then used them to investigate change in salinity due to ISOP/IOP implementation based on long-term simulations.

i. Salinity BACI Analyses

ISOP/IOP salinity impacts in ENP estuaries were investigated using historical salinity data measured at 16 stations from November 1995 through October 2002 (Smith 2003). Historical data were used to look for differences in rainfall, flow, and salinity between the Test 7I period (1996-1999) and the ISOP/IOP period (2000-2002). A BACI design with controls for rainfall and wind, climatic factors that can also influence salinity, was then used to detect changes likely to be the result of water management operations. The following conclusions are based on this study:

- ***Rainfall and Freshwater Inflow to Florida Bay***: Annual average ENP rainfalls during the Test 7 Phase I and ISOP/IOP periods are about 63 inches and 55 inches, respectively (Ahn, 2003). An average dry season rainfall during the Test 7 Phase I period (19 inches) is much greater than that during the ISOP/IOP period (13 inches). Yearly as well as seasonal flows from Taylor Slough and C-111 canal were increased during the ISOP/IOP period compared to the Test 7 Phase I periods, but those of S197 were decreased. Monthly flow differences (after minus before ISOP/IOP) from Taylor Slough and the C-111 canal were positive during the wet season (September and October) and early dry season (July-January), and negative during the late wet season (March-June). However, the ISOP/IOP impacts on such changes were not significant when tested with the BACI model. S197 flow differences were negative in June and from September through December but were positive in July and August. No water was released from this structure from January through May during either Test 7 Phase I or ISOP/IOP periods.

- ***Annual and Seasonal Salinity Changes***: Annual and seasonal mean salinity generally increased with the change from Test 7 Phase I to IOP, but most of the changes were not significant. However, the annual change at Canepatch and the wet season changes at Taylor River and Canepatch were significant. Observed differences were small (e.g., Canepatch annual mean was 1.2 ppt higher) and only part of these differences was the result of water management.

- ***Monthly salinity Changes***: Monthly mean salinity decreased at most stations during the early dry season months (November-January), and increased at most stations during the late dry season and early wet season months (February-July). Observed changes varied from station to station during the late wet season months (August –October). However, ISOP/IOP impacts on these changes were not significant in most cases when tested using the MBACI model with rain and wind as control variables. Exceptions are March mean salinity at both Canepatch and Broad River, for which the ISOP/IOP impacts were increased significantly (2.4 and 4.1 ppt, respectively). These increases are due to the reduction in discharges to Shark Slough under ISOP/IOP. March mean salinity at Highway Creek was also significantly higher (4.3 ppt) during the ISOP/IOP period. Any decrease in freshwater delivery to Florida Bay or the Gulf Coast estuaries, and resultant increase in salinity, would be counter to our efforts to restore these systems since the amount of freshwater flowing into the estuaries was greater before the water management system was built.

ii. Salinity Analyses Using Model Simulations

Marshall (2003) developed statistical models that predict daily salinity values using water level data as well as wind and sea level data as independent variables. He used these models to evaluate the long-term ISOP/IOP impact on salinity at eight sites in Florida Bay (Figure 9). The models were developed and validated with the observed salinity data (Figure 10) then used to simulate salinity using marsh water levels from the South Florida Water Management Model (SFWMM) for input. All SFWMM simulations used the same climate conditions, those for the 31-year period from 1965 through 1995. The salinity simulation models used historical wind and sea level data from the same period so that the only difference between model runs was the way water was managed.

Four water management scenarios were run: BS1995 represents regional hydrology under base operation rules as they existed in 1995, NSM (Natural Systems Model) represents regional hydrology under pre-development conditions, and ISOP and IOP represent regional hydrology under ISOP and IOP operation conditions, respectively. This analysis is based on the simulated long-term salinity values based on the simulations of different operation conditions with the same hydro-meteorological condition. This method allows for control of climate changes over a relatively long period and focus on conditions that result only from the management change. Table 2 shows simulated differences in salinity at 8 stations over the 31-year period.

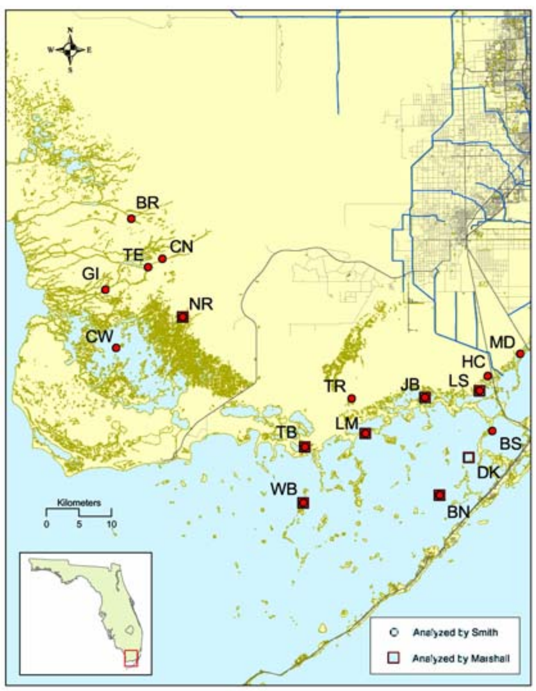

Figure 9. Map showing the location of salinity and water level stations used in the statistical salinity simulation models.

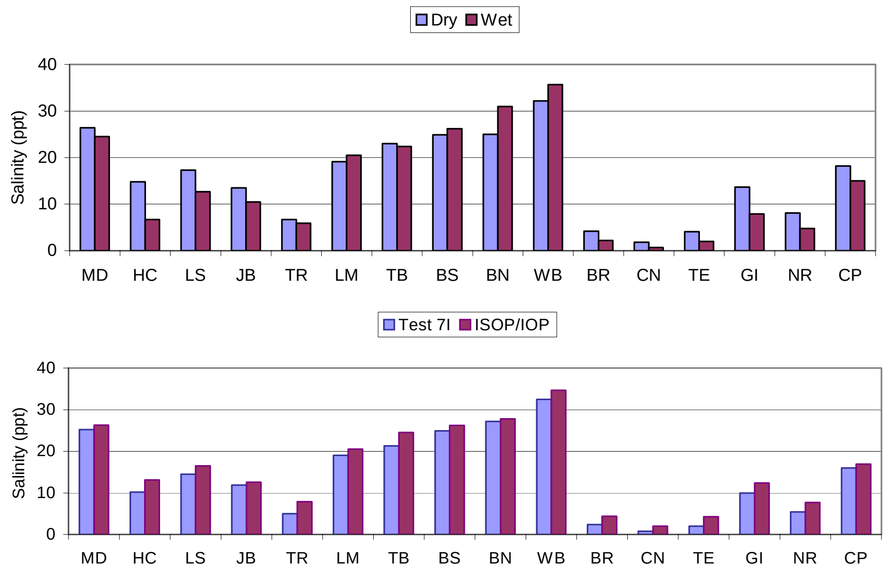

Figure 10. Comparison of historical salinity values: (a) between the wet and dry seasons, and (b) Test 7I and ISOP/IOP periods.

Table 2. Comparison of average daily salinity values (in ppt) produced by statistical models for the indicated operational scenario, where (*) indicates the salinity decrease by IOP.

Run	Joe Bay	Little Madeira	Terrapin Bay	North River	Long Sound	Whipray Basin	Duck Key	Butter-nut Key
BS1995	13.08	20.76	27.19	7.35	19.93	34.89	26.26	28.01
IOP	12.48*	23.45	32.15	9.34	19.07*	37.17	28.26	29.77
ISOP	12.65	23.15	31.32	9.04	19.16	37.13	27.71	29.35
NSM	12.3	19.86	25.61	6.77	19.87	34.16	25.6	27.53

Based on the result of model simulations (Table 2 and others in Marshall, 2003), the following conclusions were made: The ISOP/IOP runs predict higher long-term mean salinity, compared to the result of BS1995 runs, at Little Madeira Bay, Terrapin Bay, North River, Whipray Basin, Duck Key, and Butternut Key. However, the changes are not significant statistically.

ISOP and IOP simulations produce lower salinity in Joe Bay and Long Sound than the BS1995 simulation, although the changes are not significant statistically. In the case of Joe Bay, the effect of ISOP/IOP operations may not be discernable by this type of statistical analysis because of the large variance of the observed and simulated salinity values. Long Sound is relatively isolated from the open waters of Florida Bay, making the salinity prediction different from other sites.

The ISOP/IOP effect is somewhat more pronounced for monthly averages in the dry season. This finding is consistent with the result of the BACI analysis. For all sites except Joe Bay and Long Sound, there are at least four months where the salinity differences between Base95 and ISOP/IOP runs are positive and significant. For Little Madeira Bay and Terrapin Bay the differences are significant for the all months of the dry season. At Whipray Basin, the differences are significant for all dry season months except January, and for the wet season months of July, September, and October. For Duck and Butternut Keys the differences are significant for the dry season months of January through May.

Higher monthly mean salinity is also predicted by ISOP/IOP at some locations in the wet season. Statistically significant increases in salinity values are seen at two near shore stations (Little Madeira Bay and Terrapin Bay) and one open water station (Whipray Basin) during some of the months in the wet season.

The increase in monthly average salinity in the near shore central embayments is transferred to the salinity increase in open water stations of Whipray Basin, Duck Key, and Butternut Key, but the changes are not significant. This finding is also consistent with the result of the salinity BACI analysis. This is not unexpected, as the salinity at the three open water stations is a function of Little Madeira Bay and Terrapin Bay salinities that were increased by IOP.

Salinity was simulated at only one station downstream of Shark Slough, North River. ISOP/IOP was designed to reduce freshwater flow from the S12 structures to western Shark Slough during the dry season. As might be expected, ISOP/IOP runs predicted significantly higher salinity values at North River for the months of October, November, December, and January.

iii. Summary

In summary, the above two studies lead to the following conclusions: Salinity at most monitoring sites in Florida Bay and Gulf Coast estuaries increased slightly during the ISOP/IOP period compared to the Test 7 Phase I period, which is not desirable for the health of the ecosystem in Florida Bay. The increase is not statistically significant in most cases, but annual salinity at Canepatch on the Shark River and March salinity at Canepatch and Broad River were significantly increased. Long term salinity simulations using multivariate regression models predicted higher salinity under ISOP/IOP than under without-IOP at Little Madeira, Terrapin Bay, North River, Whipray Basin, Duck Key, and Butternutt Key, but projections were lower at Joe Bay and Long Sound. However, the differences were not statistically significant.

2. Biological Environment

ENP is the first National Park established solely to preserve biological resources. Key biological resources include ENPs' wading bird populations, endangered avian and mammalian faunas, tropical flora, and extensive wet prairie and sawgrass sloughs. Water management is at the core of sustaining these resources, and is the source of threats to the park's stewardship of these irreplaceable treasures. It is impossible to monitor the impact of water-management operations on all of the critical biota, so key indicators of ecosystem state and function were chosen for assessment of ISOP/IOP. These are aquatic communities indicative of nutrient enrichment and key food web linkages, vegetation dynamics, mangrove wetland food webs linked to Roseate Spoonbills, and the Cape Sable Seaside Sparrow. In sum, these indicators provide information on critical habitats affected by ISOP/IOP in WCA-3A & WCA-3B, Shark Slough and NESS, Rocky Glades and upper Taylor Slough, and in the C-111 and Taylor Slough oligohaline zone.

Our assessments focused on two types of expectations for freshwater communities, nutrient and hydrological impacts. We also tracked non-native species in aquatic habitats.

Nutrient expectations:

- Periphyton TP should not exceed 200 µg/g dry weight of tissues;
- Relative abundance of midge species characteristic of ENP wetlands and known to be sensitive to nutrient enrichment should not decrease, while relative abundance of midges known to be tolerant to nutrient enrichment should not increase.

Hydrology expectations:

- Density of fish and macroinvertebrate species known to be sensitive to drying events should not decrease in non-drought years, while those benefiting by drying events should not increase outside of drought years;

- Catch-per-unit-effort (CPUE) of long-lived fish species should not decrease outside of drought years.

Non-native species expectations:

- The range and abundance of non-native aquatic species, especially fishes, should not be increased in ENP by hydrological operations.

a. Freshwater Communities

i. Nutrient Impacts

Nutrient enrichment resulting from ISOP/IOP water management is of primary concern for the Rocky Glades and the headwaters of Taylor Slough. These relatively short-hydroperiod areas are very oligotrophic and even small additions of TP, if continued over time, could dramatically alter ecological relationships there. Evidence of elevated periphyton TP at S-332B and possibly at S-332D was found (Figure 11). At present, enrichment was limited to the immediate vicinity of input, and the S-332B enrichment may result from groundwater seepage. Midge-indicator taxa also yielded evidence of nutrient impacts in ENP by disappearance of taxa intolerant of enrichment, and increases in taxa associated with enrichment downstream from S-332B (Figure 12) and S-332C (Figure 13). A similar indication of nutrient enrichment was observed downstream from the C-111 canal (Figure 14). These observations could be transient effects of the new structures and adjustments to their management, but also indicate a potential for problems if they continue.

