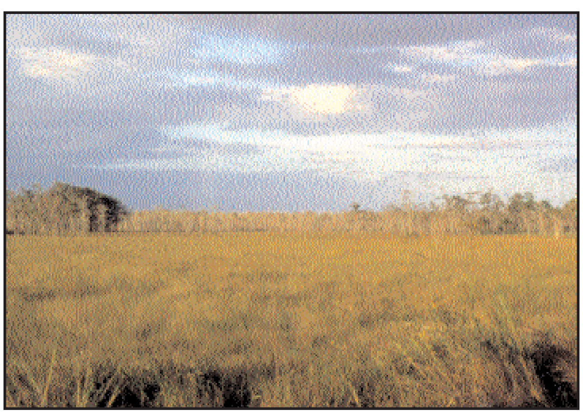
Freshwater Marshes and Wet Prairies

FNAI Global Rank:	**G3/G4**
FNAI State Rank:	**S4**
Federally Listed Species in S. FL:	**12**
State Listed Species in S. FL:	**82**

Freshwater marsh. *Original photograph by Rob Bennetts.*

Wet prairie. *Original photograph by Deborah Jansen.*



"Stability seems deadly to marsh systems..." Weller (1982).

For this account, higher elevation areas that tend to have shorter durations and lower depths of flooding are classified as short-hydropattern prairies, while areas of lower elevation are called long-hydropattern marshes. Within both general categories, there are natural mosaics of subtypes related to depressions, elevations, bedrock surface exposure, soil types, and fire regimes. Therefore, South Florida's freshwater marshes and wet prairies are best thought of as a complex mosaic that varies over time through natural succession and human-made influences (Weller 1994).

In South Florida, some marshes and wet prairies are found as isolated features in the landscape, or as zones (*e.g.* littoral zones) along significant gradients in topography and elevation around the many lakes and river systems in the northern portions of the study area (Gilbert *et al.* 1995). Other freshwater marshes and wet prairies are found along minimal gradients of topography, hydrology and soil, like those found in the Everglades and Big Cypress ecosystems. Some physiographic features, such as creeks, sloughs and seeps have, themselves, been included as marsh types (Davis 1943). The single largest, and best known freshwater marsh and wet prairie complex within South Florida is the Everglades. Isolated small freshwater marshes and wet prairies found throughout South Florida serve local and regional functions, and as Hartman (1992) has said: "Ephemeral, isolated, smaller marshes are more vulnerable to both agricultural and urban development and drainage or use as stormwater holding basin." Unique types of isolated freshwater marsh and wet prairie conditions in the Florida Keys are of critical importance to the preservation of a significant number of unique species and races found only in this chain of small islands (Moler 1992).

Synonymy

Freshwater Marsh - long-hydroperiod marshes; intermediate hydroperiod marshes; saw grass marsh; cattail marsh; flag marsh (dominated by one or more species of *Sagittaria* spp. and *Pontederia lanceolata*); mixed emergent grass/sedge marshes that include combinations of saw grass, cattails, bulrushes (*Scirpus* sp.), maidencane (*Panicum hemitomon)*, beakrush (*Rhynchospora spp*) and spikerush (*Eleocharis* sp.); sloughs, including open water marsh, submerged vegetation marsh bladderwort (*Utricularia* spp.); and floating vegetation marshes, including white water lily (*Nymphaea odorata*), floating hearts (*Nymphoides aquatica*), and/or yellow cow lily (spatterdock, *Nuphar luteum*). Other terms that have been commonly used for marshes include: water lily marsh, submerged marsh, wet prairie on peat, and open water marsh. The FLUCCS code for the freshwater marsh community includes: 641 (freshwater marshes).

Wet Prairie - short-hydroperiod prairies; marl prairies dominated or co-dominated by sparse short saw grass (*Cladium jamaicense*); muhly grass (*Muhlenbergia capillaris);* beak rush; black sedge (*Schoenus nigricans*); sandy prairies or wire grass (*Aristida stricta*) prairies; savannahs (usually dominated by short mixed prairie or saw grass prairie with isolated dwarf cypress (*Taxodium* spp.) or small isolated tree islands. Other terms that have been commonly used for wet prairie types include: short-hydroperiod prairie, wet prairie on marl, rocky glade, transverse glade, finger glade, dwarf cypress savannah, wet prairie on sand.

Olmsted and Armentano (1997) summarized the various terms used by a number of earlier authors to describe the various marsh and wet prairie associations found in the Shark Slough region in Everglades NP. The FLUCCS code for the wet prairie community includes: 643 (wet prairies).

Terminology

In preparation of this account, it became clear that there is no consensus on the terminology applied to the vegetative communities called freshwater marshes and wet prairies. Specialists in vegetative community analysis are all o aware of the wide range of plant community types found at regional scales of landscape and physiography, and as smaller localized micro-habitats, to expect an easy resolution of the terminology problems of the past (Mitsch and Gosselink 1986). In general, this account follows the classification system derived from Kushlan (1990) and Olmsted and Loope (1984), which are in strong overlap with that of Hartman (1992) used by the Florida Committee on Rare and Endangered Plants and Animals (FCREPA). In their review of plant communities in Everglades NP, Olmsted and Loope (1984) state: “We use the term “prairie” in reference to extensive short-saturated grass/sedge dominated vegetation in southern Florida which has an annual period of inundation of no more than a few months.” Kushlan (1990) stated that “Wet prairie is the least frequently flooded of any Florida marsh type. Their short hydroperiod (50-150 days per year) preclude peat development.” Finally, Olmsted and Armentano (1997) state “...that Davis [1943] intended ‘wet prairie' to refer to marl areas dominated by mixtures of forb and graminoid species but with dominance by sparse saw grass and spikerush and increasing admixtures of many other species associated with slightly higher elevations and sometimes rock outcrops."

Due to variability in the usage of the term wet prairie, a review and clarification of the terminology for the non-forested wetland communities, especially with regard to depth and duration of flooding, is necessary before they can be discussed in detail. Kushlan (1990) effectively summarized the range of hydroperiods typical of freshwater marshes and wet prairies: (1) short-hydroperiod areas, flooded less than 6 months per year--wet prairies, (2) intermediate-hydroperiod areas, flooded 6 to 9 months per year--cattail, saw grass, flag, maidencane, beakrush, spikerush freshwater marshes, (3) long-hydroperiod areas, flooded more than 9 months per year--submerged, water lily, open water marshes and slough.

Short and moderate hydroperiod prairies and freshwater marshes are seasonally dry enough to burn and they are maintained by a combination of hydropattern and fire. Frequent fires restrict the expansion of woody vegetation. Because they are seasonally flooded, the majority of wet prairie and freshwater marsh plants are tolerant of anaerobic soil conditions for varying periods of soil saturation and/or inundation. Also, depending upon their hydroperiod, the plants of a given marsh type may depend more or less on seed germination in contrast to vegetative growth.

Marshes are flooded for longer periods annually, and some types are continuously flooded. The depth and duration of flooding is greater than in wet prairies, and the plants are better adapted to continuous anaerobic soil conditions. Woody vegetation tends to be more restricted to higher elevations in the form of tree islands, or in depressions such as cypress strands or domes. Because of the longer hydropatterns, fire is a more rare event in development of marsh structure. Because they are frequently dry and contain many non-wetland species (species not listed as Facultative Wetland (FACW) or Obligate Wetland (OBL) by State and, or Federal wetland delineation lists (*e.g.* Gilbert *et al.*1995, Reed 1988), wet prairies are often difficult to delineate, and designation is often based on soil and indirect evidence of average high water levels.

No matter what else we have learned about marshes and wet prairies, it is that they are dynamic in nature and in a natural setting undergo periodic droughts, floods, and fires. In a managed state, this dynamic pattern of change must be simulated or these systems will follow successional trends toward filling in of their basins and eventual transition to forested community types ,with a dramatic loss of habitats necessary for species diversity. Much of the current problem in the Everglades is a function of holding two-thirds of the system in rigidly managed states for agriculture or water control with little or no ability for variation in the conditions needed to sustain natural biological functions.

Implications of Terminology for Management Planning

In general, the term wet prairie has been used in such a wide range of contexts as to lead to confusion by non-experts, and in planning analyses. One good example of the resulting confusion is the current wetland status of the

Pennsuco Everglades region of Miami-Dade County. This wetland is characterized by a peat soil with saw grass stands up to 3 m (9.8 ft) as the dominant vegetation with a long hydroperiod and deep water (O'Hare and Dalrymple 1997). Unfortunately, the area was and remains commonly referred to as "prairie," leading many to presume it has a shorter hydroperiod and shallower water level than actually exists. Planning options for such areas can often be dramatically misleading. Another common confusion regarding the term wet prairie has led to a great deal of misunderstanding regarding habitat preservation for Cape Sable seaside sparrows *(Ammodramus maritimus mirabilis)* and Everglade snail kites *(Rostrhamus sociabilis plumbeus)*. Both of these species have been described as using wet prairie habitat. But the Cape Sable seaside sparrow uses wet prairies on marl soils with short hydroperiods, shallow water levels, and sparse muhly grass and saw grass (Curnutt 1996), while the Everglade snail kite uses emergent grass or sedge marshes with long hydroperiods, deep water levels (required by their main prey the apple snail (*Pomaceae paludosa*), and emergent vegetation including flag marsh, white water lily marsh and open slough with submerged vegetation. When confronted with demands for preservation of wet prairie habitat for each of these species, it would be easy to presume that hydroperiod and hydropattern restoration needs of both species are similar, when in fact they could not be more different.

The simplest solution is to follow the definition of wet prairie used by Olmsted and Loope (1984) and recognize that wetlands with longer hydroperiods (typically 9 to 12 months) and greater maximum depths of flooding (30 cm [11.8 in] to a meter or more) are all easily categorized as marshes, and wetlands with short hydroperiods (typically 1 to 3 months) and shallower maximum levels of flooding (saturated soils up to about 30 cm [11.8 in]) are wet prairies. It is important to note that the clarification of the terms used herein has not included a soil designation. This is purposefully done because there are conditions in which peat, marl, or sandy soil substrates may be the current dominant soil substrate for a plant association due to geographic location along the Florida peninsula or due to short-and long-term modifications in soil formation (including soil erosion, and "oxidation" of peat) related to hydrology and fire frequency in the southern portion of the peninsula (Robertson 1954, Wade *et al.* 1980).

Distribution

The distribution of dominant plant species in freshwater marsh and wet prairie systems is considered to be a function of soil type, depth, and hydrological conditions (Kushlan 1990). Kushlan's recent review of the freshwater marshes and wet prairies of Florida identified and mapped the remaining stands of marsh habitat throughout the state. While recognizing a great many small, often isolated marshes or marsh remnants, he identified five predominant marsh systems in Florida: highlands marshes, flatwoods marshes, St. Johns marshes, Kissimmee marshes, and Everglades. (Figure 1). Davis *et al*. (1994), Light and Dineen (1994), and Olmsted *et al.* (1980) make it very clear that a variety of the freshwater marsh and prairie types are currently found in areas with hydroperiods that are much shorter than under more natural conditions.

The current problems involved in accurately distinguishing the natural historical hydropatterns and soil associations of the various non-forested wetlands are difficult, because there are significant lag-times between vegetational community change and short-term water management practices (Davis *et al.* 1994, Gunderson 1994, Light and Dineen 1984, White 1994).

Description

The majority of the plant associations of freshwater marshes and wet prairie are found throughout South Florida, including the Big Cypress Swamp region, St. Johns Marsh system, Kissimmee River floodplain, Lake Okeechobee perimeter marshes, and as far southward as isolated marshes in the Florida Keys.