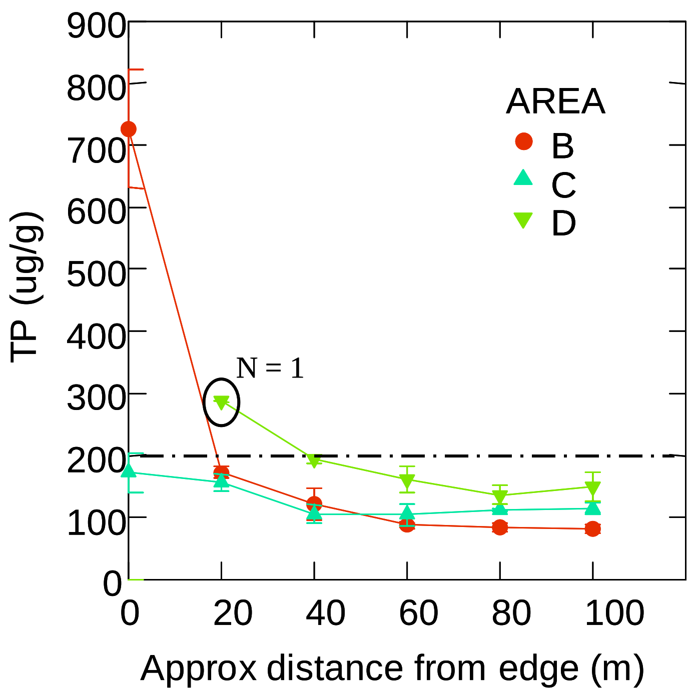

Figure 11. TP from periphyton samples taken along transects from each S-332 detention area or inflow point. Only the 0 to 20m distances at S-332B are different ($P<0.05$). The dashed line indicates a threshold for enrichment. No data were collected at the inflow of water downstream from S-332D because no periphyton was present and N=1 at the 20m site because periphyton was sparse in that area, indicative of nutrient enrichment or high flow.

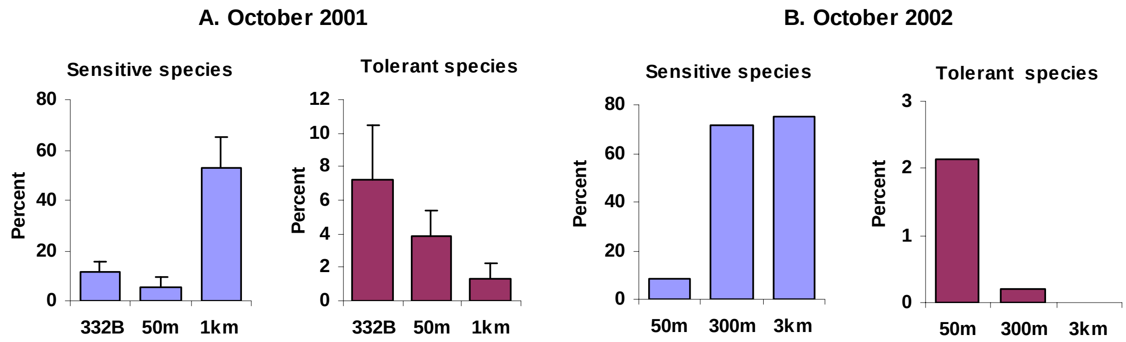

Figure 12. Proportion of nutrient-sensitive and nutrient-tolerant species in midge pupal exuviae samples collected in or near detention area S-332B. A.- October 2001 from S-332B detention area, and from sites 50 m, and 1000 m west of the detention area. B.- October 2002 from *Cladium* sites 50 m, 300 m, and 3 km west of S-332B detention area.

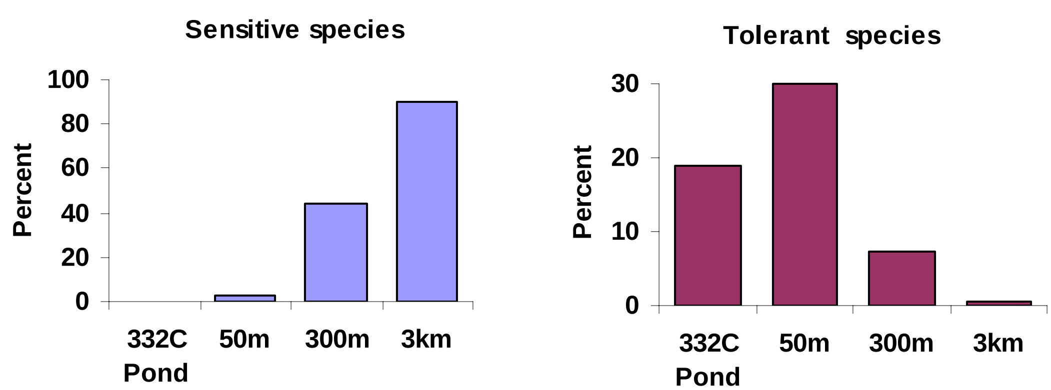

Figure 13. Proportion of nutrient-sensitive and nutrient-tolerant species in midge pupal exuviae samples collected in October 2002 from marshes near the S-332C detention area. Samples from the S-332C detention area, and *Cladium* habitats 50 m, 300 m, and 3 km west of the S-332C detention area.

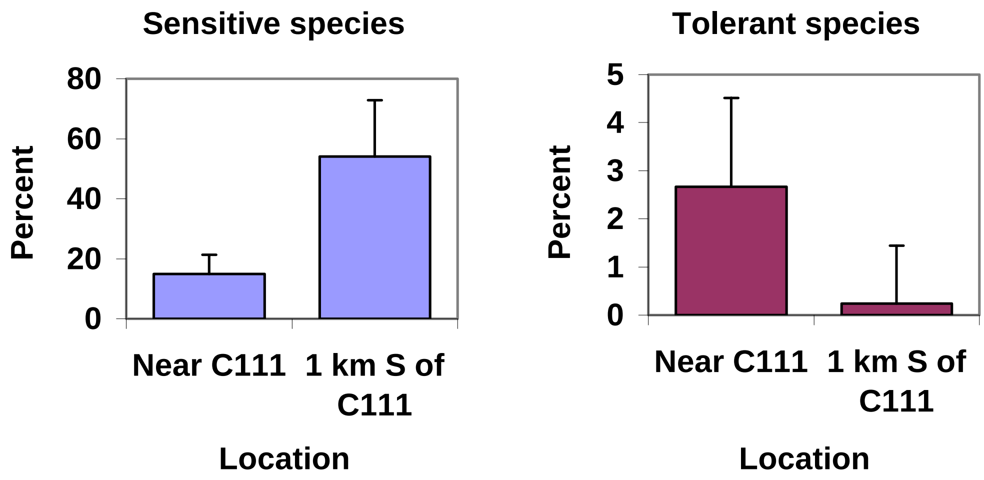

Figure 14. The relative abundances of nutrient-sensitive and nutrient-tolerant midge species in *Cladium* habitats close to, and approximately 1 km downstream from, C-111 canal inflows to Taylor Slough, October 2002.

ii. Hydrological Impacts

An important goal for CERP is to provide longer hydroperiods in Shark and Taylor sloughs. However, many parameters evaluated by BACI analyses indicated drier condition during the ISOP/IOP period. For example, the volume of floating mat (an indicator of periphyton mass) decreased following marsh drying events in Shark Slough and WCA-3A. Grass shrimp and small fishes sensitive to hydrology decreased by 50% or more in the ISOP/IOP years, relative to the preceding four years (Figure 15). A small fish species known to thrive in short-hydroperiod conditions increased in abundance under ISOP/IOP. Large fishes, including game species, decreased in density in WCA-3A and Shark Slough during ISOP/IOP, compared to the preceding years (Table 3). Also, the age structure of a relatively long-lived detritivorous fish shifted to dominance of younger individuals in ISOP/IOP in WCA-3A. These observations suggest pervasive changes in the food web in WCA-3A during ISOP/IOP. These changes cannot be linked explicitly to the operation changes of 2000-2002 because these correspond to drier years than the pre-ISOP/IOP comparison period. Because all study areas had lower dry-season water depths in these years, no benchmark from unaffected sites was available to compare to. However, operations in ISOP/IOP did not result in a lengthening of regional hydroperiods. At least in 2000, this appears to be the result of water management driven by concerns north of Lake Okeechobee, where a severe drought was experienced.

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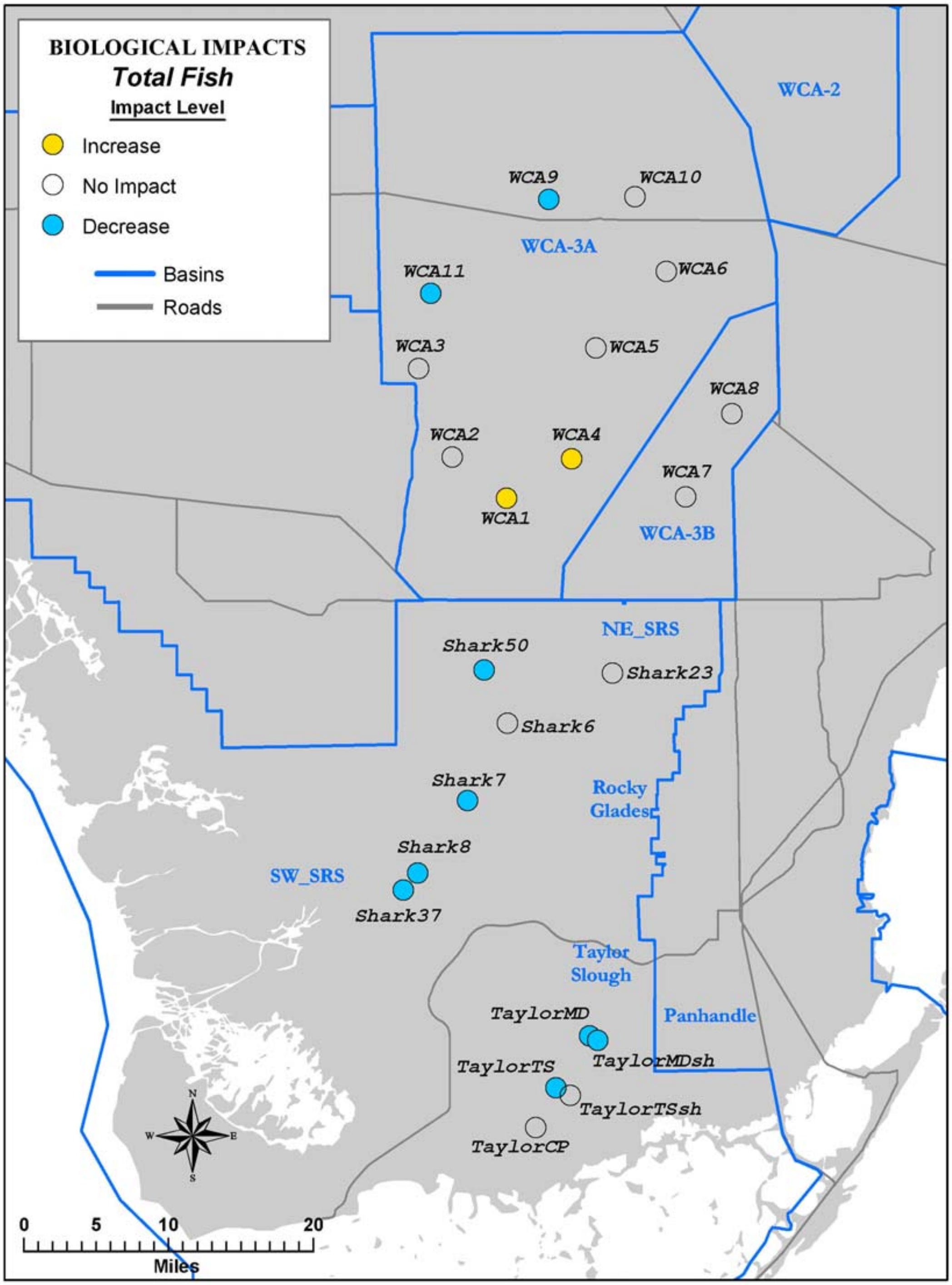


Figure 15. Long-term monitoring sites examined for this assessment. Small fish density decreased at most sites in the ISOP/SOP period compared to the previous four years. Small fish are all species whose maximum size is less than 8 cm; these are the dominant fishes of the Everglades are primary food items of wading bird species, especially smaller species such as snowy egrets. Predatory fish decreased at all sites (see below), possibly influencing the increase of small fish in southern WCA-3A, where predatory fishes were most abundant prior to ISOP/IOP.

Table 3. Summary of BACI tests for effects of ISOP/IOP on big fish in WCA-3A, WCA-3B, Shark Slough, and Taylor Slough. Predatory species are those consuming other fish as a primary diet item and include largemouth bass, gar, and warmouth. The data reported are log-transformed mean number of fish collected in a 5-minute electrofishing transect; Diff is the percentage change of CPUE from Test 7 to ISOP/IOP. Changes indicated as significant (P<0.05) by a Tukey's post-hoc test indicated.

Variable	Region	1996-99 Test 7	2000-02 ISOP/IOP	Diff	P-adj
Predatory Fishes	Shark River Slough	0.435	0.360	-7.6	0.90
	Taylor Slough	0.299	0.197	-9.7	0.8061
	WCA-3	0.790	0.495	-25.7	0.0009
All fish over 8-cm long	Shark River Slough	1.247	0.817	-34.9	0.0002
	Taylor Slough	0.600	0.495	-10.0	0.91
	WCA-3	1.133	0.795	-28.7	0.007

iii. Non-Native Species

IOP construction/operation facilitated both the spread of non-native species into ENP marshes (Table 4) and range expansion of native species atypical for Rocky Glades habitats. The new S-332 structures provide direct access to ENP marshes from L-31W canal. Their completion coincided with first collection of two new species of non-native fish and subsequent range expansion of two others, plus range expansion of two native taxa, into nearby Rocky Glades and Taylor Slough habitats (Figure 16). Also, two new non-native fish species observed in marl prairies downstream from C-111. Fishes were not the only taxa affected. Midge species typical of canals were observed in ENP near S-332B and S-332D overflow, and near C-111 in the eastern panhandle region. This appears linked to the observation that detention areas and canals have high diversity and density of non-native fish and macroinvertebrate taxa and are potential sources for primary and secondary invasions.

Furthermore, the current configuration of the structural components of IOP allows for the introduction of non-native aquatic species into ENP through weirs on detention pond levees located on the eastern park boundary. Non-native fishes, while present, have previously not been particularly abundant in the fresh waters of ENP. These new routes of invasion appear to be permitting entry by species previously absent from the Park, and these species are obtaining locally high abundance. Non-native fish have been shown to decrease the abundance of native fish in estuarine areas of ENP, including alteration of food-webs leading to wading birds in ways that are not predictable and inconsistent with Park management goals. In addition, the presence of non-native species appears to be contradictory to the National Park Service Organic Act (16 U.S.C. l 2 3, and 4) which states the fundamental purpose of the Service 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".

iv. Rocky Glades

Annual minimum groundwater depths in Rocky Glades area were too low during Test 7, and IOP operations failed to improve this situation. Current water-level minima leave few solution holes inundated through the dry season to provide aquatic refuge for animals (Kobza et al. 2004). In addition, pre-storm drawdowns and related operations that increase the recession rate of water appear to result in additional fish mortalities. At times, pre-storm operations prematurely exposed the marsh surface in this area, which was subsequently re-flooded, only to dry again (called a "reversal"). Reversals in the Rocky Glades appear to diminish the fish spawning stock surviving the dry season because each re-flooding event reshuffles fishes among refuges, compounding losses with each event. The dry season corresponds with the winter, the non-breeding season for fishes. Thus, there is a concern that reversals exacerbate existing problems from the diminished availability of dry-season refuges in decreasing the breeding population of adults needed to re-populate the area in spring.

Table 4. Non-native fish species first noted in ENP after opening of S-332 structures, raising water levels, and lowering the berm on L-31W leading to increased flows in to the Park.

Common Name	**Species Name**	**First observed in ENP**	**Notes**
jaguar cichlid	*Cichlasoma managuense*	Aug 2000	First appeared in the canal system in Dade Co. in 1990's
jewel cichlid	*Hemichromis letourneauxi*	Aug 2000	Very abundant in 2003
armored catfish	*Hoplosternum littorale*	Aug 2002	Invaded Dade Co. via canals from east central Florida around 2000
butterfly peacock bass	*Cichla ocellaris*	Nov 2002	Collected in L31W prior to 2002

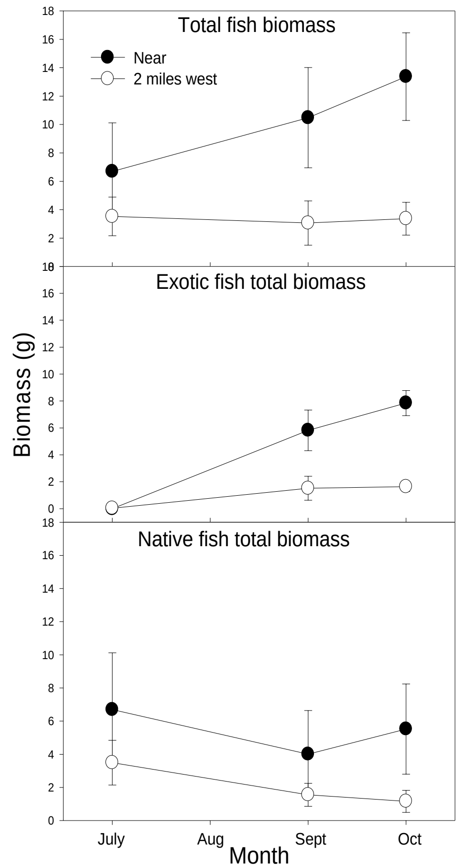


Figure 16. Biomass (g) of all fish, non-native fish, and native fish collected by minnow traps in ENP marshes near S-332D inflow (solid symbols).

v. Summary

Unfortunately, our assessments of expectations for ISOP/IOP provided reason for concern both for potential nutrient enrichment and a deterioration of ecological conditions in Shark River Slough and Taylor Slough.

Nutrient expectations

- Periphyton TP should not exceed 200 µg/g dry weight of tissues;
    - Values in excess of this cut off downstream of S-332C and, possibly, S-332D were observed.

- Relative abundance of midge species characteristic of ENP wetlands and known to be sensitive to nutrient enrichment should not decrease, while relative abundance of midges known to be tolerant to nutrient enrichment should not increase.
    - A decrease of sensitive midges and increase of tolerant ones inside ENP in areas adjacent to S-332B, S-332C, and C-111 berm removal were observed.

Interpretation: These results raise reason for concern about both surface flow and groundwater seepage from new structures and operations in the L-31W and C-111 areas. Further monitoring is needed and responsive actions would be prudent.

Hydrology expectations

- Density of fish and macroinvertebrate species known to be sensitive to drying events should not decrease in non-drought years, while those benefiting by drying events should not increase outside of drought years;
    - Dry-down sensitive fish and macroinvertebrates decreased in density and a dry-down tolerant species increased during ISOP/IOP compared to Test 7 in Shark Slough and Taylor Slough. Similar impacts were noted in western and northern WCA-3A.

- Catch-per-unit-effort (CPUE) of long-lived fish species should not decrease outside of drought years.
    - Large fish generally decreased in CPUE during ISOP/IOP compared to Test 7 in WCA-3A, Shark Slough, and Taylor Slough.

Interpretation: The scale of drying in WCA-3A, Shark Slough, and Taylor Slough observed in 2000 and 2001 was not expected based on Test 7 operations and observed rainfall. This drying led to high mortality of long-lived fishes that require several years to recover population sizes following dry-down events.

Non-native species expectations

- The range and abundance of non-native aquatic species, especially fishes, should not be increased in ENP by hydrological operations.
    - Four species on non-native fishes were observed to expand their range in ENP during ISOP/IOP, two of which were new invasions to the Park at a time corresponding to new water flows in ENP from L-31W at the old S-332 pump station. Expansions were noted in both the Rocky Glades and C-111 areas.

Interpretation: Changes in water delivery to ENP from the L-31W and C-111 appear to have facilitated the movement of non-native fishes into ENP, including to Federally designated Wilderness Areas.

b. Vegetation

Retrospective paleoecological studies and early observers depict the Everglades as a flowing-water system that favored formation of peat in sloughs and of marl in the slightly higher seasonal marshes that flank the sloughs. Patches of forested habitat were found as small inclusions on local elevated sites. Ecosystem restoration goals focus on recreating these conditions where they have been lost and maintaining them where they have persisted in the altered system. For Taylor Slough expectations include a central channel where hydrological conditions favor peat formation and accumulation, and marl formation occurs across the full range of flanking marshlands. Hydroperiods would be long enough to retard the spread of woody species into the more elevated prairies adjacent to the Atlantic Coastal Ridge. Expectations for Shark Slough concern mainly providing hydroperiods and water depths sufficient to support white water lily peat formation in sloughs and Everglades peat and Gandy peat in tall sawgrass strands and wet tree islands, respectively, without compromising water quality.

i. Taylor Slough Marsh

Aerial photograph of Taylor slough depicting the main flow way and adjacent shorter hydroperiod prairies. As part of the C111 Project, this area acquired increased capacity to convey water thanks to a newly constructed set of bridges.

The freshwater marsh communities in ENP and Big Cypress National Preserve are critical components in the biodiversity of the Everglades, both for the structure they provide in support of other biotic elements, and for the intrinsic values of their constituent plant species assemblages. To examine the changes in the marsh vegetation associated with the ISOP and IOP management periods, temporal and spatial co-variation of vegetation and hydrology in seasonally flooded marshes was analyzed, focusing specifically on the upper reaches of Taylor Slough during the period 1979-2003.

Vegetation data were collected along five line transects (Figure 17) of *ca* 2-km length: two representing the headwaters of Taylor Slough (Transects 4 and 5), two in Upper Taylor Slough (Transects 1 and 2), and one in middle Taylor Slough (Transect 3). The three lower transects were established 1979 and were resampled in 1992 (Transect 2), 1995 (Transects 1 and 2), and 1996 (Transect 3). Transects 4 and 5 were established and sampled in 1997, and all five transects were resampled in 1999 and 2003. In 1979, half of the plots established along Transects 1-3 were subjectively located in *Cladium jamaicense* (sawgrass) stands (C-plots) intersected by the lines, and half were in *Muhlenbergia filipes* (muhly) stands (M-plots). In contrast to Transects 1-3, the plots established in Transects 4 and 5 in 1997 were selected not on the basis of existing cover types, but rather at 100-meter intervals along the transect, adjusting distances where necessary to avoid tree islands.

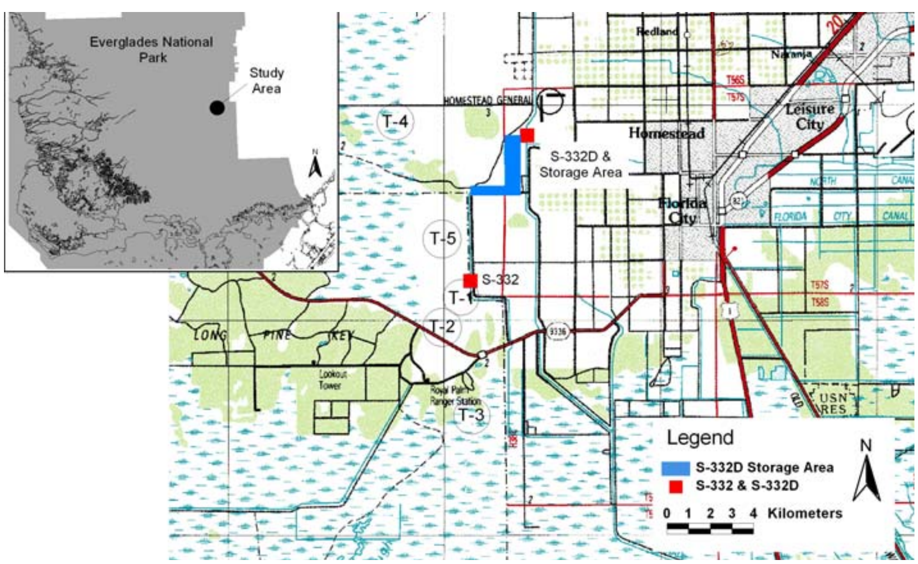


Figure 17. Location of Taylor Slough sampling transects, S-332 and S-332D water control structures, and detention area on the eastern boundary of ENP.

ii. Hydrological Changes in Taylor Slough

Water level in Taylor Slough was much higher in the 1980's and 1990's than in the two previous decades (Figure 18). During 1961 through 1980, prior to operation of the S-332 pump station, mean daily water level in the Slough in both dry and wet seasons was significantly correlated with rainfall. In contrast, during 1981 through 2002, rainfall was a poor predictor of water levels, which were primarily determined by water management operations (Figure 18).

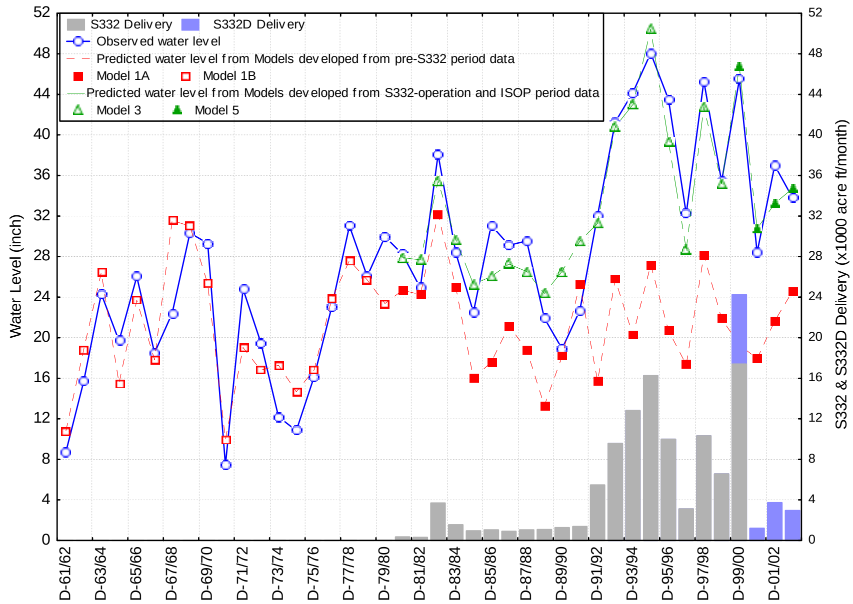


Figure 18. Observed and predicted water level and water flow through S-332 and S-332D into Taylor Slough during the 1961-2002 dry seasons.

iii. Changes in Vegetation Patterns along and across Taylor Slough Transects

Vegetation composition along Transects 1-3 changed substantially over the study period (1979 – 2003). Changes in vegetation composition along Transect 1, 2 and 3 became apparent by 1995, when a substantial decrease in muhly cover and an increase in sawgrass cover occurred in the M-plots (Figure 19). In the same year, sawgrass declined in the C-plots. Changes in both plot types were most dramatic on Transect 1 where the absolute cover of muhly in the M-plots on Transect 1 decreased by 1700% by 1995, compared to 400% and 300% on Transect 2 and 3, respectively (Figure 19). Similarly sawgrass decreased in C-plots. In contrast, sawgrass cover increased significantly in M-plots over the sampling period. *Eleocharis cellulosa* (Spikerush), a dominant of wet prairies, which was present only in the C-plots of Transect 1 in 1979, became established in M-plots on Transect 1 and 3 by 1995, and later became one of major species in C-plots on all three transects.