Besides the enormous expanse of marshes found in the Everglades region of South Florida, marsh and wet prairie communities are associated with natural depressions, the edges of natural lakes, ponds, creeks, rivers, and human-made impoundments such as borrow pits and canals. When these communities are found within the study area from Lake Okeechobee northward, they are frequently associated with lakes, creeks, and rivers, and are often described as littoral zones. Natural lakes and rivers are absent from South Florida below Lake Okeechobee (with the exception of Lake Trafford, near Immokalee, in Collier County). However, numerous artificial impoundments and lakes are common in the southern portion of the study area, in the form of canals, borrow pits, and human-made lakes.

The soils associated with marshes are histosols, composed of thick organic peat underlain by marl and/or limestone. The soils associated with wet prairies in the southeastern portion of the study area are entisols, dominated by either poorly drained marls or mixtures of marl and sand underlain by limestone. The wet prairies of the southwestern and more northern portions of the study area are either entisols, or spodosols, which are poorly drained sandy soils with loamy subsoils (Brown *et al.* 1990). However, frequent shifts in water management practices have created a recent history of changes in many of these soils, with layers of marl and peat reflecting variations in hydrology and decomposition rates of vegetation.

Long-and Intermediate-Hydropattern Freshwater Marshes

Saw grass Marsh

The saw grass marshes tend to be dominated by tall, dense to sparse stands of *Cladium jamaicense*. Saw grass once covered more than 800,000 ha (1,920,000 acres) of the Everglades, and Loveless (1959a) estimated that it covered 70 percent of the remaining Everglades at the time of his study. These freshwater marshes also may have significant invasions of *Melaleuca quinquenervia*, or native trees (*e.g. Myrica cerifera, Persea borbonia* and *P. palustris, Salix carolina,* and *Ilex cassine)*. Some sparse saw grass marshes are more savannah-like, and have widely scattered individual dwarf cypress trees and isolated cypress domes.

Saw grass marsh is defined here as any wetland in which the dominant plant species is *Cladium jamaicense*. This plant species is found in a wide range of ecological settings including estuarine and coastal grasslands;

mangrove forests; wet prairies; short-hydropattern prairies; lakes, ponds, and other depressional features; cypress savannahs, cypress domes and swamps; and hardwood forests (Craighead 1971, Kushlan 1990, Olmsted *et al*. 1980, Wade *et al*. 1980). It is clear that the species is tolerant of a wide range of physiological stressors (Steward 1984). Marshes that are dominated by saw grass are generally subdivided into dense saw grass and sparse saw grass marsh types (Kushlan 1990). In dense saw grass marshes, the species reaches heights of 3 meters (9.8 ft), is extremely dense, and forms a near monoculture. In sparse saw grass marshes, the species is usually much shorter, only about a meter (3.28 ft) in height, and the space between individual stems is occupied by a diversity of other marsh plant species (Craighead 1971, Olmsted and Armentano 1997, Wade *et al.*1980, Werner 1975). Olmsted and Armentano (1997) recognized that an "intermediate" category of saw grass (between tall dense and short sparse saw grass) could be identified, but they felt that it was unnecessary, since the density and height of saw grass appears to respond rapidly to changes in hydropattern and fire.

Cattail Marsh

Cattail marshes are dominated by dense stands of *Typha* spp. with *Scirpus* spp. In many areas, the marsh complex is in dynamic transition from saw grass marsh to monotypic stands of *Typha* spp. These changes have been related to changes in water quality and/or quantity (Craft *et al.* 1995, Davis *et al.* 1994). In the southern portion of the study area, it is natural to find small dense stands of *Typha dominguensis*, while *Typha latifolia* is more common farther north.

Lodge (1994) and Newman *et al.* (1996) considered *Typha dominguensis* to be an indicator of eutrophication, especially of high phosphorus levels. Newman *et al.* (1996) noted that *Typha dominguensis*, in experimental treatments, responded positively in terms of growth to both increased water levels and increased phosphorus loadings. Net accumulation of phosphorus was 2 to 3 times greater than in *Cladium jamaicense* or *Eleocharis interstincta.* They noted that *Typha* showed an increase in biomass in response to elevated phosphorus by as much as 45 percent, and an increase in biomass to higher water levels by as much as 60 percent (Dalrymple, Everglades Research Group, personal communication 1998). *Typha dominguensis* often occurs naturally in the most isolated, oligotrophic, and pristine waters of the southern marl prairies in Everglades NP. In the marl prairies, the cattail stands tend to be in depressions with longer hydropatterns and where more peat and less marl is found. Small dense stands of cattails are also a normal part of the mosaic in both freshwater marshes and wet prairies, and are valuable habitat for many animals (including least bitterns (*Ixobrychus exilis*), common snipe (*Capella galinago),* limpkin (*Aramus guarauma),* red-winged blackbird (*Agelaius phoeniceus),* and round-tailed muskrat (*Neofiber alleni*). The rapid expansion of cattail marsh in the long-hydropattern marsh system is probably a long-term response to altered hydropatterns as well as increased phosphorus levels and the exclusion of fire.

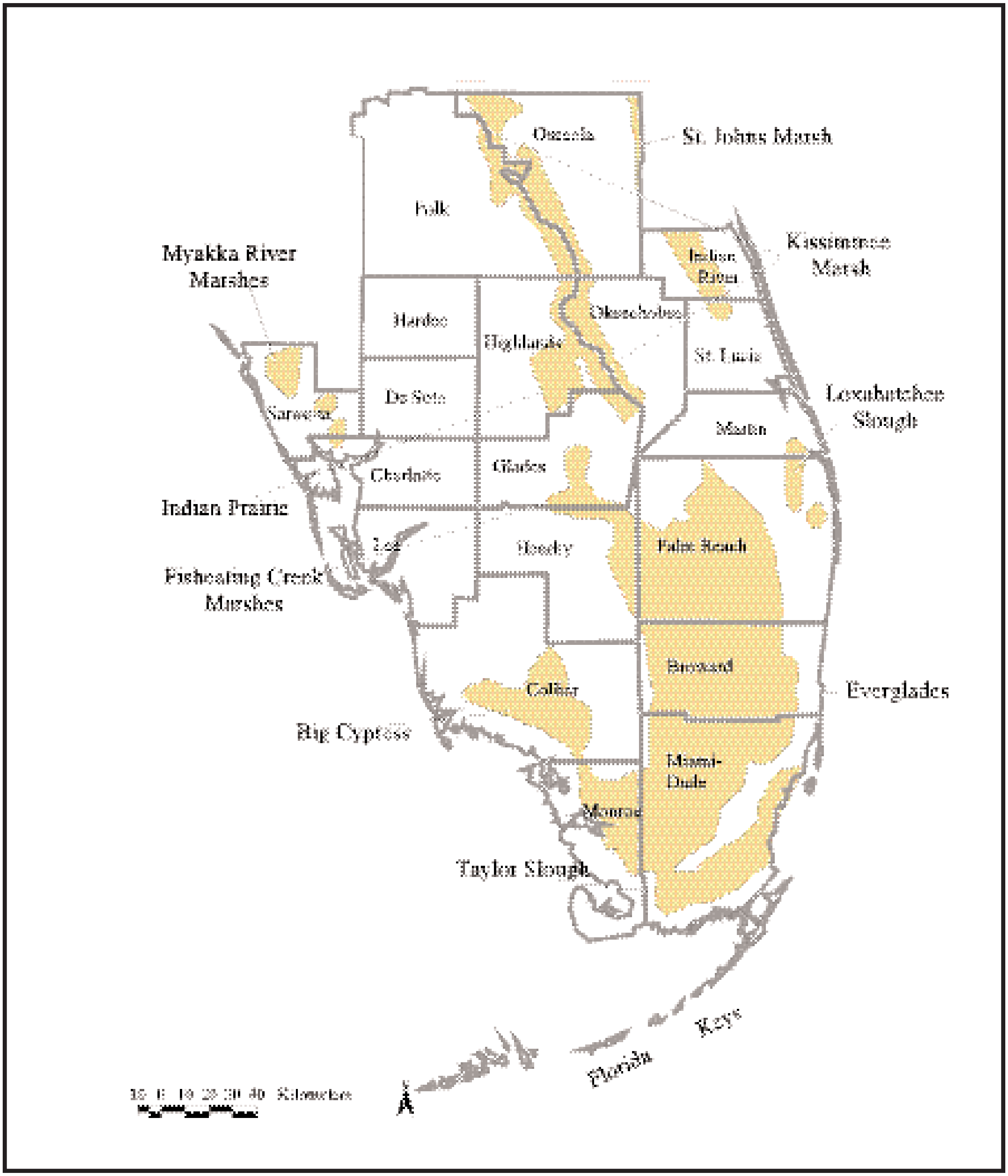


Figure 1. The distribution of major freshwater marshes and wet prairies in South Florida.

Maidencane Marsh

This is typically dominated by *Panicum hemitomon*, but often has rice cut grass (*Leersia hexandra*), *Sagittaria lancifolia*, *S. latifolia*, *Xyris difformis* and *Pontederia lanceolata*. In Paynes Prairie, Birkenholz (1963) considered this marsh type to be typical of water 15 to 46 cm (6 to 18 inches) deep. In the northern portions of the study area, maidencane marshes may grow on pure sand substrates (Birkenholtz 1963), and show a marked seasonality in growth and coverage, due to varying hydropattern and cold winter temperatures. Loveless (1959a) considered maidencane marshes to be rather recent in their dominant role in the marsh system. He considered this species to be better adapted to drier conditions, where it showed higher density, but noted that it can withstand long periods (up to 9months) of flooding up to one meter (3.28 ft) by growing rapidly. Propagation by rhizomes is common in flooded conditions, but seeds commonly germinate during dry periods. The species is well adapted to fire, showing rapid growth of new sprouts. According to Kushlan (1990), maidencane marshes cannot tolerate continuous flooding and require an annual period of drying down. However, Gilbert *et al.* (1995) found maidencane marsh occupying the deepest portions of the marshes that they evaluated in Jonathan Dickinson SP in southern Martin County. In the Martin County marshes, the substrate was described as Waveland soil. In the Everglades, maidencane marshes are usually found on peat, show little seasonal variation due to the more subtropical growing conditions, and are in a range of hydropatterns.

Beakrush Marsh and Spike Rush Marsh

These marshes are typically dominated by *Rhynchospora tracyii* or *Eleocharis* spp., respectively, but often have a mix of other rushes. These areas are often called *Rhynchorpora* or *Eleocharis* flat. In general, they occur in intermediate water depths with hydroperiods that show more variation, with continuous surface flooding being more variable, and periods when the surface peat is merely saturated are not uncommon under natural conditions. This marsh type is often found in deeper areas within wet prairie mosaics.

Flag Marsh

Flag marshes are dominated by *Sagittaria lancifolia*, *S. latifolia*, or *Pontederia lanceolata*. They are generally found in deeper areas and depressions surrounded by other marsh types, such as saw grass or maidencane. This marsh type is frequently found as isolated small areas within the wet prairies as small marshes in solution holes and depressions, frequently with a higher peat soil layer. When this marsh type is found in a mosaic of short-hydropattern wet prairies, it becomes an especially important refugia and breeding area for apple snails, crayfish, and a host of other invertebrates as well as fishes and amphibians (Dalrymple, Everglades Research Group, personal communication 1998). As isolated marshes in a wet prairie matrix, there may be significant amounts of *Bacopa* spp., *Proserpinaca* spp., *Utricularia* spp., *Chara* spp., *Crinum americanum*, and *Oxpolis filiformis* in these solution hole flag marshes.