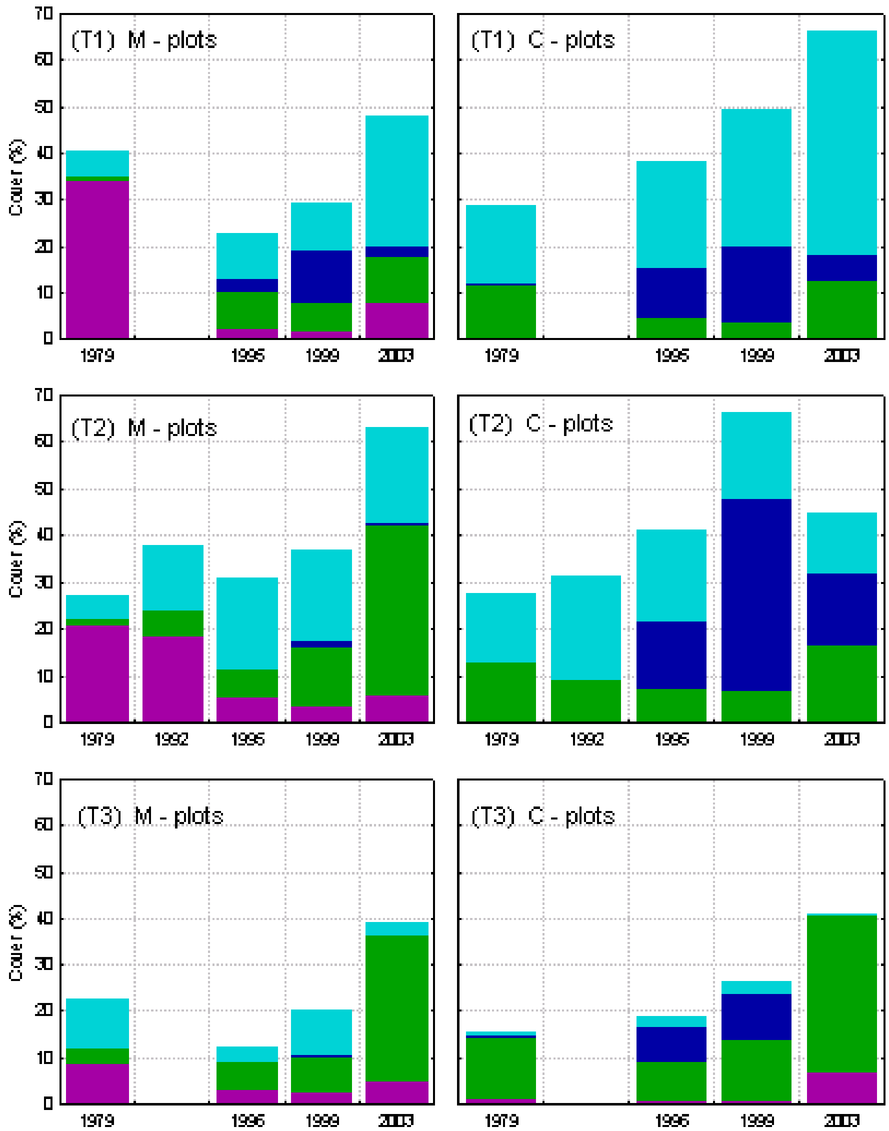


Figure 19. Absolute cover (%) of major species averaged across all M- C-plots on Transects 1, 2, and 3 1979-2003. sawgrass (green), spikerush (dark blue), muhly (purple), other species (aqua).

The trends in vegetation between 1979 and 1995 continued through 1999, though the changes in muhly and sawgrass cover were smaller. During this period, the cover of spikerush increased in the M-plots on Transect 1 and in the C-plots on all three transects (Figure 19), and spikerush was the most abundant species in M- and C-plots on Transect 1. Its average cover reached its highest abundance in the C-plots on Transect 2.

Trends between 1999 and 2003 were the opposite of the pattern prior to 1999. Muhly and sawgrass cover increased in M- and C-plots, respectively (Figure 19), while spikerush decreased. Spikerush was virtually absent (mean cover < 0.1%) in the M-plots of Transect 2 and 3, and the C-plots of Transect 3. However, increasing sawgrass cover in the M-plots continued through 2003. Total cover of all species increased sharply in M-plots in all three transects, and in C-plots in Transects 1 and 3, but not Transect 2. This recent change appears to indicate that vegetation was responding to the decrease in Taylor Slough water levels during ISOP. Species other than the dominants also underwent changes, with, in some cases, an apparent relationship to hydrology.

Along Transects 4 and 5 during 1997-2003, vegetation dynamics differed. The plots grouped by years in multivariate analysis, indicating a directional change in vegetation along an unidentified gradient. Total cover increased markedly, paralleling the trend in Transects 1-3 in 1999-2003. This increase was concentrated particularly among the two major species, sawgrass and muhly. In the six-year study period, the mean cover of sawgrass increased from 3.7% to 37.8%, and from 2.8% to 22.3% on Transects 4 and 5, respectively. The cover of muhly also increased more than 7-fold on these transects.

The proportion of total cover contributed by species other than sawgrass and muhly decreased significantly by 2003, and the change was more extreme during the ISOP/IOP period (1999-2003) than in first two years (1997-1999). Overall macrophyte species richness varied during the study period. On Transects 1-3, species richness decreased dramatically between 1979 and 1995, and then remained almost stable through 1999. During the ISOP-IOP period, species richness increased in the M- and C-plots on Transect 1, and in the C-plots of Transects 2 and 3. An increase in species richness at the transect level was also observed on Transect 5 during the ISOP period, while on Transect 4, species richness remained nearly stable over the 6-year study period.

iv. Vegetation-hydrology Relationships

Vegetation-hydrology relationships were examined using a weighted averaging regression and calibration model developed from vegetation cover data collected in 2003 on Transects 4 and 5 and from marl prairies west of Shark Slough. Hydroperiods were estimated from mean plot elevations and water level records from the 1996-2001 water years at ENP recorders CR-2, NTS-1 and NP-205. This model was applied to the historical and current vegetation data from the five Taylor Slough transects, and used to estimate vegetation-inferred hydroperiods for each sampling year during the S-332 operation and ISOP periods (Figure 20).

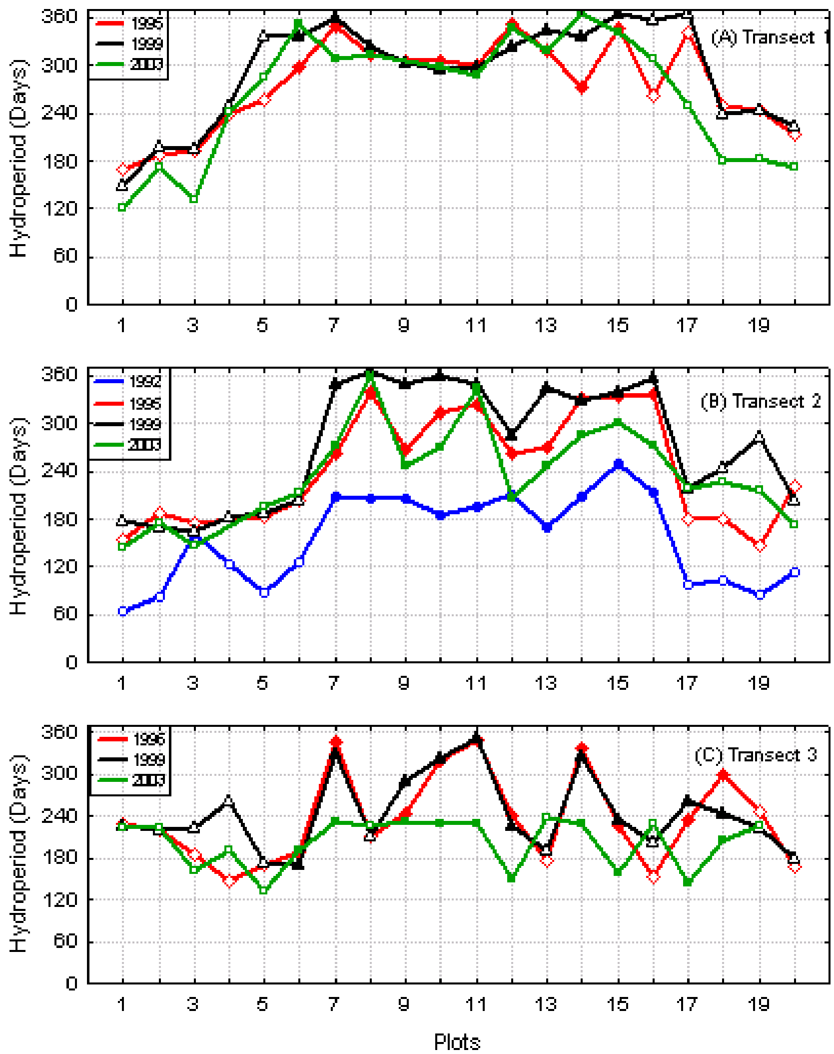


Figure 20 (a, b, and c, respectively). Plot level vegetation-inferred hydroperiods estimated in Muhly and *Cladium* plots along the Transects 1,2 and 3, 1992-2003. Open symbols= Muhly plots; Closed symbols – *Cladium* plots.

During the S-332 operation and ISOP periods, temporal changes in vegetation-inferred hydroperiods were substantial, especially on Transects 2 and 3 (Figure 20). On Transect 1, inferred hydroperiods did not differ significantly between 1995 and 1999, but in 2003 were shorter than in 1999, particularly at the two ends of the transect where muhly once dominated (Figure 20a). On Transect 2, inferred hydroperiods were significantly longer in 1995 and 1999 than in 1992 and 2003 (C-plots only) (Figure 20b). Inferred hydroperiods along Transect 3 did not differ significantly between 1996 and 1999, but were shorter in 2003 than either of the previous years. The shorter inferred hydroperiods on all three transects in 2003 in comparison to 1995 and 1999 (Figure 20c) provide strong correlative evidence that the decrease in Taylor Slough water level during the ISOP period was responsible for the vegetation change in this portion of Taylor Slough.

Among-year differences in inferred hydroperiods for Transect 4 and 5 during 1997-2003 were not significant on either transect. In conjunction with other results, these analyses suggest that factors other than hydrology were responsible for vegetation change in the headwater portions of Taylor Slough.

v. Summary

Under ISOP/IOP, hydrological conditions in Taylor Slough produced marsh community responses that were broadly predictable based on prior field studies. That is, the hydroperiods supported a shift in dominance, particularly the decline in Eleocharis and the increase in Muhlenbergia, which created communities approaching those found in the Slough in 1979 when the marsh was much drier. Species richness increased, another result associated with shorter hydroperiods than found in the natural system and in the mid-1990s. Thus the Slough reverted to a state that was further displaced from the restoration expectations of a wetter system than was the case under Test 7. No data were collected in Shark Slough so the possibility of a changing vegetation pattern in response to ISOP/IOP could not be tested there.

c. Mangrove, Estuarine, and Marine

Previous research has identified two major effects of upstream water management practices on the mangrove ecosystem bordering the northern shoreline of eastern Florida Bay. First, diversion of natural flows alters the salinity regime in the wetlands that results in a reduction in primary production in the submerged aquatic vegetation community within the mangrove zone, which in turn causes lower abundance of prey. The decline in prey fish likely explains declines in predator populations dependent on this food resource. The second effect of water management is dry season pulse releases of water from the canal system, which cause reversals of seasonal drying patterns within the mangrove ecosystem. Drying events are critical in that many predators take advantage of abundant fish concentrated in the remaining small pools. Wading birds, including Roseate Spoonbills, generally time their nesting to these drying events enabling them to readily meet the high energetic requirements of their rapidly growing young. Reversals in the drying pattern allow prey base fishes to spread across the landscape making them relatively unavailable to wading birds, resulting in nesting failure. Fish begin to move into deeper habitats (i.e., begin to concentrate) when water levels on the wetland surface within this area drop below 12.5 cm or 5 inches.

A productive mangrove ecosystem is dependent on lower salinity within the mangrove wetlands, made possible by high wet season water levels and relatively large flows through Taylor Slough. Prey fishes would be expected to respond by increasing numbers under these low salinity conditions. During the dry season, low water levels and curtailment of reversals are desirable. These conditions would be promoted by reduced flows through the system especially through the C-111 canal. A relatively high availability of prey and high reproductive output by spoonbills would be expected. Thus the restoration expectations associated with improving ecological conditions in the mangrove zone include lowering salinities of coastal wetlands so as to increase fish productivity and providing for dry season reduction of marsh water depths to critical levels for concentrating fishes into drying pools within the foraging grounds of Roseate Spoonbills and other piscivores.

To assess potential impacts to the estuarine region three sampling sites were evaluated using BACI analysis: Taylor River (TR), Joe Bay (JB) and Highway Creek (HC) located in the Taylor Slough/C-111 area (Figure 21). Two control sites, one for salinity on Biscayne Bay, outside the effect of Test 7 or IOP, and one for water level analysis at Bear Lake were also evaluated. All sites were sampled for fish in June, September and monthly from November to April. Thus, six fish samples were collected at each site in each dry season and two were collected during wet seasons. Spoonbill nesting success data were collected at two sites (Tern and Sandy Keys). Tern Key is located directly downstream of the Taylor Slough/ Panhandle region. Birds from this colony feed in the coastal mangroves represented by the impact sites and thus comprise the impacted colony. Sandy Key is located on the western edge of Florida Bay. Birds from this colony feed in the Cape Sable area (as represented by the BL site), which is designated the control site since this is not directly impacted by water management practices.

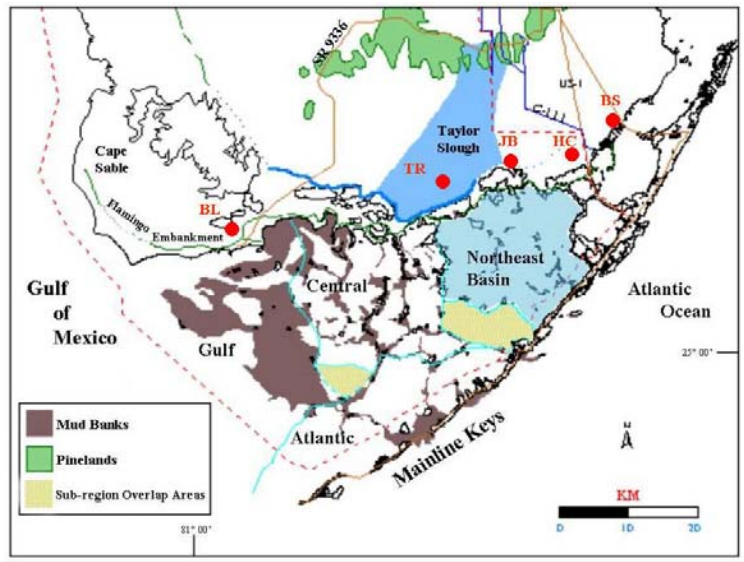


Figure 21. Control and impact sites for the mangrove wetlands and spoonbill study.

i. Freshwater Flows to Mangrove Region

There were no significant differences in annual flow between the Test 7 and IOP periods for either C-111 discharges or Taylor Slough Bridge. However, during the wet season, there was significantly higher flow to the C-111 area than down Taylor Slough during IOP as compared to Test 7, an undesirable effect based on analyses of mangrove salinity patterns in response to basin flows. During the dry season, no statistically significant differences were observed between IOP and Test 7.

ii. Salinity within the Mangrove Region

Statistical analysis showed no significant difference in rainfall or salinity at the control site between the Test 7 and IOP periods. In contrast at the three impact sites, salinity was significantly higher during IOP than during Test 7. These results indicate that Test 7 was better than the IOP at achieving the desired responses of reduced salinity within coastal wetlands. Furthermore, based on the relationships between Taylor Slough flow and salinity in the mangrove wetlands, these results suggest that Test 7 was better at forcing more water into the natural flow way of Taylor Slough.

iii. Water Level Effects within the Mangrove Region

Overall, there was no apparent effect of water management on annual water levels in the coastal wetlands. Although annual water levels are important determinants of ecosystem function, depth affects the system primarily during the dry season. Dry season water levels at the control site were not significantly different between Test 7 and IOP, but at the impact sites, water levels were significantly higher during Test 7. As discussed below, these results suggest that the IOP produced better conditions in the dry season than Test 7.

iv. Fish Abundance and Availability

Fish abundance is a measure of the biomass of fish present regardless of their role as prey for predators. Fish availability reflects the accessibility of the fish to predators. Overall, there was no significant difference in fish abundance at either the control or impact sites. Although not statistically significant, the greater reduction of abundance at the impacted sites than the control site (23% vs. 15%) in IOP may be biologically relevant. The lack of significance may result from having only eight samples from the control site. In contrast, when the control and impact sites are combined, the BACI analysis indicated that fish abundance during the Test 7 period exceeded that of the IOP period. Based on the inconclusive nature of the BACI interaction, however, we must assume that regional conditions account for the differences between the two periods rather than water management practices.

BACI analysis showed that fish availability was significantly different due mostly to greater availability at the control site during Test 7 (Figure 22). Given that there was little difference in water levels during the two periods at the control site, the difference is most likely attributable to higher fish abundance at the beginning of the dry season leading to greater concentrations of fish under Test 7. Fish abundance was higher at the end of the wet season under Test 7 at the impacted sites but the difference was non-significant.

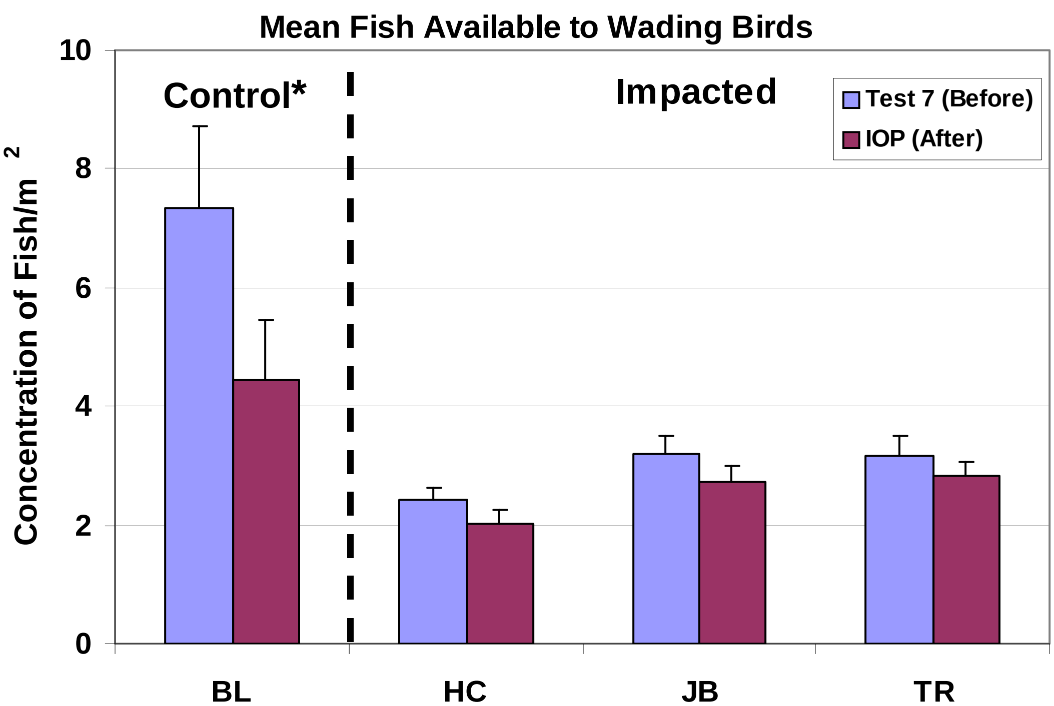


Figure 22. Mean fish number (with standard error) available to wading birds during the dry season (i.e., fish concentration) from four sites for both operational periods. Analytical results indicate that the BACI interaction was significant. Least squares means indicate that there was no significant difference at the impacted sites, however, at the control site, fish were 39% more concentrated during Test 7 than during the IOP (*P=0.004).

Because lower dry season water levels concentrate fish in pools, if drying conditions were the same under both operational plans, higher availability would be expected under Test 7 at the impacted sites as was observed at the control site. This was not the case. Dry season fish availability was very similar for the two periods at the impacted sites. The most likely explanation is that higher dry season water levels under Test 7 (above the critical level below which fish become concentrated) masked the effect of the higher “starting” abundance at the end of the wet season (Figure 23). In other words; the lower water levels under IOP resulted in fish being as available to predators as under Test 7 even though Test 7 had significantly higher fish abundance when calculated for the entire landscape (Figure 23).

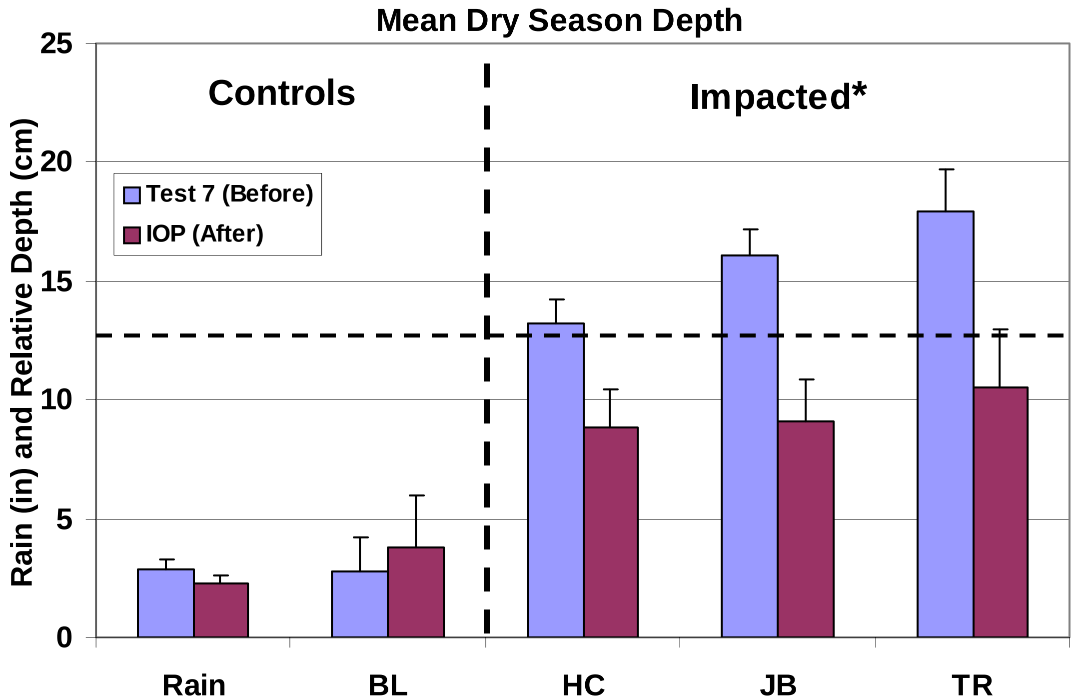


Figure 23. Least squares means indicate that there was no dry season depth difference in the controls but at the impacted sites, combined depth was 34% greater during the Test 7 compared to IOP (*P=0.0001). Also note that at the impacted sites mean water level was above 12.5 cm during Test 7 but below 12.5 cm during IOP.

v. Impacts on Spoonbills in Mangrove Region

Spoonbills generally begin nesting in Florida Bay between November 1 and December 15. The incubation period is approximately 21 days. After hatching, the chicks require constant care and an unbroken supply of food for about 42 days. After this period, the chicks are more self-reliant but still unable to leave the colony for another 42 days. Thus, the critical period for spoonbills in Florida Bay is approximately from December 1 to March 31. Foraging spoonbills require water levels at or below the concentration threshold of 12.5 cm somewhere within the coastal mangrove wetlands for the duration of this period.

Relative depth under Test 7 operations averaged well above the concentration threshold of 12.5 cm while under IOP water levels were well below this stage (Figure 23). In short, the IOP resulted in better foraging conditions for spoonbills in the coastal wetlands than Test 7.

Although not proven statistically because of a paucity of data points (three in each of the four categories), the data clearly indicate that Test 7 had a profound negative effect on spoonbill nesting success (Figure 24). At the impacted colony, fewer than 2 chicks fledged per 10 nesting attempts under Test 7. Under IOP, 10 nests produced about 9 chicks. At the control site, the production rate was almost eight chicks per 10 nests during the Test 7 period and increased to 11 chicks per 10 nests during the IOP. These results suggest that conditions throughout Florida Bay were not as good for spoonbills during Test 7 period as during IOP. Test 7 operations exacerbated already poor conditions causing almost complete failure in colonies impacted by these operations.