Floating Vegetation Marsh

White water lily (*Nymphaea odorata*), floating hearts (*N. aquatica*), and/or yellow cow lily (spatterdock, *Nuphar luteum*) form expansive regions in deeper water with longer hydroperiods. Associated submerged and floating plants include heavy mats of periphyton and *Utricularia* spp. *Nymphaea* spp. is commonly associated with Loxahatchee peat, which is considered to form only under almost continuous inundation (Cohen and Spackman 1984).

Slough

The freshwater marshes with the longest hydroperiods and deepest water levels include open water marsh and submerged vegetation marsh. *Utricularia* spp. and periphyton are the most common plant associations in these areas.

Davis *et al.* (1994) defined slough as: “A composite of two plant associations growing in deeper areas of peat and characterized by *Eleocharis cellulosa*, *E. elongata*, *Rhynchospora tracyii*, *R. inundata*, *Panicum hemitomon*, *Nymphaea odorata*, *Nymphoides aquatica*, *Nuphar luteum*, *Utricularia foliosa*, and periphyton.” Common plant species in these marshes include *Nymphaea odorata*, *Orontium aquaticum*, *Nelumbo lutea*, *Najas guadalupensis*, *Utricularia* spp., *Potamogeton* spp., *Pontederia lanceolata*, *Sagittaria latifolia*, *Eleocharis* spp., *Panicum hemitomon*, *Thalia geniculata*, *Rhynchospora colorata, R. tracyii*, *Spartina bakeri*, and *Hypericum* spp. (Davis 1994, Egler 1952, Gunderson 1994, Kushlan 1990, Lodge 1994, Olmsted *et al*, 1980, Robertson 1955, Wade *et al.* 1980).

Short-Hydropattern Wet Prairies

This category includes wet prairies found on marl soils, sandy soils (farther northward), and exposed limestone bedrock in the rocky glades region of the southeastern Everglades, as well as in dwarf cypress savannahs. These wet prairies typically have a high frequency of limestone exposures above the marl soil, resulting in what is locally called a micro-karst topography. However, in some areas such as the rocky glades region of the east Everglades and in peripheral wet prairies to Taylor and Shark sloughs, there may be numerous solution holes in bare limestone. Some of the solution holes retain organic matter, and over long periods of time, develop a soil locally known as “Gandy peat” within them. One early describer of the wet prairies said they had more holes than solid ground (Dade County 1979). These numerous solution holes are in direct contact with the underlying aquifer and serve as vital refugia for aquatic and semi-aquatic species during seasonal drying down of water levels. These refugia become concentrated with fishes, amphibians, reptiles, and invertebrates, and are preferred foraging areas for a wide range of wading birds as water levels are dropping.

Marl Prairies, Short Saw grass Prairie, Muhly Prairie, Mixed Grass/Sedge Prairie, and Rocky Glades Prairie

Olmsted *et al.* (1980) and Kushlan (1990) described wet prairies as the driest of the marsh categories. Olmsted *et al.* (1980) found that “*Muhlenbergia* appears to thrive best where hydroperiods of 2 to 4 months occur.” Wet prairies on marl soils and exposed limestone have a mixture of *Muhlenbergia capillaris,* short *Cladium jamaicense*, *Schoenus nigricans*, *Rhynchospora* spp., *Hypericum* spp., *Baccharis* spp., *Panicum* spp., *Aristida purpurascens*, *Schizachyrium rhizomatum*, *Eragrostis ellioti*, and *Spartina bakeri*. Overall, this wetland type is found on the widest range of environmental conditions with regard to substrate, soil, and salinity. Most of the species in the wet prairies tend to be herbaceous, not graminoids, but the short *Cladium* or *Muhlenbergia* is the dominant plant by coverage.

Early descriptions of the marl prairies did not mention muhly grass, leading many to believe it is a recent community type, related to reduced hydroperiods and/or more frequent fires in prairies previously dominated by saw grass. Much attention has been recently given to muhly prairie as the preferred habitat for the endangered Cape Sable seaside sparrow. Olmsted *et al*. (1980) evaluated this issue at length: "Although *Muhlenbergia* prairie is presently one of the most extensive communities of Everglades National Park and occupies large areas in Big Cypress National Preserve, this may be the result of recent vegetation changes." Werner (1975) states that "some of the older South Florida naturalists claim that *Muhlenbergia* was somewhat rare in the past and that it is only the recent destruction by drought fires of the shallow organic soil which formerly overlaid the marl and the general drying of South Florida which has propagated the vast *Muhlenbergia* prairies of today." Two other factors should be noted: In the vegetative state, *Muhlenbergia fillipes* [*capillaris*] and *Schoenus nigricans* look very much alike and are not distinguishable from afar. It is very possible that *Muhlenbergia* was mistaken for *Schoenus* in earlier days. The beakrush, *Rhynchospora tracyii*, also looks very much similar to *Muhlenbergia*.

When wet prairies are found as elongated strips of lower-lying land intersecting sections of the large stands of *Pinus ellioti* and tropical hardwood hammocks in the southern portions of the elevated Atlantic Coastal Ridge, they are locally called transverse or finger glades. These finger glades are narrow and abundant in the remaining large pinelands of Long Pine Key in Everglades NP and in parts of the Big Cypress National Preserve, and are seasonally available to a wide range of animals and plants. As ecotones, they have a higher overall annual diversity of plants and animals than the upland habitats they intersect (Dalrymple 1988, Olmsted *et al.* 1980).

Wet Prairies on Sandy Substrates

These wet prairies are often difficult to delineate due to their short hydropatterns and high frequency of non-wetland herbaceous species including wiregrass (*Aristida stricta)*, *A. spiciformis*, *Andropogon virginicus*, *Asimina* spp., *Befaria racemosa*, *Drosera* spp., *Eragrostis* spp., *Euthamia* spp., *Hypericum reductum*, *H. tetrapetalum*, *Ilex glabra*, *Lyonia fruticosa*, *L. lucida*, *Penstemon australis*, *Rhexia* spp., *Schizachyrium* spp., *Serenoa repens*, *Sabal palmetto*, *Vaccinium myrsinites*, as well as *Quercus pumila*. They are often delineated on the basis of the geographic distribution of the dominant wetland species and evidence of algal mats of periphyton, and hydric soils. Dominant wetland plants include: *Aster* spp., *Baccharis halimifolia*, *Drosera* spp., *Eustachys* spp., *Hypericum cistifolium*, *H. fasiculatum*, *Myrica cerifera*, *Panicum scabrisculum*, *Scleria* spp., and *Xyris brevifolia*. Further northward in the South Florida study area, sandy soils become more common, especially along the Lake Wales Ridge and the Kissimmee chain of lakes, and the species composition is significantly different than in the southern Everglades region (Gilbert *et al.* 1995, Wunderlin 1982).

The Everglades

The Everglades is the largest single basin of diverse wetlands in the study area, originally covering over 6,440 square km (4,000 sq. miles). The basin is bordered on the east by the Atlantic Coastal Ridge and on the west by the Big Cypress Swamp. The basin is approximately 160 km (100 miles) long, and 65 km (40 miles) wide, with an average slope of only 3.16 to 4.73 cm per km (about one ft in 10 miles) (Izuno and Bottcher 1994, Light and Dineen 1994). Depth in the Everglades historically varied seasonally, but was never much more than 1.3 m (about 4 ft) in its deepest marshes. The southern portion of the Everglades, the western edge of the Shark Slough has a more abrupt change from higher to lower elevations, but both edges of the basin are bordered by distinct edges that show a transition from longer hydroperiods with peat soils, to shorter hydroperiods with marl soils and extensive limestone bedrock exposures (Olmsted and Armentano 1997).

Historically, when waters in Lake Okeechobee rose over 1.4 m (4.5 ft) above mean sea level, a sheet of water up to 51 km (32 mi) wide overflowed the southern rim of the lake into the Everglades (Parker, 1984). The Lake Okeechobee basin historically covered approximately 193,333 ha (464,000 acres) (Izuno and Bottcher 1994) with a mean depth of only 3 meters. This extremely large basin of shallow water made the historical Kissimmee-Lake Okeechobee-Everglades basin attractive habitat for a wide range of semi-aquatic and aquatic plant communities, and diverse food webs dominated by hundreds of thousands of water birds, wading birds, and alligators.

The single most important element in adding habitat interspersion and a higher diversity of organisms in the Everglades is the presence and distribution of tree islands. Loveless' (1959b) review of the Everglades' white-tailed deer herd recognized the importance of these dry islands of hardwoods for a variety of wildlife, and he estimated that approximately 12 percent of WCA 2 was tree island habitat during the time of his studies. Tree islands play the most significant role in determining overall marsh and wet prairie diversity in the Everglades, and excessive flooding due to management practices has a slow but dramatic effect on the health of tree islands (Guerra 1998).

Plant Density and Composition

The identification of flag marshes, water lily marshes, and others. are all based on the fact that a single species dominates a local area (Gunderson, 1994, Turner 1996). In his study of marsh types in relation to apple snail oviposition preferences, in Blue Cypress Water Management Area (Indian River County), Turner (1996) chose a variety of marsh types in which he measured stem density per square meter. In saw grass marshes, stem density averaged 151 per square meter. In maidencane (*Panicum hemitomon*) marshes, stem density averaged 255 stems per square meter; in deep marshes, stem densities were only 18 per square meter; and in mixed shallow marshes (*Eleocharis elongata*, *Sagittaria lancifolia*, *Panicum hemitomon*, and *Pontederia cordata*) density averaged 286 stems per meter square.

In wet (marl) prairies in the southern Everglades, "*Cladium* generally provides 80 to 90 percent of the cover in *Cladium* prairie. *Muhlenbergia* typically provides 70 to 90 percent of the cover in the community with a shorter hydroperiod" (Olmsted *et al*. 1980). Other important species include *Schizachyrium rhizomatum*, and *Schoenus nigricans*. In the dwarf cypress savannahs, *Taxodium distichum* forms an open canopy of up to 20 percent (see below). More than 100 species can be found in the muhly prairies, with 4 to 13 species per square meter, and 10 to 22 species per five square meters (Armentano *et al.* 1998b, Dalrymple *et al.* 1993, Dalrymple and Doren 1998, and Olmsted *et al*. 1980) Freshwater marshes of the Lower Keys are typified by saw grass, buttonwood (*Conocarpus erectus*) , red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), wax myrtle (*Myrica cerifera*), saffron plum (*Sideroxylon celastrinum*), *Fimbrystylis* spp., and. *Eleocharis cullulosa*.

Olmsted and Armentano (1997) reviewed the distributions, soil depths, soil types, percent coverage and species per square meter in a series of transects in Shark Slough in Everglades NP and summarized their results by saying: "The Shark Slough marsh communities are distinguished by their low plant species diversity (3 to 6 species/m^2), and single species dominance and low vascular plant cover (2 to 16 percent) except for tall saw grass stands where cover reaches 96 percent." The researchers find "The available evidence, however, suggests the conclusion that saw grass communities have expanded in Shark Slough as a response to reduction in hydroperiods."

Species Diversity

Weller (1982) recognized the importance of the wide diversity of semi-aquatic and upland species that seasonally use and contribute to the productivity and diversity of wetland settings. Weller noted that: "Commonly, marshes are viewed as basins that can be changed to a unit more productive of a single species or complex of species other than those found there at a given time." And he considered it important in both natural and artificial wetlands to maintain species diversity for overall system health.

Weller (1982, 1994) reviewed the literature on nesting by wetland birds and noted the following:

(1) There was a positive correlation between the number of bird nests with the number of plant communities in marshes.

(2) Many marsh birds nest near water/cover interfaces or the meeting of two cover types.