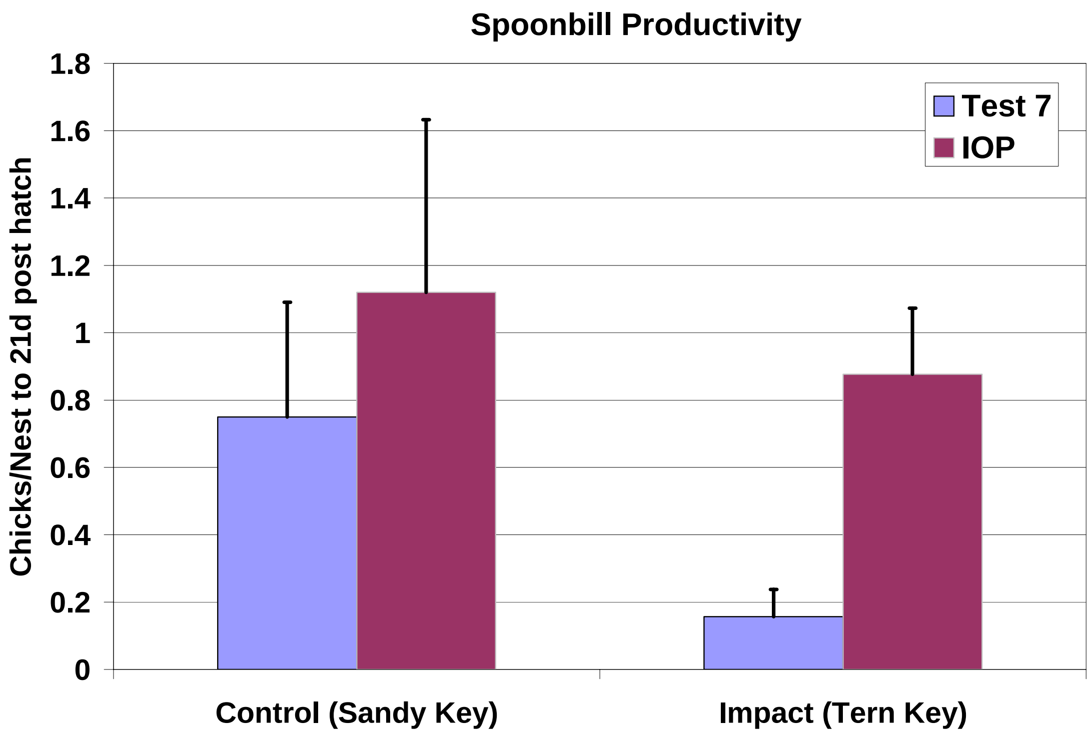


Figure 24. Mean success rate of nesting spoonbills at two locations. The virtual lack of reproduction at the impact site under Test 7 and over 400% increase during IOP indicate a strong anthropogenic effect despite the lack of statistical significance.

vi. Summary

The big increase in Spoonbill nesting success under ISOP/IOP indicates a marked improvement over Test 7 and a trend moving towards restoration expectations. The more favorable water levels in IOP during the critical foraging period for the Spoonbills may partially explain this improvement. However, because the responses in salinity patterns and in fish biomass and availability, which presumably govern the success of piscine predators in the coastal areas, were mixed or inconclusive, more data are needed to determine if the positive Spoonbill response continues and whether it is statistically explainable from the fish and salinity data.

d. Cape Sable Seaside Sparrow

The Cape Sable Seaside Sparrow is a medium-sized sparrow that today occurs in Miami-Dade and Monroe counties of south Florida. This non-migratory sparrow has the most restricted range of any bird in North America and occurs almost exclusively within the boundaries of ENP and Big Cypress National Preserve.

Male Cape Sable Seaside Sparrows occupy and defend their territories during the breeding season. Breeding activity, particularly singing behavior by males, appears to decrease with increased surface water conditions. Nests are cups constructed of grasses and are on average approximately 4 inches above the ground. When water levels exceed about 4 inches, nesting activities cease.

The Cape Sable Seaside Sparrow was among the first group of species listed as endangered by the FWS on March 11, 1967. The sparrow was listed because of its limited distribution and threats to its habitat posed by large-scale conversion of land in southern Florida to agricultural uses. Presently the sub-species is restricted to six small sub-populations in ENP and Big Cypress National Preserve. Surveys of the sparrow, employing helicopters to ferry observers to its remote locations, began with Harold Werner in 1974. In 1981 the first range-wide survey was undertaken. This was repeated in 1992, and range-wide surveys have continued every year since. The surveys show that sparrows are found in a set of sub-populations (A through F) separated to various degrees by unsuitable vegetation (Figure 25). With so many events occurring in more or less the same timeframe, biologists must be careful in assigning cause and effect. For a detailed discussion the reader is referred to the body of work encompassed in Pimm et al. (2002).

One of the critical outcomes for the Cape Sable Seaside Sparrow is the expectation that IOP/ISOP would produce appropriate hydrologic conditions over a substantial amount of sparrow habitat west of Shark Slough sufficient to produce two broods (two nesting cycles) a year. It was expected that this condition would allow sub-population A to at least maintain their current numbers as required by the RPA.

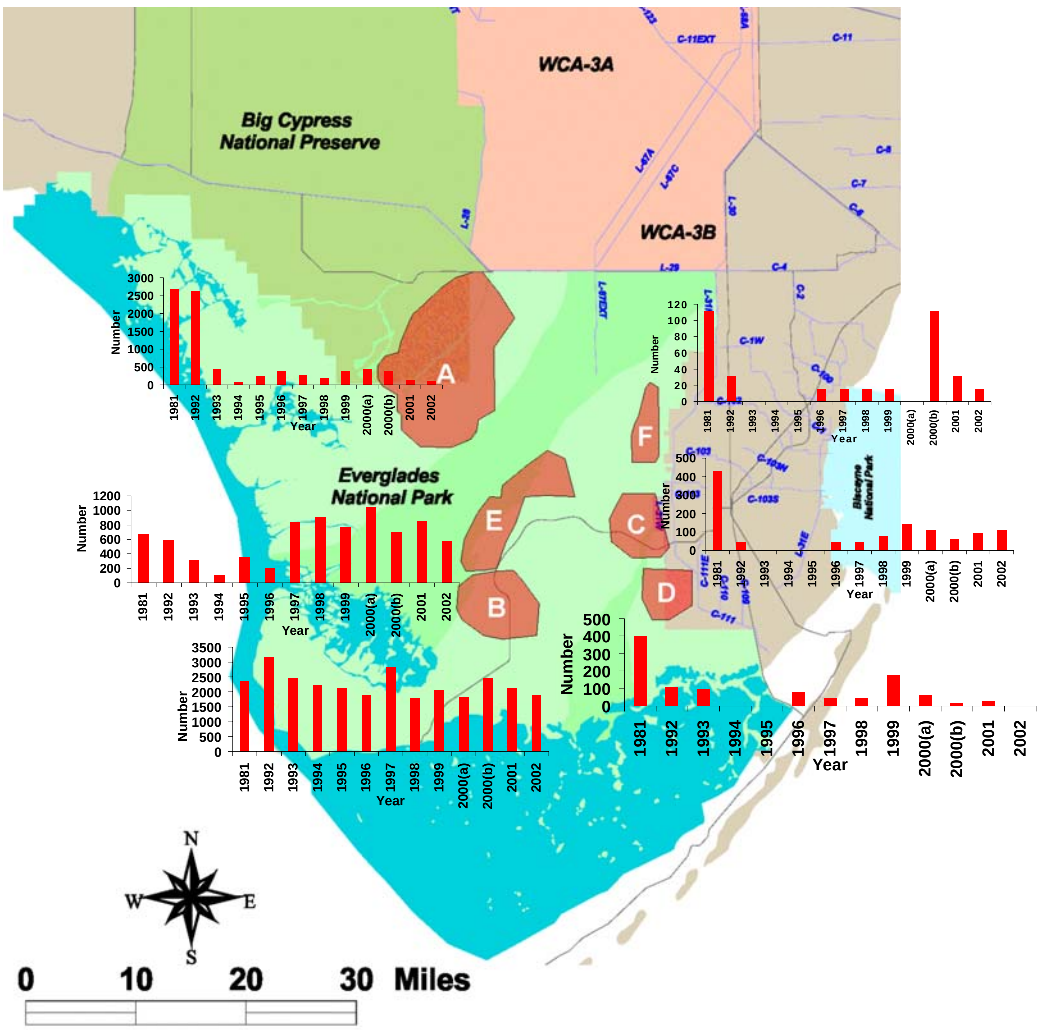


Figure 25. The location and population estimates for the six sub-populations of the Cape Sable Seaside Sparrow.

i. The Western Sub-Population (A): A Comparison of the years 1996 through 1999 with the years 2000 to 2003:

Given the importance of sub-population A, being the population most impacted by water management, the water levels within sub-population A will be discussed first. Water monitoring station NP205 provides the best record of water levels for this sub-population. The dynamics of NP205 have been discussed elsewhere (Pimm et al. 2002).

Water-level data at NP205 are available for the period 1975-2003 (Figure 26). There were dry years in the late 70s to early 80s, when breeding season water levels were often under 6 feet (the approximate height of NP205), followed by wetter years in the mid-80s. The late 80s to 1992 were usually dry, while the years from 1993 to 1995 were exceptionally wet, a condition exacerbated by water-releases from the S-12s during the sparrow breeding season.

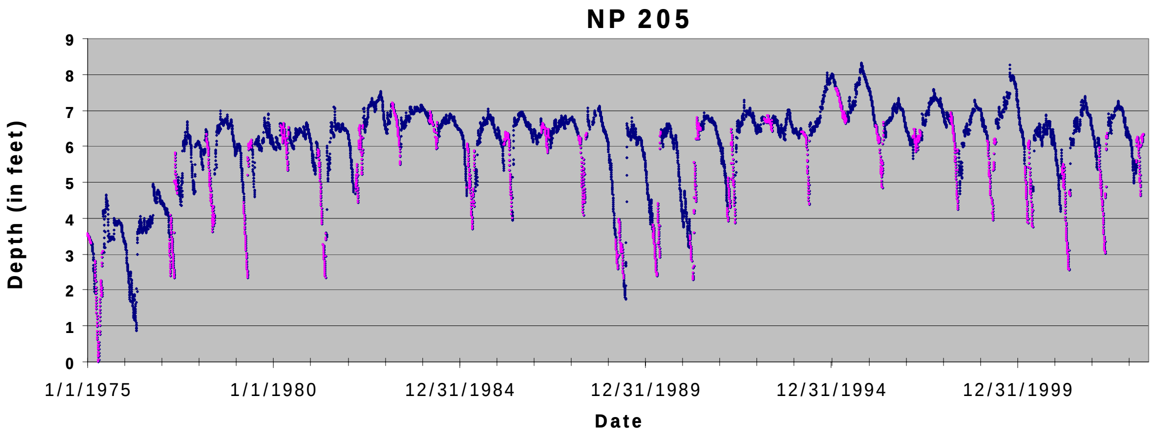
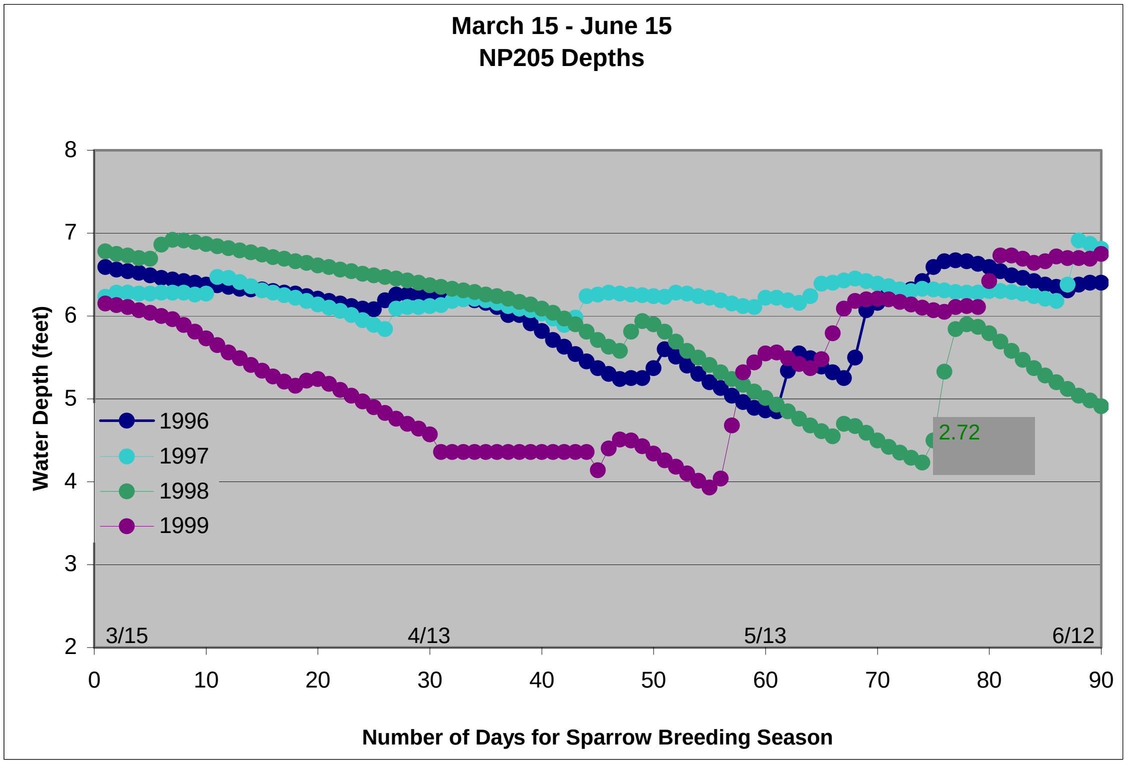


Figure 26. Daily water levels at NP205; pink points are those during the breeding season, taken as the 90 days starting March 15th.

The period of interest compares 1996 to 1999 (pre-IOP) to 2000 to 2003 (post-IOP) and involves the 90 days following March 15th each year (Figure 27a, b). The figures show the same data as in Figure 26, though in more detail. Also relevant are rainfall events, for these elevate the water levels considerably. Generally, heavy rains (defined as totals of >1-5 inches) are spread over two days. However, in some cases, heavy rain continued over three or four days. The figures also show these events and their durations.

Water levels at NP205 remained above 6 feet for all but about 20 days of 1996, all of 1997, and about 30 days in 1998 (ending with a 2 day rainfall total of 2.72 inches in late May). In 1999, water levels were below 6 feet for the 90-day period commencing on March 15th.

In contrast, water levels in 2000 to 2003 were nearly always below 6 feet during these 90 days. Generally, water levels dropped at about one foot per 20 days. However, in most years, large rainfall events raised water levels dramatically during the breeding season. For example, a mid-April rain (3.76 inches in two days) in 2002 raised water levels by over two feet and a late April rain (2.66 inches in two days) in 2003 raised water levels by one foot.