(3) Most species favor marshes with a ratio of 1:1 cover-water interspersion.

(4) The greatest species richness and greatest density of nests occurred where there was high interspersion of open water within the vegetated portions of marshes (ranging from 1:1 to 1:2 cover-water interspersion).

(5) Marshes with a complete plant zonation also have several layers of vegetation.

(6) To preserve a typical marsh avifauna, it is best to have several wetland types, as well as upland areas present.

Weller (1982) also reviewed the importance of aquatic invertebrates and mammals in overall wetland function and concluded that a healthy marsh is part of a wetland-upland complex that includes fully aquatic, semi-aquatic and upland species (*e.g.* herbivores such as nutria, deer, muskrat). He stated that "Stability seems deadly to marsh systems, at least where terrestrial or semiaquatic faunas are preferred to open marsh or lake faunas."

Mammals

The mammal fauna of saw grass marshes includes species that are well adapted to the community, including: rice rat (*Oryzomys palustris natator),* round-tailed muskrat, river otter (*Lutra canadensis),* and highly mobile species that regularly or seasonally move through the marshes, including the white-tailed deer (*Odocoileus virginianus),* Florida panther (*Puma concolor coryi),* bobcat (*Lynx rufus),* and raccoon (*Procyon lotor).* The Lower Keys marshes are very important to Key deer and Lower Keys rabbits.

Birds

In marshes, passerine birds show low species richness and abundance (Robertson 1955, Robertson and Kushlan 1984), especially in dense pure stands of saw grass and cattail marshes. Two to six species of passerine birds are typical in open country habitats (Cody 1985). Most wading birds and water birds find the dense stands of tall emergent plants difficult to forage in (Hoffman *et al*. 1994, Kushlan 1976). The absence of true grass species and small trees in pure saw grass marsh limits the value of this marsh type for nesting habitat for birds. There are some species that do regularly use these denser tall emergent marshes including: common snipe (*Gallinago gallinago*), limpkins (*Aramus guarauna*), bitterns (*Botaurus lentiginosus*), and red-winged blackbirds (*Agelaius phoeniceus*). Wading birds and water birds, including: cormorant (*Phalacocorax auritus),* anhingas, (*Anhinga anhinga),* moorhens (*Gallinula chloropus*) and purple gallinule (*Porphyrula martinica),* use the more open marsh types more commonly, especially flag marshes, where lower stem densities and dropping water levels during the dry season make them particularly attractive foraging areas (Bancroft *et al.* 1994, Hoffman *et al.* 1994, Kushlan 1976, Ogden, 1994). Wading birds normally exploit forage fishes during periods of dry-down, when the fishes are trapped in small puddles and pools of water at extremely high densities (Frederick and Collopy 1988, Kushlan 1976). Such drying down currently does not exist for many portions of the WCAs and Everglades NP, which have long periods of near-constant high water levels artificially maintained for water management purposes. Great concentrations of ducks can be found in the most open water marshes including submerged marsh, water lily marsh, slough, and along the littoral zone edges of lakes and rivers.

The wet prairies also have low densities and low richness of breeding species including the common yellowthroat (*Geothlypis trichas*), eastern meadowlark (*Sturnella magna*), and Cape Sable seaside sparrow; and neotropical migratory birds (*e.g.* bobolink (*Dolichonyx oryzivorus*), yellow-rumped warbler (*Dendroica coronata*)*,* but they usually focus on trees found as small tree islands within these prairies and in savannah settings (O'Hare and Dalrymple 1997). The sparser vegetative cover of wet prairies makes them particularly attractive to wading birds as foraging sites, especially as water levels are falling and prey are being concentrated in depressions (Hoffman *et al*. 1994).

Herpetofauna

In comparison to the bird fauna, the herpetofauna of saw grass marsh is diverse and abundant. While many vertebrate groups show a significant decline in species diversity proceeding down the peninsula of Florida (Robertson and Kushlan 1984, Robertson and Frederick 1994), salamanders are the only group of amphibians or reptiles that shows an appreciable decline in diversity in the southern portion of the state (Dalrymple 1988). Only four species, *Amphiuma means*, *Siren lacertina*, *Pseudobranchus striatus*, and *Notopthalmus viridescens*, are recorded from the Everglades region (Dalrymple 1988, Duellman and Schwartz 1958). The other major herptile groups are well represented (Dalrymple 1988, Dalrymple *et al.* 1991a, b). As in the case of freshwater fishes, what the herpetofauna may lack in diversity is compensated for by the high standing crops of the existing species. Without these high standing crops, the forage base for higher trophic levels, including wading birds, many raptors, carnivorous mammals, and the American alligator (*Alligator mississippiensis)* would not be as abundant as it once was, and still is.

Snakes, turtles, and lizards are able to bask on dead and live saw grass blades and on larger clumps of saw grass. Both salamanders and frogs are numerous in the wide range of marshes, and frequent the water lily and flag marshes as areas for egg laying. They also readily exploit saw grass mounds constructed by alligators for nesting and the nests and platforms of round-tailed muskrats. The frogs and toads that are abundant include the pig frog (*R. grylio*), southern leopard frog (*R. sphenocephala*) cricket frog (*Acris gryllus*), little grass frog (*Pseudacris ocularis),* green treefrog (*Hyla cinerea),* squirrel tree frog (*Hyla squirella*), and chorus frog (*Pseudacris nigrita*). Both the southern toad (*Bufo terrestris)* and the oak toad (*Bufo quercicus*) are common in wet prairies and saw grass marshes. The exotic Cuban treefrog (*Osteopilus septentrionalis*) is not as common in open marshes as it is in ruderal and forested ecological communities, but is expanding its range rapidly into more remote marsh and prairie habitats (Dalrymple 1994b).

The cottonmouth (*Agkistrodon piscivorus*), mud snake (*Farancia abacura*), and water snakes of the genera *Nerodia*, *Regina*, and *Seminatrix* are all very abundant, as are the soft-shelled turtle (*Apalone ferox*), snapping turtle (*Chelydra serpentina*), sliders and cooters (*Trachemys* and *Pseudemys* spp.), stinkpot (*Sternotherus odoratus*), and mud turtles (*Kinosternon* spp). The only common lizard in saw grass marsh is the green or Carolina anole (*Anolis carolinensis*), which occurs in high abundances. The southeastern five-lined skink (*Eumeces inexpectatus*) and ground skink (*Scincella lateralis*) are common in the wet prairies during the dry season. In general, about 75 percent of the 72 species of South Florida amphibians and reptiles (Duellman and Schwartz 1958) seasonally move from uplands and marshes into seasonally flooded wet prairies at different times during the course of a hydroyear (Bernardino and Dalrymple 1992, Dalrymple 1994b). This seasonal shift in habitat use helps to emphasize the role of a mosaic of habitat types required to sustain the normal trophic dynamics of South Florida freshwater wetlands (O'Hare and Dalrymple 1997).

Fishes

Williams *et al*. (1985) gave extensive details and reviews of habitat characteristics of freshwater marsh and lake littoral zones that are beneficial to forage fish, sport fish, and overall wetland quality. They also emphasize the role of periodic drawdowns, as have Frederickson and Laubhan (1994) in improving overall quality of marshes for vegetative interspersion, habitat quality, forage fish populations, and habitat for fish nesting.

The saw grass marsh has a limited native fish community (Dineen 1984, Loftus and Kushlan 1987) that is generally dominated by small species of detritivores, omnivores and insectivores, with cyprinodontids and poecilliids composing 50 percent of the total in the study by Loftus and Kushlan (1987). Common species include: mosquito fish (*Heterandria formosa*), flagfish (*Jordanella floridae*), bluefin killifish (*Lucania goodei*), top minnows (*Gambusia* spp.), and small centrachids such as Everglades pygmy sunfish (*Elassoma evergladei*), bluespotted sunfish (*Enneacanthus gloriosus*), and other sunfishes (*Lepomis* spp.). Some species show dramatic adaptations for withstanding drought, with eggs that can undergo long dry periods (Harrington 1959) or by tolerating very low oxygen levels via hemoglobin polymorphisms (Lodge 1974). Others show significant annual mortality and residual populations surviving in subterranean refugia (O'Hare and Dalrymple 1997).

Quantitative samples were made by Loftus and Ecklund (1994) to compare the hydropattern effects for diversity and density of fishes in the Everglades NP Shark Slough marshes west of the L-67 extension canal, and in the area to the east of the canal in the Northeast Shark River Slough (NESRS). Fish densities in NESRS were much lower than in the Everglades NP, even after prolonged flooding from 1982 to 1985. They theorized that the carrying capacity of NESRS marshes for fishes was greatly reduced due to long-term effects on the detrital food chain.

In discussing the largemouth bass (*Micropterus salmoides)*, that they considered the "most highly prized freshwater game fish in Florida," Williams *et al.* (1985) state: "Florida bass are largely oriented to the littoral zone, preferring shallow, highly vegetated areas. Blocknet samples taken from Lake Kissimmee showed a littoral/limnetic population density ratio of 10:1 for harvestable sized bass (greater than 25 cm TL), while the littoral/limnetic density ratio for nearby Lake Tohopekaliga was 16:1 in 1977. In the southern Everglades, long-term data sets are available for fish communities in alligator holes (Nelson and Loftus 1998), and in spike rush dominated slough marshes in the southern Everglades (Trexler *et al.* 1998). These studies included periods of drought, as well as the most recent high water conditions of the 1990s. In both cases the authors were hesitant to draw conclusions, citing sampling biases (large versus small fish species, and lag time between water stages and fish community structure). They have re-emphasized the need for long-term monitoring and the need to standardize sampling methods. In general, Trexler *et al*. (1998) felt that their data suggested that species richness is slightly higher in long-hydroperiod marshes than in short hydropattern marshes (wet prairies). They also felt the evenness is greater in longer-hydropattern marshes due to the predation on abundant small species of fishes by larger piscivorous fishes. Finally, their data indicate that fish densities peak at intermediate hydroperiods, and that standing crop increases with hydroperiod, due to the bias of the rare but heavier, large species found in longer-hydroperiod settings (Loftus and Ecklund 1994).

Aquatic Macroinvertebrates

Nationwide numerous aquatic larval or nymphal stages as well as adult invertebrates are imperiled. In South Florida, most aquatic macroinvertebrates are poorly known and/or the actual preferred aquatic habitats used by the juvenile stages are not documented (Franz 1982). Nevertheless, they play a vital role in the food chain and overall ecosystem dynamics.

Turner (1996) investigated the use of emergent plant stems by apple snails in the Blue Cypress Water Management Area in the St. John's River Water Management District in Indian River County. The plants most commonly used for egg laying by apple snails were *Cladium jamaicense*, *Crinum americanum*, *Pontederia cordata*, and *Sagittaria lancifolia*. Turner recommended that marsh management to promote apple snail populations involves maintaining a heterogeneous community of broad-stemmed emergent aquatic plants at moderate density. In the much shorter-hydropattern wet (marl) prairies of the southern Everglades, in Everglades NP, apple snails seldom used any emergent plant other than *Sagittaria lancifolia*. The *Sagittaria* were always located in solution holes with deeper water and longer hydroperiods than the surrounding matrix of sparse saw grass and muhly prairies.

In marshes and canals and along rivers and lakes, large floating mats of the exotic water hyacinth (*Eichornia crassipes*) shade out the submerged native plants of open marshes, including native forage foods for apple snails. Compounding the problem are the direct and indirect effects on apple snails of herbicidal treatment of aquatic pest plants (Bryan 1996). Because the apple snail is a staple prey item for such a wide range of species, including Everglade snail kites, limpkins, grackles, young alligators, many turtles, raccoons, and otters, it is an important indicator of the status and health of a wide range of South Florida wetlands.