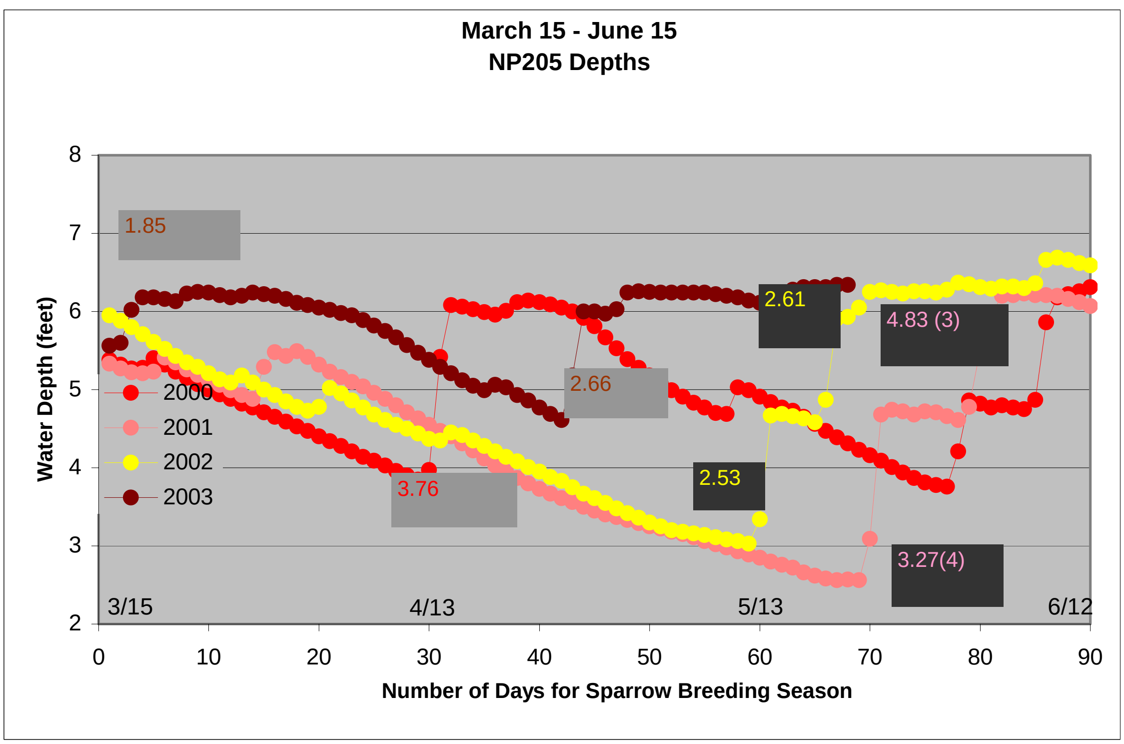


Figure 27. (a) Water levels at NP205 from 1996 to 1999 and (b) from 2000 to 2003 for the 90 days starting March 15th each year. Numbers in boxes show two-day rainfall totals, except when the rainfall events were distributed over longer than two days, when the duration, in days, is shown in parentheses. For further details see text.

ii. Habitat availability for sub-population A in west Shark Slough

NP205 water level data were translated into available sub-population habitat by established method (Pimm et al. 2002) and these data are summarized in Figure 28. Approximately, 275 km^2 of this area is >5 ft, 175 km^2 > 6 ft, 75 km^2 >6.5 ft and none >7 ft. These areas are total areas; not all afford suitable habitat for the sparrow. Using a well-calibrated satellite-image based model of sparrow habitat that excludes areas that are too bushy for sparrows or too small to support sparrow territories, the amount of available habitat was estimated. Above 5 ft, approximately 125 km^2 of this area is suitable sparrow habitat in one or more years, 90 km^2 >6 ft, and 40 km^2 >6.5 ft.

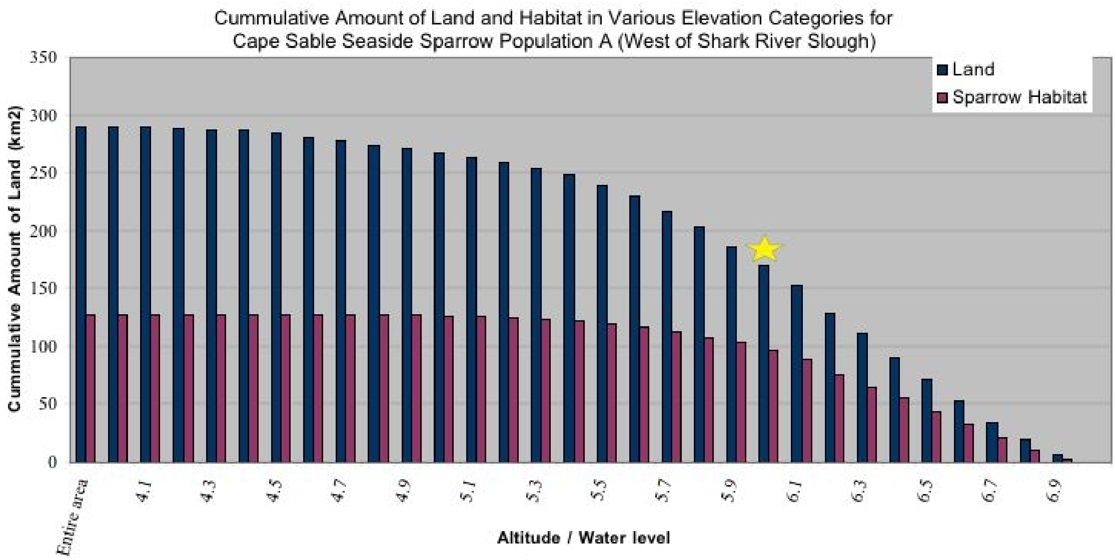


Figure 28. Shows the areas in sub-population A that are dry ("land") and in habitat that is predicted to be suitable habitat in one or more years. Predicted habitat in any given year is likely to be no more than three-quarters of this latter area and the birds, at best, will be able to use only a fraction of this area (see text for details).

For a given water depth (see Figure 27), Figure 28 predicts how much habitat is predicted to be suitable in one or more years. Perhaps three-quarters of this area is suitable in a particular year, but not all is available throughout the breeding season. The word "available" is the key. To be able to produce one brood, the birds must have dry habitat for about 40 days continuously to complete a nesting cycle (two broods require longer).

The heights of water at NP205 below which the water remained for about 40 continuous days in the breeding season, plus the estimates of potential available sparrow habitat (in km^2) at that height are shown in Table 5.

Table 5. Potential available sparrow habitat.

Year	Height (ft)	Area (km2)	Estimated Sparrow Numbers
1996	6.2	76	384
1997	6.3	66	272
1998	6.2	76	192

Year	Height (ft)	Area (km2)	Estimated Sparrow Numbers
1999	5.4	122	400
2000	6.1	89	448
2001	4.5	128	128
2002	4.7	128	96
2003	6.2	76	128

Pimm and Bass (2003) emphasize that estimates of potential area are best viewed as comparative, since the area the sparrows can occupy will be substantially less. Clearly, the three years following the massive flooding of 1993 to 1995 were still not good for the sparrow breeding. In 1999, low water levels afforded larger dry areas for the birds to breed. The following year, the breeding season was likely interrupted by a mid-season storm that flooded large areas. The following two years were relatively dry, but 2003 looks as though it might be a very poor year for sparrow breeding.

iii. Sub-population A numbers

Table 5 also shows the estimated number of sparrows in sub-population A. Because of the small numbers of individuals actually counted, interpretation requires care. The highest estimate (448) corresponds to the year after one of the best years for sparrow habitat (1999). Biologists expect that good breeding years would be apparent the following year. The mid-season flooding of 2000 likely had a negative affect on the sub-population, so that despite the next two years being relatively dry, the sub-population may have had trouble recovering. Figure 29 shows their distribution.

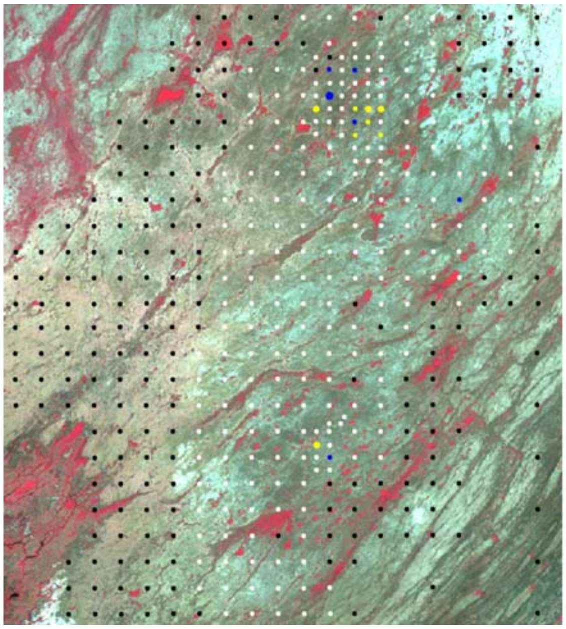


Figure 29. Counts of sparrows in 2003 in sub-population A. Black dots are sites counted in others years, white dots sites counted in 2003, but not found to hold birds. Blue dots are sites holding one (small dot) or two (larger dots) on the regular survey. Yellow dots are comparable, but counted on a supplemental survey (see text).

In order to improve the confidence of the estimates of the now small sub-population A, biologists conducted an additional survey in this area in 2003, using a 0.5km grid, rather than the more generally applied 1km grid (see Figure 29). The figure shows that the remaining birds are found in two concentrations, a larger one in the north, a smaller one in the south; both closely match the areas of highest ground.

Pimm et al. (2002) estimate the potential for sparrow numbers to increase from one year to the next. In brief, they find that when the sparrow population (as a whole) can produce only one clutch per year, it likely cannot increase and will merely hold its own. Only when the population (as a whole) can produce two broods a year will the population increase. Figure 27 and the calculations derived from it show that only a small part of sub-population A nests on sufficiently high ground that it can produce even one brood a year consistently, year after year. An even smaller part of sub-population A is free from flooding for long enough to produce two broods a year and so have the potential to export birds to areas from which flooding has removed them in the past.

iv. The Eastern Sub-Populations (C-F)

The work of Lockwood (in Pimm et al. 2002, and in preparation) determined that sparrow nesting is delayed by at least two years following fires. Fires are most frequent along the eastern boundary of the sparrow's range, likely a result of this area being simultaneously drier than it was historically and adjacent to areas outside the natural system subject to human use and abuse.

Sub-populations C, D, and F are subject to frequent fires and part of sub-population C, that near Taylor Slough Bridge has suffered altered hydrology that has made the habitat unsuitable. The small numbers of birds counted, as illustrated by the population estimates in Table 6, means that it would be difficult to detect any improvement in the habitat since the implementation of IOP. Sub-population D, however, is cause for concern. Only two birds were counted in 2001 (for a sub-population estimate of 32) and none since.

Table 6. Population estimates in three eastern sub-populations.

POP	**81**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**
C	432	48	0		0	48	48	80	144	112	96	112	96
D	400	112	96		0	80	48	48	176	64	32	0	0
F	112	32	0		0		16	16	16	0	32	16	32

v. Summary

Target hydrologic conditions in western Shark Slough were largely attained through the implementation of IOP operations. Prior to the implementation of IOP, water levels at indicator site NP-205 remained above the threshold level of 6.0 feet (NGVD) much of the time.

Implementation of IOP resulted in water levels nearly always below this threshold, particularly during the Cape Sable Seaside Sparrow nesting window. Thus, overall conditions for sparrow nesting were generally more favorable in the years since the implementation of IOP than in the years prior to its implementation.

Although conditions were improved considerably for sparrows in sub-population A since the implementation of IOP from 2000 onwards, in most years since IOP, large rainfall events raised water levels dramatically during the breeding season. Sub-population A was almost certainly negatively affected by a mid-April 2000 rain event. It is of particular concern that the area that remains dry during the breeding season is still very small compared with the extent of the sparrow's distribution in 1981 and 1992, when sub-population A held almost half of the total sparrow population.

When the sparrow population as a whole can produce only one clutch per year, it likely cannot increase its numbers from one year to the next and will merely hold its own. Only when the population as a whole can produce two broods a year will a population increase be detected. Only a small part of sub-population A nests on sufficiently high ground that it can produce even one brood a year consistently, year after year. An even smaller part of sub-population A is free from flooding for long enough to produce two broods a year, and so have the potential to export birds to areas from which flooding has removed them in the past. Therefore, despite improved hydrologic conditions, sub-population A numbers remain low and are still at a high risk of extinction.

Sub-population D is cause for concern. Only two birds were counted in 2001 (for a population estimate of 32). No birds were seen in 2002 and 2003. A fire burned a large part of what was once sparrow habitat in 2000, the same year that this area was flooded during the breeding season. It seems likely that the flooding event of 2000 was responsible for the recent crash of sub-population D.

Sub-population B, as expected, was not changed by the IOP and there is not enough information to assess the impacts of the IOP on sub-populations C, E, and F.

VI. Conclusions and Recommendations

IOP modifications began as recently as mid-2002 and thus only very limited amounts of hydrological and biological data were available for analysis. To increase the amount of data available for analysis, ISOP and IOP datasets were combined. This is justifiable because the operations under IOP were largely an extension of the ISOP protocols. As a result, many of the analyses conducted in this report examined an aggregate of the data from both the ISOP (December 1999-June 2002) and IOP (July 2002-present) periods. This aggregation of ISOP/IOP data improved the ability to conduct statistical analyses but could not completely eliminate the constraints of a short-term data collection period. Consequently, for some particular analyses, it remains difficult to make definitive statements as to the benefits and impacts associated with these operational changes and even more difficult to assign cause and effect.

The limitations of the dataset are particularly evident when analyzing the ecological data. Many of the species common in the Everglades landscape respond relatively slowly to hydrological changes. The communities and species examined in this report were chosen in light of this problem. For example, one would expect to be able to see more immediate response from species lower in the food chain and with relatively short generation times, such as the aquatic midge species which were used to assess water quality under ISOP/IOP, than in those which occupy positions higher in the food chain and with longer generation times, such as the Wood Stork. The report does attempt, however, to provide insights on longer-lived organisms, such as the Cape Sable Seaside Sparrow, when the changes in the communities were likely due ISOP/IOP operational changes.

Two over-arching management recommendations result from the analyses included in this report. First, it is of paramount importance to continue the existing long-term monitoring programs. Second, research is required to understand better the complex processes operating within the Everglades ecosystem, including the consequences of water management decisions, in order to ensure the restoration, protection, and preservation of the resource within the context of the Everglades restoration effort. It is also the expectation of ENP that future structural and operational modifications associated with CSOP and CERP will be designed in a manner that will accentuate the observed ecosystem improvements and also ameliorate the issues of concern.

1. Positive Outcomes in the Assessment of Interim Operations

a. Physical Environment

i. Hydrology:

Conclusion: IOP appears to have substantially corrected the unnatural and undesirable impacts in upper Taylor Slough associated with operations during ISOP. More natural wet season recession patterns, a greater spatial extent of surface water during the wet season, and a possible decrease in seepage losses were observed during IOP. All these suggest that IOP resulted in more natural timing and distribution of inflows to Taylor Slough.

> ***Recommendation:*** Apparently, the significant benefits observed in upper Taylor Slough do not propagate very far downstream. The most likely explanation is that the lower L-31W and Aerojet canals capture groundwater and surface water and rapidly convey it back towards C-111. Modifications to the operational and structural configuration of the L-31W and lower C-111 canals could correct this problem and should be investigated in future operational evaluations.

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Conclusion: Target hydrologic conditions in western Shark Slough were largely attained through the implementation of IOP operations. Prior to the implementation of IOP, water levels at indicator site NP-205 remained above the threshold level of 6.0 feet-NGVD much of the time. Implementation of IOP resulted in water levels nearly always below this threshold, particularly during the Cape Sable Seaside Sparrow nesting window. Thus, overall conditions for sparrow nesting were generally more favorable in the years since the implementation of IOP than in the years prior to its implementation.

> ***Recommendation:*** *Continue IOP operations associated with the S-12 structures until completion of all features associated with the Modified Water Deliveries and C-111 Projects, including the implementation of the operational plan for the combined projects.*

ii. Water Quality

Conclusion: There is no evidence of a deterioration of water quality at structures (S-332B, S-332D, and S-18C) along the eastern side of ENP, associated with IOP operations in the L-31N and C-111 canals.

> ***Recommendation:*** *These analyses should be viewed with caution given the projected changes within the basins associated with the implementation and operation of C-111 Project features and land use changes. Extensive monitoring, data analysis, modeling, and research to ensure protection of ENP resources from potential, yet unrealized, water quality problems should guide future management.*

b. Biological Environment

i. Mangrove, Estuarine, and Marine

Conclusion: IOP resulted in lower water levels during the dry season than during the Experimental Program Test 7 within the mangrove region of Eastern Panhandle, ENP. This allowed for improvements to spoonbill nesting success during IOP when compared to Experimental Program Test 7.

> ***Recommendation:*** *Several modifications would allow these conditions to persist during the dry season: (1) allow for the more storage of water and better control in the L-31N and C-111 basins, (2) implement the Modified Water Deliveries Project to introduce more water into NESS and upper Taylor Slough, (3) backfill the lower C-111 canal to prevent large flood releases to the Eastern Panhandle and Manatee Bay, and, (4) redistribute flows to the Taylor Slough/Eastern Panhandle to deliver a greater percentage of water to Taylor Slough than the Eastern Panhandle.*

ii. Cape Sable Seaside Sparrow

Conclusion: Sub-population B, as expected, was not changed by the IOP.

> ***Recommendation:*** *Continue to monitor sub-population B at the present level of effort.*

2. Sources of Concern in the Assessment of the Interim Operations

a. Physical Environment

i. Hydrology:

Conclusion: ISOP/IOP resulted in lower average water levels and shorter dry season hydroperiods in western Shark Slough, and Water Conservation Area 3B when compared to Test 7, after accounting for rainfall.

> ***Recommendation:*** *Implement the structural and operational features of the Modified Water Deliveries and C-111 projects, which will allow introducing more water into NESS thereby increasing water depths and hydroperiods.*

ii. Water Quality

Conclusion: Available water quality data do not support reliance on the detention areas of the C-111 Project as mechanisms for water quality protection. Because of the high seepage rate of water out of the detention areas, the current footprint of the detention areas is not sufficient to remove nutrients from the incoming water.

- ***Recommendation:*** *Design the detention areas to minimize input to ENP in the form of either seepage or direct surface water flow. Specifically, it is recommended that the proposed culverts along the western side of the detention areas be eliminated. It is also recommended that these structural modifications to the C-111 Project be evaluated during CSOP for compatibility with the other authorized purposes of the C-111 Project.*

Conclusion: There is an increase in TP concentrations in Shark Slough inflows after IOP implementation. There is strong evidence linking this increase to the change in the WCA-3A regulation schedule required by ISOP/IOP. The lower WCA-3A stages in the WCA-3A regulation schedule reduces the occurrence of S-140 and S-9 flows entering WCA-3A marshes where nutrient uptake occurs. The result is direct canal flow from S-140 and S-9 to Shark Slough inflow structures (S-12's and S-333).

Recommendations: *Several actions can be taken to address these problems.*

1. *Modification of the WCA-3A regulation schedule to avoid drawdown of water levels below Zone E, particularly to stages less than 9.5 feet.*

2. *Plug the L-67A canal to reduce transport of TP loads from the S-9 outflow to Shark Slough inflow structures along the Tamiami Canal.*

3. *Initiate further monitoring, analysis, and modeling of future and existing data from WCA-3A to further evaluate factors contributing to recent increases in TP concentrations at the S-12's and S-333.*

Conclusion: Increases TP concentrations at S-12A were larger than those observed at other Shark Slough inflow structures.

Recommendation: *Assess factors contributing to elevated TP concentrations at S-12A such as, the Zone E1 WCA-3A regulation schedule and inflows from S-140 and S-9.*

Conclusion: A sampling strategy of biweekly grab samples is generally inadequate for detecting infrequent spikes in TP concentration and loading associated with runoff events and flood-control operations. This problem was revealed when comparing TP data from grab samples and composite samples at S-332D and S-18C.

Recommendation: *Use composite sampling to track TP concentrations and loads at monitoring sites in the L-31N/C-111 region, including sites on the mainstream canals, sites on eastern canals (C-102, C-103, C-113, C-111E), pump stations, and buffer/detention area overflow points.*

Conclusion: TP transport mechanisms from the detention areas, including the effects of antecedent soil TP, are unknown.

Recommendation: *Intensified monitoring of the L-31N/C-111 detention areas to support development of accurate water and TP budgets, to assess the transport and fate of TP in surface and groundwater flows, and to support modeling of TP dynamics.*

Conclusion: Evidence of nutrient enrichment is apparent from elevated TP in soil and periphyton samples from the marsh just west of the S-332B detention area, as well as from aquatic insects used as indicator species.

Recommendation: *Eliminate the surface water discharges from the S-332B detention areas until the source of the elevated TP can be conclusively determined. Continued monitoring of nutrient levels in the soil, periphyton, surface and groundwater, along with aquatic insects in and around the detention areas, is recommended.*

iii. Salinity

Conclusion: Statistical tests reveal that yearly and seasonal salinity values in Florida Bay were increased slightly during the ISOP/IOP period compared to the Test 7 period. Long-term model simulations reveal that the ISOP/IOP scenario provides less water to Florida Bay through Taylor Slough. As a result, the calculated mean salinity values at the northeast Florida Bay area increase under ISOP/IOP compared to Test 7 conditions.

Recommendation: *Restore the flow through Taylor Slough at the level of the natural condition so that favorable salinity conditions for a healthy Florida Bay ecosystem will be reestablished.*

b. Biological Environment

i. Freshwater Communities

Conclusion: Two new species of non-native fish have been detected and the range of a third non-native fish has expanded in the Taylor Slough, Rocky Glades, and C-111 regions due to the operations of structural features associated with the South Dade Conveyance System and ISOP/IOP.

- ***Recommendation:*** *Eliminate all surface water inflows from the L-31W, L-31N, and C-111 canals via the S-332, S-332C, S-332D, and their associated detention areas. Eliminate the L-31W canal to further prevent the introduction of other non-native species. It is also recommended that these structural modifications to the C-111 Project be evaluated during CSOP for compatibility with the other authorized purposes of the C-111 Project.*

Conclusion: Pre-storm drawdowns and repetitious fluctuations of water level above and below the ground surface (reversals) may reduce the dry season survival of fishes in the Rocky Glades.

Recommendation*: Initiate a study of Rocky Glades fishes with sampling frequency that is adequate to evaluate the impact of these events.*

Conclusion: Lower average water levels and shorter dry season hydroperiods in central Shark Slough and central Taylor Slough when compared to Test 7 led to lower density of several species of native fishes and macroinvertebrates.

Recommendation: *Implement the structural and operational features of the Modified Water Deliveries and C-111 projects, which will allow introducing more water into NESS thereby increasing water depths and hydroperiods.*

ii. Vegetation

Conclusion: During the IOP operational period, the composition of marsh vegetation, including species diversity, appeared to shift towards patterns observed in the drier periods of the 1960's through 1980's and away from the trends observed in the past decade. This trend is opposed to the ecosystem restoration goal of restoring the hydrology and the associated natural communities of Taylor Slough.

Recommendation: *Increase hydroperiods and water depths in Taylor Slough by providing water as far north as possible in the drainage basin, with as much of the flows as possible originating from overland and ground water flows coming from the natural system. Assure that this water is of the highest water quality**.** Implement the structural and operational features of the Modified Water Deliveries and C-111 projects, which will - introduce more water into NESS, thereby increasing water depths and flows into Taylor Slough.*

Conclusion: Measurable changes in the dominant vegetative species were apparent within a period of two to three years; evidently, the changes in marsh vegetation within Taylor Slough occur rapidly and in response to changes in water management.

> ***Recommendation****: Continue the fixed-plot monitoring program, adding new plots to improve the ability to detect effects of water management operations. In conjunction with related work funded by other sources, the expanded database will provide a more robust basis for drawing conclusions as to causative relationships between plot-level marsh water levels, water management operations, and vegetation response.*

iii. Cape Sable Seaside Sparrow

Conclusion: Despite improved hydrologic conditions, sub-population A numbers remain low and are still at a high risk of extinction.

> ***Recommendation:*** *Continue the monitoring of Cape Sable Seaside Sparrow sub-population A and its habitat to determine if these operations actually result in increases in the population size, and the recovery and protection of its habitat. In addition, sub-population A should be surveyed on a finer scale (0.5km) each year and intensive on the ground surveys of population A should continue.*

Conclusion: Sub-population D is cause for concern. Only two birds were counted in 2001 (for a population estimate of 32). No birds were seen in 2002 and 2003.A fire burned a large part of what was once sparrow habitat in 2000, the same year that this area was flooded during the breeding season. It seems likely that the flooding event of 2000 was responsible for the recent crash of sub-population D.

> ***Recommendation:*** *A detailed analysis of water levels in this sub-population before and after IOP should be undertaken. Continue to monitor sub-population D at the present level of effort. In addition, sub-population D should be surveyed on a finer scale (0.5km) each year and intensive on the ground surveys should search for birds in sub-population D.*

Conclusion: There is insufficient information to assess the impacts of the IOP on sub-populations C, E, and F.

> ***Recommendation:*** *Continue to monitor sub-populations C, E, and F at the present levels of effort. In addition, sub-population F should be surveyed on a finer scale (0.5km) each year. On the ground surveys of sub-population E should continue. In addition, intensive on the ground surveys should search for birds in sub-populations F.*

VII. Supporting Documents

This report is based on technical documents prepared by staff of ENP in collaboration with scientists from other state and federal agencies, scientific organizations, and universities. These documents provide detailed technical analyses in support of the information contained in this report and are available at the following web site: www.sfnrc.ever.nps.gov/IOP_data/

Hydrology, Hosung Ahn, Robert Fennema, Kevin Kotun, Sherry Mitchell-Bruker, Sara O'Connell, Thomas Van Lent;

Water Quality, Bob Kadlec, Mike Zimmerman, Nick Aumen, Bill Walker, Dan Childers;

Salinity, Hosung Ahn, Dewitt Smith, Bill Nuttle, Frank Marshall;

Freshwater Communities, Joel Trexler, Bill Loftus, Christina Bruno, Rick Jacobsen, Evelyn Gaiser, Jeff Kline;

Vegetation Communities, Mike Ross, Thomas Armentano;

Mangrove, Estuarine, and Marine, Jerry Lorenz, Thomas Armentano;

Cape Sable Seaside Sparrow, Skip Snow, Oron “Sonny” Bass, Stuart Pimm.

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Water Quality

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