The crayfish (*Procambarus alleni)* is another very important food item for a wide range of freshwater marsh and wet prairie predators, including wading birds, raccoons, alligators, turtles, snakes, larger frogs, and fishes. Sampling for crayfish abundance in the upper St. John's River basin by Jordan *et al.* (1996a) showed significantly higher densities of crayfish in denser marsh vegetation, with an average of over 25 crayfish per square meter (10.8 sq ft) in marshes with high stem densities, and an average of less than 5 per square meter in slough habitat. Jordan *et al.* (1996b) performed laboratory experiments on habitat preferences for vegetation common to the study area.

They found that crayfish preferred vegetated habitats over open habitats both during the day and night, but crayfish were more likely to use open water sites at night. Large crayfish were shown to prey on smaller crayfish. When the predatory largemouth bass was introduced to lab aquaria with various size classes of crayfish, there was reduced survival of smaller-sized crayfish but no effect on adult crayfish. Predation was lower when the complexity of the vegetation in experimental tanks was increased.

Plants

Plants in the marshes and wet prairies show a wide range of adaptations for dealing with floods and anaerobic conditions, droughts and aerobic conditions, fire, and reproduction. In general, saw grass stems are eaten by few or no herbivores, while the stems and leaves of flag, lilies, and some of the grasses, submerged plants, and woody species are valued by a wide range of insects, mammals, and turtles. The seeds of many marsh plants are important seasonal food for water birds and wading birds, especially ducks. The below-ground plant tissue is often the preferred food of a number of marsh dwelling mammals including the round-tailed muskrat, and white-tailed deer (Kushlan 1990).

Most marsh types are dominated by fewer than 10 species (Craft *et al.* 1995, Kushlan 1990, Olmsted and Armentano 1997). Wet prairies have much higher species richness. In their comparison of species richness in marshes and wet prairies in Taylor Slough, Olmsted *et al.* (1980) listed 70 species in muhly prairies, 89 species in sparse saw grass prairies, 18 in spikerush flats, and 8 in open sloughs (ponds). In most studies of sparse saw grass prairie and muhly prairie, only 1 to 3 species make up over 90 percent of the cover in plot samples. Additional studies have documented over 100 species in marl prairies of muhly or mixed saw grass and muhly grass (Dalrymple and Doren 1998, Olmsted *et al.* 1980, Werner 1975).

Wildlife Species of Concern

Federally listed species that depend upon or utilize the marsh and wet prairie communities in South Florida include: Florida panther, Key deer (*Odocoileus virginianus clavium*), Lower Keys rabbit (*Sylvilagus palustris hefneri*), Silver rice rat, Audubon's crested caracara (*Polyborus plancus audubonii*), bald eagle (*Haliaeetus leucocephalus*), Cape Sable seaside sparrow, Everglade snail kite, Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), wood stork (*Mycteria americana*), and eastern indigo snake (*Drymarchon corais couperi*). Biological accounts and recovery tasks for these species are included in "The Species" section of this recovery plan.

Saw grass marshes and wet prairies are not preferred habitat for Florida panthers, bobcats, or white-tailed deer (Harlow 1959, Loveless 1959b, Smith and Bass 1994). Nevertheless, all of these species are traditional users of the Everglades wetlands, especially during dry seasons and droughts. Florida panthers and white-tailed deer frequently cross wetlands to move between Everglades NP and Big Cypress National Preserve, and during the drought years of 1989 to 1991 one Florida panther in Everglades NP became a common predator on alligators during radiotracking studies of the species (Dalrymple and Bass 1996).

In the southern Everglades, Miller (1993) and Smith *et al.* (1996) stated that adult bucks spent more time alone, and prefer to spend time on tree islands. Isolated bucks in the dense cover of tree islands may be easier to stalk by panthers. They also noted that females tend to stay in groups in more open prairie habitat. Such groups may be more difficult to approach and stalk by panthers. Moreover, the reduced rate of deer kills in the wet months of July through September in Everglades NP (Dalrymple and Bass 1996) correspond to the months when bucks are more commonly associated with groups of does in open prairie habitat (Smith *et al.* 1996), and again this may make close approach by stealth more difficult for panthers to successfully kill deer.

In the Big Cypress National Preserve, Miller (1993) found adult male deer to be twice as likely to use hardwood tree islands as females. Miller also suggested groups of female deer may use open habitat more often as part of a predator avoidance behavior.

In evaluating bobcat predation on fawns in the Big Cypress, (Land 1991) pointed out that peak rates of bobcat predation on fawns were in June and July, and that rates of fawn kill were much lower from August to December. The acquisition of additional upland habitat, especially for movement and dispersal corridors (Cox *et al.* 1994) is fundamental to the long-term preservation of the Florida panther and its main prey. But, in the Everglades, extended periods of natural or human-caused flooding in the WCAs and Big Cypress National Preserve have led to numerous documented periods of high mortality in white-tailed deer populations, that have significant effects on their predators (Loveless 1959b, Harlow and Jones 1965, Jansen 1998). Restoring hydropatterns that include seasonal drydowns for access to marsh habitat and isolated tree islands is essential to the preservation of these species in the Everglades (Harlow and Jones 1965, Maehr 1997, Smith and Bass 1994).

The **Florida sandhill crane** (*Grus canadensis pratensis*) is a non-migratory bird that utilizes the freshwater marshes and wet prairies in South Florida. This species differs from its related *G.c. canadensis* by being much larger. Nesting typically occurs in shallow ponds, marshes, and lakes with thick emergent vegetation such as: *Pontederia*, *Sagittaria*, and *Panicum*, or bog button (*Sclerolepis* spp.), saw grass, and/or cattails. It tolerates limited human disturbance, but is threatened by continued habitat loss due to hydrologic alterations for agriculture and development. The Florida sandhill crane is listed as threatened by the State of Florida.

White ibis. *Original photograph by Barry Mansell.*

The **white ibis** (*Eudocimus albus*) is a colonial breeding, medium-sized wading bird with a long decurved bill, long legs, and a long neck; which is extended in flight. The species typically nests in trees or shrubs near water, especially in wooded swamps or other marsh vegetation. It is often associated in nesting with smaller *Egretta* herons and is most sensitive to intrusion when nesting or roosting. The white ibis is State-listed as a species of special concern.

The **round-tailed muskrat** is a FWS species of management concern. Maidencane marshes, cattail marsh, and even sugar cane fields are used by this species (Lefebvre 1992). Preferred marsh habitat has water levels that do not exceed 50 cm (20 in), with soft substrates of peat or sand that are deep enough to permit it to burrow down to the water table during dry periods (Birkenholtz 1963, Tilmant 1975). The major threats to this species include drainage practices in marsh systems, poor management of agricultural soil conservation, prescribed burning practices in salt marshes and fresh water marshes, and mechanical harvesting practices in sugar cane fields. Isolation of small populations by urbanization makes re-establishment of local populations more difficult.

This species remains poorly studied. At one time, its population numbers may have been much greater than today. Like the northern muskrat (*Ondatra zibethicus*), it is capable of rapid recovery from periods of drought and flooding (Birkenholtz 1963), but it may never have played as significant a role as a major herbivore in marsh ecosystems that its northern counterpart has (Weller 1982, 1994).

The South Florida population of the mink, commonly called the **Everglades mink** (*Mustela vison evergladensis)* is listed as threatened by the State of Florida. While mink are common in northern Florida, they are rarely seen in South Florida, and most of the information on the species comes from road-killed specimens and from sightings along levees (Smith 1980). The preferred habitat is shallow freshwater marshes and wet prairies in southern Collier

County, northeastern Monroe County, and Miami-Dade County. It also uses swamps and salt marshes. Mink were once common and trapped around Lake Okeechobee; there are no current records of the species in the lake area (Humphrey 1992). Humphrey (1992) noted that museum specimens only verify the current range to extend as far north as Interstate Highway 75 (Alligator Alley) and as far east as the Florida Turnpike. The mink is so poorly known that it is difficult to make clear recommendations for habitat management, and additional research appears fundamental to a better understanding of the South Florida population.

The **Cape Sable seaside sparrow** is currently the subject of intense evaluations with regard to modified water deliveries in Water Conservation Area 3 and the Everglades NP (COE 1998). These sparrows live in wet prairies dominated by muhly grass and short sparse saw grass (Howell 1932, Werner 1975, Curnutt 1996). Habitat conditions may change from year to year due to flooding by excessive rains or due to drought. Hydroperiod dictates the length of the nesting season; however, rising surface water abruptly halts breeding activity. Eastern meadowlark behaviors are very similar to that of the Cape Sable seaside sparrow. The preservation of the vegetational communities that are beneficial to the Cape Sable seaside sparrow will also benefit a very wide range of other species of animals and plant species, including the meadowlark.

Cape Sable seaside sparrows nest during a period from late February through early August, with most activity occurring in April and May, when the marl prairies are dry. Their variable cup-shaped nests are usually on or within 20 cm (7.9 in) of the ground, composed of sedge or coarse grass, and filled with finer materials (Werner 1975). Therefore, even slight shifts in water depth can cause significant nesting mortality from flooding.

Loss of wet prairie habitat along the eastern edge of the southern Everglades has reduced the habitat available for the eastern sub-population. In addition, excessive discharges of water through the S-12 structures in the southern boundary of WCA 3A has severely reduced the reproductive potential of the western subpopulation (Curnutt 1996).

The high rainfall from 1994-1998, including El Nino effects, resulted in most of the SFWMD basins having water levels at or near capacity, requiring excessive releases from Lake Okeechobee through the Caloosahatchhee and St. Lucie drainage systems, with significant impacts on associated estuaries. Additionally, the high water conditions in WCA 3A and continued releases of water through the S-12 structures led to an emergency status evaluation of Cape Sable seaside sparrow habitat needs (COE 1988). As of March 1998, the COE and SFWMD have been diverting water from WCA 3A to WCA 3B (see habitat recommendations for the species in this chapter, and then southward through canal C-111 to give relief to the western core population of the Cape Sable seaside sparrow.

Wherever it is found, the activities of the **American alligator** as a major predator and landscape architect have led to the use of the term “keystone” species to emphasize its ecological importance in wetlands dynamics (Hines 1979, Kushlan 1974, Kushlan and Jacobsen 1990, Mazzotti and Brandt 1994). While the species rapidly recovered from the endangered status, it deserves

American alligator. *Original photograph by Dawn Jennings.*

special attention and emphasis in any discussion of the fauna and community dynamics of Florida's wetland marshes and prairies.

Alligators feed on snails, crayfish, amphibians, mammals, birds, and reptiles, including themselves (Barr 1997, Delaney and Abercrombie 1986, McNease and Joanen 1977). Alligators excavate and maintain "gator holes" that serve as aquatic refugia during the dry season. Without alligators, there are fewer ponds to serve as dry season refugia for fishes and aquatic invertebrates and, therefore, less prey for the populations of wood storks and other wading birds (Craighead 1968, Mazzotti and Brandt 1994). Finally, alligator nests serve as important egg-laying sites for other reptiles (Kushlan and Kushlan 1980).

Fragmentation of alligator habitat includes two components: (1) reduction in total habitat area, which primarily affects population sizes and thus extinction rates; and (2) redistribution of the remaining area into disjunct fragments, which primarily affects dispersal and thus immigration rates; both components cause extinctions (Wilcove *et al.* 1986).

A population of alligators lives in the Lower Keys that moves through and feeds in many different habitats, including open waters, tidal mangroves, hardwood hammock, pine rockland, freshwater marsh, and buttonwood basins. On some islands, they maintain the only year-round water holes that exist.

Recent research (Guillete *et al.* 1994, Rice and Percival 1996) has identified reduced hormonal levels correlated with reduced reproduction in alligators in central and northern Florida marsh and lake systems related to contaminant levels. In the southern Everglades, biopsies of alligators have identified elevated mercury levels in limited samples (Roelke *et al.* 1991).

A natural source of mortality in alligator populations is egg mortality caused by flooding; egg loss can become excessive due to large and/or rapid water discharges associated with water management (Kushlan and Kushlan 1979, Kushlan and Jacobsen 1990, Ogden 1976). The most recent extensive studies of alligator populations in the Everglades NP indicate that the major problem facing the alligators in the park since scheduled deliveries of water began in 1971 has been excessive nest flooding (Kushlan and Kushlan 1979, Ogden 1976).

Plant Species of Concern

Federally listed plant species that depend upon or utilize the freshwater marsh and wet prairie communities in South Florida include the Okeechobee gourd (*Cucurbita okechobeensis).* The biological account and recovery tasks for this species are included in "The Species" section of this recovery plan.

Numerous other species, including some State-listed species, are under threat by improper water management practices. Some species are associated with wetlands, but are not wetland or aquatic plants. These include: epiphytic orchids, bromeliads, and ferns that are found in swamps or low-lying pinelands but have distributions that include shorter-hydroperiod wet prairies and marsh ecotones. This is especially true in the southern Everglades ecotones between pine rockland and wet prairies, and cypress and mixed hardwood swamps and wet prairie. (refer to Appendix C for a list of other species that utilize freshwater marshes and wet prairies).

The **twospike crabgrass** (*Digitaria pauciflora*) is a herbaceous perennial grass that is known from freshwater marshes and wet prairies. This species also occurs in pine rocklands. *Digitaria pauciflora* is shade intolerant and requires periodic burning to reduce competition from woody vegetation. The number of remaining plants has been estimated at fewer than 10,000 individuals. It is currently restricted to a range of approximately 8,000 ha (31 square miles). Fire suppression and exotic plant invasion are the greatest threats to the species. The species has been listed by the State of Florida as an endangered species.

The **Edison's ascyrum** (*Hypericum edisonianum*) is a colonial shrub that utilizes wet prairies in South Florida. Periodic burning during the dry seasons has helped maintain the species. Insect pollination of the showy white flowers is believed to occur. The species is threatened by loss of habitat due to hydrologic alteration, development, and agriculture. *Hypericum edisonianum* is listed by the State of Florida as an endangered species.

Ecology

Physical Regulating Factors for Freshwater Marshes and Wet Prairies

The major factors regulating freshwater marsh and wet prairie dynamics are: (1) hydropattern; (2) water quality; (3) sea level change; (4) hurricanes and tropical storms; (5) freezes; (6) fire regime; (7) salt water intrusion; (8) non-endemic or exotic pest species; and (9) water management and flood control practices (DeAngelis and White 1994, Duever *et al*. 1994, Wanless *et al.* 1994).

Some of the above factors are natural phenomena in which no human intervention is involved. Others, however, such as fire, saltwater intrusion, and water management, are more frequently human-induced and/or regulated activities that can be altered to improve ecosystem structure and function.

Perhaps the more pressing issues fall into the socio-economic realm of land use and planning and involve human population expansion, potable water supply, urbanization, and agricultural practices. DeAngelis and White (1994) have stressed the importance of understanding the relationship between the temporal and spatial relations in each of these types of disturbance and regulating factors in order to prioritize management and restoration objectives.

Davis *et al.* (1994) discussed all the factors that may have contributed to shifts in vegetative cover within the Everglades basin. They discussed previous work that related shifting vegetation patterns to fire regimes, soil depths, and drainage trends (both pre- and post-flood control development). They were not able to come to a conclusion on the role of the various factors, nor the importance of specific temporal periods in affecting the shift in vegetative cover types. In general, Davis *et al*. (1994) did stress that the significant shift to saw grass was related to a reduction in overall system productivity, especially for periphyton, lower consumers, and forage fishes and wading birds. In essence the remaining portions of the “river of grass” have too much tall dense emergent “grass” (saw grass or cattails) and not enough of the less dense and more open marsh types to sustain the historical abundance diversity and productivity of the region.

Regardless of the extent or geographic location, South Florida freshwater marshes and wet prairies are generally considered to be a function of the distinctive array of physiological and morphological adaptations of the species to survive under low nutrient conditions. For the deeper marsh types, these include adaptations to prolonged hydroperiods in anaerobic soil conditions and rapid growth response after fires. For the shorter-hydroperiod wet prairie these include wide tolerances to drought and flooding, in aerobic soils, and rapid growth response after fires. So much of our understanding of the natural ecological conditions and regulating factors has been derived from studies done after the human modification of the system had begun (Beard 1938, Davis 1994, Egler 1952), that it is best to expand on the ecological issues in relation to our current knowledge based on empirical and modeling studies on the status and trends of freshwater marshes and wet prairies.

David (1996) reviewed vegetation data collected in WCA 3A from 1978 through 1984 relative to changes in water delivery. He noted that *Rhynchospora tracyii* was more common in areas that had been able to dry down, and suggested that regular seasonal dry down of marsh allowed the residual seed bank for this species to germinate and recapture some areas. In the absence of regular dry down, this species as well as many other species of *Rhynchospora* were absent from this region. However, *Rhynchospora tracyii* is also found in short-hydropattern wet prairies on marl soils of Everglades NP (Olmsted *et al.* 1980; Dalrymple, Everglades Research Group, personal communication 1998) that regularly have much shorter hydroperiods and depths of flooding. In this habitat, the species seed bank experiences regular periods of dry down that permit it to persist. Conversely, Loveless (1959a) considered *Rhynchospora tracyii*, in what he called *Rhynchospora* flats, to be “usually covered with surface water for longer periods of time than any of the other communities, excluding the sloughs, and, except during abnormally dry years, the water level rarely recedes more than a foot below the surface of the ground." The relationship between soils, hydrology, and plant species preferences is not clear, and much more information on habitat requirements is needed to avoid premature and rigid definitions of indicator species of freshwater marsh and wet prairie types (David 1996). Moreover, many other wetland plants listed as obligatory or facultative wetland by the Federal and State listings show extremely wide ranges of habitat use (Godfrey and Wooten 1979, 1981).

Fire

Fire is critical to controlling the degree of expansion of hardwood perennials, trees, and tree islands into adjacent herbaceous wetlands, because fires limit the build up of peat (Craighead 1971, Gunderson and Snyder 1994, Wade *et al.* 1980). When fires are suppressed or infrequent, peat builds up and willow (*Salix carolina)*, buttonbush (*Cephalanthus occidentalis)*, wax myrtle (*Myrica cerifera)*, and the exotic pest species Brazilian pepper (*Schinus terebinthefolius),* Australian pine (*Casuarina* spp.), and melaleuca (*Melaleuca quinquenervis)* rapidly invade. Once these species have invaded a marsh or prairie, future fires simply increase their rates of expansion, due to their fire adaptations (Ewel 1986, Myers 1983, and Wade *et al*. 1980). Therefore, the timing of fire and post-fire flooding combine to strongly regulate the mosaic of herbaceous and forested wetland types that is critical to overall ecosystem function and, therefore, meet the requirements of the widest range of plant and animal species (the basic multi-species recovery goal).

Whether the fires are prescribed burns, or wildfires, the timing of the fire event in relation to flooding is critical (Davis *et al*. 1994, Gunderson 1994, Herndon and Taylor 1986, Wade *et al*. 1980). Fires in the dry season or early wet season burn back the fuel load of many wetland types, and this is especially well documented for saw grass marshes. The marsh plants rapidly begin to resprout from growing tips buried deep in thick protective stems or from underground rhizomes and root systems. However, rapid reflooding after fire does not give them new growth time to reach heights that will tolerate the flooding, and may result in death to the regenerating vegetation. Frequently, this leads to a complete transformation from one community type to another (*e.g*. from saw grass to muhly prairie, or saw grass marsh to maidencane or beakrush marsh). Vegetative density in saw grass marshes varies with hydrology and fire frequency (Alexander and Crook 1984). Davis *et al*. (1994), David (1996), Gunderson (1994), and Alexander and Crook (1984) noted "decadent" stands of saw grass marsh in areas where fire had been excluded for many years, and pointed out that the dead stem densities get so great as to crowd out live stems, resulting in hardwood colonizations (*e.g*. willow and buttonbush).

Patterns of fire and fire suppression may have a significant role in obtaining reasonable ranges of productivity for South Florida freshwater marshes and wet prairies (Robertson 1953, 1954; Olmsted *et al*. 1980; Wade *et al*. 1980). For example, after a fire, saw grass can reach a height of 20 to 40 cm (8 to 16 in) in 2 weeks (Forthman 1973), and maidencane shows rapid regrowth within 30 days postburn. Herndon and Taylor (1986) emphasized the rapid accumulation of tissue mass in muhly prairies with regard to fire frequency and effects. Werner (1975) evaluated muhly prairies occupied by Cape Sable seaside sparrows after fires, and this led him to suggest an important relationship between fire frequency and sparrow nesting habitat value. In all of the above reviews, the effective regulation of water depth after fire was essential to allowing sufficient regrowth of the native plant community. Currently managed fires coordinated with water flow are not effectively practiced in most freshwater marsh and wet prairie settings.

Trophic Status

Trophic status refers to the fertility of a wetland and is a direct function of nutrient loading. Oligotrophic, nutrient-poor, wetlands generally have plant communities that provide habitat for sport and forage fish, but lack of nutrients inhibits production so that total biomass and potential harvest of fish is low. The low nutrient supply also inhibits periphyton and phytoplankton production in open water areas, so that fish populations are severely limited. In its original state, the Everglades system was oligotrophic, and much of the southern Everglades, especially Everglades NP, remains so today. But increased levels of phosphorus and nitrogen runoff from agricultural lands in the EAA through the WCAs, and thick mats of exotic floating vegetation (*e.g.* water hyacinth) have resulted in rapid eutrophication of the northern Everglades (Bryan 1996, Davis and Ogden 1994, Snyder and Davidson 1994).

The Everglades marshes and wet prairies are basically a detritus or "brown" food chain (Odum 1983), *i.e.*, the majority of net primary production dies without being consumed by herbivores, and becomes the nutrient source for a complex decomposer/detritovore-based food chain. The deep peat soils of the long-hydropattern marshes are generated by the high rate of net primary production that decomposes slowly in low-oxygen conditions. The marl soils of the shallower short-hydropattern prairies are produced by a function of blue-green algae and green algae incorporating the dissolved calcium carbonate from the underlying limestone bedrock into their cell walls. Annual drying down results in large amounts of dead periphyton to contribute this to calcium carbonate as marl soils (Browder 1981, Browder *et al.* 1994).

Comparison of estimates of standing crop of forage fish per unit area for open marsh systems versus saw grass or cattail marsh have proven difficult and often misleading. Moreover, the estimates vary widely, and are significantly affected by sampling methods and hydrological conditions (Loftus and Eklund 1994). Part of the problem with comparisons of forage fish standing crops is that they do not include information on the actual availability to consumers, *e.g.* foraging wading birds.

Diseases and Parasites

Frederick and Spalding (1994) have reviewed the literature on the occurrence of a wide range of diseases and parasitic infestations in wading and water birds. They noted that general emaciation, lack of fatty tissues, and decreased muscle mass may be related to a variety of conditions including sublethal levels of contaminants. They found outbreaks of eustrongyloidosis caused by a nematode in some colonies in the Everglades, and noted that increased nutrient loads and physical alterations of foraging sites have been implicated in the occurrence of this condition. Considering how many wading birds are currently found foraging in polluted small ponds near point sources of pollution, as well as along many canal edges, it is likely that shifts in water quality, and increased biomagnification of nutrients and contaminants in the tissues of prey species are probably being passed on to these top predators.

Status and Trends

Loss of Spatial Extent and Shifts in Plant Community Coverage

Dredge and fill operations and flood control structural management, including dikes and canals with levees, have had a major role in affecting the distribution, interspersion, and productivity of freshwater marshes and wet prairies. Dredging and filling in wetlands permanently destroys habitat vital to biological productivity and fishery resources. Shallow vegetated areas of marsh and littoral zones are extremely important to the production of forage fishes by serving as breeding, nursery, and refuge habitat.

Throughout South Florida, there has been progressive loss of total functional coverage of freshwater marshes and wet prairies due to development, excessive drainage, exotic plant infestations, water management restrictions on volume and timing of flow, and eutrophication. While many isolated freshwater marshes and wet prairies still occur in South Florida, they are usually degraded and isolated from connections with upland habitats that are so critical to the interspersion of habitats required for complete ecosystem structure and function (Hartman 1992, Weller 1994). In the Everglades region, vast amounts of peripheral wetlands are being invaded by exotic pest plant species.

Jordan *et al.* (1997) reviewed their quantitative findings from an analysis of marsh communities in the northern Everglades in the Arthur R. Marshall Loxahatchee NWR. They point out that the pre-drainage landscape of the area was comprised of long-hydropattern marshes, saw grass marsh, sloughs, and tree islands overlying peat. Using multivariate statistics, they found strong quantitative relationships of slough habitat with *Utricularia* spp. and *Nymphaea odorata*, of long-hydropattern marsh with *Eleocharis cellulosa*, *E. elongata*, and *Rhynchospora tracyii*, and of saw grass marsh with *Cladium jamaicense*. Jordan *et al*. (1997) found that sloughs, long-hydropattern marshes (wet prairies on peat) and saw grass marshes “occupy a gradient of decreasing water depth. The significance of this finding is that small differences in topography among habitats (especially wet prairies and saw grass stands) have been masked and the ability to determine the roles fire and hydroperiod play in structuring Everglades landscape has been hampered....”

In evaluation of changes in vegetation types through time, Davis *et al*. identified not only a significant reduction in the overall regionwide extent of Everglades natural plant communities, but a significant trend for saw grass to replace wet prairie/slough.

Bancroft *et al.* (1994) and Hoffman *et. al.* (1994) have pointed out that significant shifts in the extent and distribution of tree islands have had a significant effect on the pattern of foraging activity in relation to wading bird rookeries in southern Florida. They recommend modifications in the pattern of water deliveries more closely mimicking the natural system to promote a more complex mosaic of forested and graminoid wetland communities to enhance wading bird habitat. In wet prairies, numerous studies have identified shifts in species composition in Everglades NP related to fire and/or hydropattern changes (Armentano *et al.* 1998b, Herndon and Taylor 1986, Herndon *et al.* 1991, Olmsted *et al*. 1980). These authors, as well as Alexander and Crook (1984), Davis *et al.* (1994) Gunderson (1994), and Kushlan (1990) all recognized that some of the shifts in marsh and wet prairie distribution and species composition are strongly related to a history of disturbance near canals associated with increased nutrient loadings, alterations in the hydropattern, and alterations in the pattern of fire.

The current patterns of spatial distribution and coverage by freshwater marsh and wet prairie types have shifted in all regions of the Everglades. Perhaps the most distinctive shift in species distribution in wet prairies has been in the southeastern marl prairies. A large proportion of the peripheral wet prairies of the southern Everglades were transformed into agricultural lands and others have been transformed into housing developments (Light and Dineen 1994, National Audubon Society 1997). Perhaps the clearest example of these management modifications are seen in the North East Shark River Slough east of the original Everglades NP boundary. The problems associated with the trends identified by Fennema *et al*. (1994) have also been identified in the empirical data from studies of freshwater fishes and invertebrate communities (Loftus and Eklund 1994, Nelson and Loftus 1998), in the Everglade snail kites, the wood stork and other wading birds (Bancroft *et al.* 1994, Frederick and Collopy 1994, Hoffman *et. al.* 1994, Ogden 1994), and the American alligator (Mazzotti and Brandt 1994).

Additional empirical data regarding hydropattern and water quality impacts in the managed system come from the period of high water conditions experienced from 1994 and into the 1997 to 1998 “El Nino” effects (Armentano 1998a). Impacts were identified on everything from plant communities such as periphyton and tree islands in the freshwater marsh mosaic to Florida Bay salinity, as well as impacts on a wide range of fauna including the Cape Sable seaside sparrow, Everglade snail kite, wood storks and other wading birds, white-tailed deer, small mammals, freshwater and estuarine fishes, American alligator, and other reptiles.

Water Budget and Discharge Management

Overall, the data from empirical studies and models indicate that the current C&SF system is inadequate for the regional water budget for both natural systems and human population needs. Water in excess of amounts needed to reach ecological goals for the estuaries is still being shunted down canals out to Lake Worth Lagoon, and other estuaries in the study such as the Indian River and Caloosahatchee River. The consensus of opinions (Davis and Ogden 1994) is that we must recapture much of the peripheral wetlands that border the WCA’s. In a review of the 1980-1989 records for total discharge from the C&SF project’s water control system, Light and Dineen (1994) noted that out of a total average annual discharge of 4,113,000 acre-feet (5,058,990,000 cu m), 80 percent goes to the Atlantic Ocean, 13 percent gets to the Shark River Slough, 2 percent to Taylor Slough, and 4 percent enters Barnes Sound and northeast Florida Bay. The proposed Modified Water Deliveries Plan to

Everglades NP, including the acquisition of North East Shark River Slough, the C-111 project for improving the area over which water flows to Florida Bay and Barnes Sound, and the National Audubon Society's (1997) suggested expansion of the original SFWMD Lower East Coast Buffer (LEC) or Water Preserve Areas (WPA) are all initiatives that will increase the amount of wetlands available for storing water, restoring sheet flow, enhancing natural functions in peripheral wetlands, and reducing water losses from canals to estuaries and bays (SFWMD 1995).

Natural System Model vs. Managed System Hydropatterns

Using models to simulate the natural system's hydropattern in comparison to the hydropattern with current water management practices of the southern marshes, below Lake Okeechobee, Fennema *et al*. (1994), demonstrated prolonged hydroperiods and increased depths of flooding in many portions of the original region that were classified as shorter-hydropattern wet prairies and saw grass marsh. In their comparison, they made it clear that the current pattern of water storage in the SFWMD's system of canals, levees, and WCAs, including the Arthur R. Marshall Loxahatchee NWR, has resulted in significant changes in conditions that are causing a loss in peripheral wet prairies and freshwater saw grass marshes, an increase in the area of prolonged flooding in some areas that were naturally drier, and a simultaneous drying of large areas that were deeper marshes (flag marshes, water lily marshes and sloughs) (Davis and Ogden 1994).

Pulsed Discharges with Rapid Reversals of Flow vs. Attenuated Sheet Flow

Many reviews of current water discharge practices have emphasized the shift from natural slow attenuated sheet flow driven by rainfall events to rapid pulsed discharges through point sources of release at water management structures with decreased sheet flow. They also recognize that within-year rapid reversals in flow are caused by the opening and closing of water release structures that rapidly change standing water levels resulting in sudden elevations and decreases in water levels may severely impact reproductive and foraging success for a wide range of species (Light and Dineen 1994; COE 1992, 1994). The sooner the marsh system is restored with more natural flows and levels, the better the chances are of recovering the ecosystem.

Water Quality and Eutrophication

Water quality, especially eutrophication from increased phosphorus and nitrogen runoff from agricultural lands and cattle ranches, has become an increasingly high-profile issue, and is well documented to rapidly alter the successional dynamics of wetland complexes (Davis *et al*. 1994, Porter and Sanchez 1994. The vast majority of literature is on the natural vegetation of the South Florida marshes and prairies that are adapted to low-nutrient conditions (Gunderson 1994, Kushlan 1990, Wade *et al*. 1980). Increases in phosphorus, in particular, permit plant species that are capable of rapidly absorbing and growing under higher-nutrient conditions to expand their ranges until they begin to create monocultural stands. The best documented cases of this phenomenon are the replacement of saw grass marshes by cattail marshes. The issues surrounding the levels and sources of eutrophication remain controversial (Bottcher and Izuno 1994, Craft *et al*. 1995, Davis *et al*. 1994).

Fertilizers are widely used in South Florida to maintain high levels of agricultural productivity. From July 1, 1990 through June 30, 1991, fertilizers sold in South Florida contained 140,000 tons of inorganic nitrogen and 56,000 tons of phosphate. Nutrient loading from the Everglades Agricultural Area (EAA) and urban areas have significantly increased nutrient concentrations, particularly phosphorous (Stober *et al*. 1996). This has resulted in increased soil phosphorous content, changed periphyton communities, loss of native saw grass communities, increased organic matter in water, loss of dissolved oxygen, conversion of wet prairie plant communities to cattails, and loss of important wading bird habitats (Stober *et al*. 1996). Nutrient loading from the EAA has been associated with eutrophication in the WCAs having greater than 50 ppb phosphorous concentrations.

The natural background levels of phosphorous in the Everglades are 10 ppb or less. The Miccosukee Tribe has set a standard of 10 ppb for phosphorous in water quality standards for tribal lands. Craft *et al.* (1995) found that additions of phosphorus, and nitrogen plus phosphorus had a significant effect on species composition in their slough plots, with a decline in the *Utricularia* spp. and periphyton mat after one year. At the same time, there was a rapid expansion of *Chara* spp. until this submersed macroalga had replaced the floating mat of vegetation as the dominant vegetation. They observed no significant changes in the macrophyte species diversity or expansion of cattails during the 2 years of their study on saw grass or mixed saw grass and cattail (*Typha dominguensis*) plots. They considered replacement of the floating mat of *Utricularia* spp. and periphyton by *Chara* as an early indicator of phosphorus enrichment in Everglades waters.

The major threats to sustaining the current distribution of saw grass marsh have to do with alterations of hydropattern, increased eutrophication of water, especially by phosphorus associated with agricultural and cattle land runoffs, and encroachment of native and exotic plant species that aggressively expand into stressed saw grass marsh habitat. *Typha* spp. are documented as being able to replace saw grass as hydroperiods are prolonged in water conservation areas, and when nutrient loads are anthropogenically increased (Davis *et al*. 1994, McPherson *et al*. 1976, Wiggins and Bottcher 1994).

Weller (1994) and Williams *et al*. (1985) point out that early in the eutrophication process there are benefits to fish populations and habitat conditions, but a point is reached where the system becomes degraded. Increasing nutrient loading eventually can lead to hypereutrophic conditions, with increased density of marsh plants (cattails, periphyton, phytoplankton, water lilies, and water hyacinth), decreased dissolved oxygen, increased algal biomass and phytoplankton turnover and development of mucky sediments, declines in sport and forage fish populations, and increase in “rough fish” populations.

Herbicide/Pesticide and Mercury Contaminants

Pesticides have also been widely used in agricultural and urban areas in South Florida for more than 50 years to control insects, fungi, weeds, and other undesirable organisms. Because of year-round warm temperatures and moist climate, Florida agriculture requires vigorous pest control, thus while Florida agricultural production ranks about 30th in the nation, pesticide use per acre is in the top five. The compounds used vary in their toxicity, persistence, and transport. Since the late 1960s, persistent organochlorine pesticides have been detected in fish that are part of the Everglades food chain (McPherson 1973, Haag and McPherson 1997). Some more persistent pesticides, such as DDT, Chlordane, Dieldrin, and Aldrin have been banned for use in Florida, but their residues still occur in the environment. Although pesticides are usually applied to specific areas and directed at specific organisms, these compounds often become widely distributed and are potentially hazardous to nontarget biota (McPherson and Halley 1996). Herbicides including Atrazine, Bromacil, Simazine, 2-4-D, and Diuron, which have the highest rate of application, are among the most frequently detected pesticides in Florida's surface waters (Shahane 1994). By far the most frequently detected insecticides in surface waters are the chlorinated hydrocarbon ones that are no longer used in the state, such as DDD, DDE, DDT, Dieldrin, and Heptachlor.

Chlorinated chemicals, such as polychlorinated biphenyls (PCBs), dioxins, and furans, which are generated and used primarily in urban and industrial areas, pose serious concern to fish, wildlife, and human populations (Colborn *et al*. 1993). Although most uses of PCB's have been banned since the late 1970s, these persistent chemicals are still found in the environment and continue to pose potential threats to fish, wildlife, and humans. In recent years, many organochlorine pesticides and PCB's have been linked to hormone disruption and reproductive problems in aquatic invertebrates, fishes, birds, and mammals (Colborn *et al*. 1993). In a study of nine species of ciconiiform birds, Spalding *et al*. (1997) found that geographic location within South Florida affected the levels of contaminants, including chlorinated hydrocarbons, lead, cadmium, and copper. Chlorinated hydrocarbons were found in highest concentrations and most frequently from brain tissue samples of nestlings from the Lake Okeechobee area. Rodgers (1997) evaluated egg and liver tissues for pesticide and heavy metal levels in eight species of waterbirds in the EAA. Mercury, lead, DDT, DDE, Dieldrin, Heptachlor, Trans-nonachlor, Chlordane, Endrin, Toxophene, and PCBs were found in low concentrations in most samples. The concentrations were below levels currently considered to have significant impacts on birds, but a few birds had alarmingly high levels of some contaminants.

The evidence of mercury contamination in fish and wildlife in South Florida freshwater ecosystems is extensive. Piscivorous freshwater sport fish and alligators in many watersheds have high mercury levels in their tissues (Ware *et al*. 1990, Eisler 1987). After discovering the extent and severity of mercury in fish in 1989, the State Health Officer issued advisories to anglers, warning against consumption of several species throughout more than 1,000,000 acres of the Everglades, and advised restricted consumption of others over most of the State. Besides human health concerns, ecological resources may be at risk as well. In the early 1990s, three Florida panthers inhabiting the Everglades died. Mercury was determined to be the proximate cause of death in one and a contributing cause of death in the other two cases (Roelke *et al*. 1991). High mercury levels have been detected in the endangered wood stork and other birds (Sundlof *et al*. 1994). There is much concern that the 50-year decline in wading bird numbers in South Florida may be a result of increased mercury exposure; intensive studies are underway to further define this concern.

Trends in mercury accumulation in South Florida, as evidenced by sediment profiles, show that mercury deposition has increased approximately fivefold since 1900 (Rood *et al*. 1995). The deposition rate of mercury by rainfall measured today is at least double that of other remote sites in North America (Guentzel *et al*. 1995). Some of that deposition must result from the threefold anthropogenic enhancement of the global mercury cycle, making this a significant fraction, if not a majority, of the deposition (Dvonch *et al*. 1995, 1996); extensive studies are underway to define local source-receptor relationships with greater precision.

Storms

Major storms can be a significant and unpredictable element affecting the structure of freshwater wetlands. While most emphasis is placed on hurricanes and the degree of damage they have on forested and coastal plant communities, this damage is associated with high winds and storm surges (Armentano *et al*. 1997, Craighead and Gilbert 1962). The major impact of tropical storms in wetlands is not from wind damage, but from extensive flooding (Light and Dineen 1994). The tropical storms, whether of hurricane strength or not, that are of most importance are those of large geographic coverage that drop high amounts of rainfall as they pass through (COE 1994). A good example of such a storm was tropical storm Dennis in the fall of 1981. This storm arrived at the end of a serious drought, when water managers were desperately trying to conserve water. The storm stalled over the Everglades, and dropped 51 cm (20 inches) of rain in a 24-hour period, and led to extensive flooding. This storm occurred during Herndon and Taylor's (1986) study of fire effects on wet prairies, and they noted that young saw grass shoots regrowing in one of their burned plots were completely flooded and died due to the heavy rainfall. The high water levels during this storm resulted in the decision to cut open the earthen dams in the southern C-111 canal. Massive amounts of freshwater were released into Barnes Sound causing serious impacts on the coastal marshes, prairies, estuarine and bay animal and plant communities (COE 1994).

While high winds associated with severe storms topple trees and are a serious impact on forested uplands and swamps, they are only of concern in wetlands and estuaries when they carry a high storm surge of salt water into the ecotones of estuaries. Hurricanes Donna and Andrew are good examples of hurricanes that had severe wind storm and tidal surge impacts that dramatically changed the structure of coastal mangrove communities for decades afterwards, as well as severely damaging pinelands and hardwood hammocks (Craighead and Gilbert 1962). Hurricane Andrew was so compact and moved through South Florida so quickly that rainfall was of secondary importance and of little consequence. Hurricane Georges of September, 1998 sent a storm surge over the middle of Big Pine Key and inundated 40.5 to 81 ha (100 to 200 acres) of freshwater wetlands with saltwater. Subsequently non-salt tolerant plant species have died out. In general, hurricanes are considered a natural, unpredictable part of the natural ecological setting of the study area, and are recognized as impacts that have severe and long-term effects on the mosaic of South Florida's plant communities (DeAngelis and White 1994, Duever *et al*. 1994).

In recent years, there is more awareness of "El Nino" effects which have prolonged impacts with periods of excessive rainfall, extended high water levels, and unpredictable patterns of storm fronts often accompanied by tornadoes (Duever *et al.* 1994, Robertson and Frederick 1994). The 1998 high water levels in South Florida resulted in releases of very high amounts of water through the Caloosahatchee and St. Lucie River drainages, causing serious impacts on estuaries, and filling Lake Okeechobee and the WCAs to capacity. Overall, these high water levels result in typical conflicts with regard to which species and vegetative communities will suffer the most impact (estuaries, lake and riverine marshes, WCA marshes, or downstream wet prairies).

Freezes

During the dry season (winter months) in non "El Nino" years, South Florida may experience periods of rapid storm front movement accompanied by high winds and very low temperatures. In some instances, the ambient air temperatures and wind chill factors result in serious freezes that are especially detrimental to native tropical plant species, especially in hardwood hammocks. There are often major economic losses experienced by row crop, tropical orchard and citrus farmers. However, these freezes are of minor consequence in the non-forested wetlands of the region (Duever *et al.*1994).

Saltwater Intrusion, Sea Level Rise, and Global Warming

Perhaps the most subtle and underappreciated driving force in the natural dynamics of South Florida's ecology is changing boundaries between the freshwater aquifers and salinity gradients in the underground aquifer system (*e.g.* Egler 1952), and rising sea level and global warming (Wanless *et al*. 1994). Salt water intrusion is strongly related to freshwater storage levels in aquifers, flood control, water management discharge practices, and expanding demand for potable water from the rapidly increasing human population. Sea level rise is certainly a longer-term and more difficult factor to contend with. Together, these factors result in shifts in estuarine and coastal plant communities inland with the displacement and reduction in freshwater marshes and prairie community types (Wanless *et al.* 1994).

Exotic Pest Plants

There are more than 900 exotic (non-indigenous) plant species in Florida (Schmitz 1994). Many of these species are rather benign, but a significant and growing number of plant species are currently considered non-indigenous pest species. These species invade disturbed and natural sites, especially wetlands. Many develop into monocultures that exclude most if not all native plant species, and significantly alter the plant and animal species composition and food chains of the communities they invade (Schmitz and Brown 1994). According to the Environmental Pest Plant Council (EPPC) there are 31 Category I non-indigenous plant species that are currently known to be widely distributed in Florida and have invaded and disrupted native plant communities (Schmitz 1994). The largest amount of land colonized by exotic pest plant species is forested and non-forested wetlands. Well over 416,667 ha (one million acres) of wetlands are currently invaded with aquatic weeds and wetland -shrubs and trees, including torpedo grass (*Panicum repens*), hydrilla (*Hydrilla verticilata*), water hyacinth, melaleuca, Brazilian pepper, Australian pine, Old World and Japanese climbing ferns (*Lygodium* spp.), air potato (*Dioscorea bulbifera*), tropical soda apple (*Solanum viarum*), water spinach (*Ipomoea aquatica*), and water lettuce (*Pistia stratiotes*). Melaleuca currently has invaded nearly 208,333 ha (a half million acres) of southern Florida's wetlands, and aggressively expands into saw grass marsh and wet prairies. Hydrilla currently infests more than 31,250 ha (75,000 acres).

Many of the fully aquatic species (hydrilla, water hyacinth, water lettuce) can rapidly expand via the hundreds of miles of canals and ditches dug for flood control and water management. In the SFWMD alone, there are 1,167,895 ha (2,802,947 acres) that must be managed for non-indigenous pest species (Thayer and Ferriter 1994). The 2,240 km (1,400 miles) of canals within the district make up only 7, 953 ha (19,087 acres) of this total area to be managed, but are a critical focal area for establishment and invasion of the total managed area.

Melaleuca rapidly expands into marshes and wet prairies regardless of hydropattern, and the seeds are rapidly dispersed by wind, especially after wild- fires (Bodle *et al*. 1994, Wade *et al*. 1980). In a study of melaleuca invasion in the southeastern Everglades, as melaleuca cover increased beyond 75 percent, it created a closed canopy that reduced sunlight penetration to the understory and, therefore, reduced primary productivity in the water column, especially in the periphyton and submerged macrophytes (O'Hare and Dalrymple 1997). This had a dramatic effect on the primary consumers and detritovore macroinvertebrates (*e.g.* apple snails, crayfish), resulting in overall lower abundance and productivity in the understory. Areas with less than 75 percent canopy closure had aquatic species diversity and abundances typical of areas without melaleuca invasion (O'Hare and Dalrymple 1997). Complex patterns of hydrology, and gapping in forest canopy due to wind storms and fires permits light penetration and the persistence of productive pockets of aquatic life even within some dense stands of melaleuca.

Programs of aerial spraying and the introduction of biological controls for exotic pest plant species have made great advances in stemming the expansion of at least some exotics. Melaleuca expansion is a persistent problem, but the recent application of aerial spraying and biological control through the introduction of insects that feed on melaleuca appear promising. While initial experimental control of melaleuca by aerial herbicidal treatments is encouraging, "the continuing problem has been how to manage the seed drop from dying melaleuca trees. Each tree can easily hold millions of seeds which are released when treated with herbicide" (Jordan 1994). There is little or no funding available to monitor the seed germination rates after herbicidal treatments and the Federal and State agencies have been reduced to using volunteer days to attempt some evaluation of success (Jordan 1994).

Brazilian pepper alone has expanded into 291,667 ha (700,000 acres) of upland and wetland habitat, and is especially invasive of short-hydropattern prairies and abandoned farm land in the rocky glades region of the east Everglades, as well as coastal mangrove communities (Dade County 1979, Dalrymple *et al.* 1993, Doren and Jones 1994, Ewel *et al.* 1982). Brazilian pepper is being effectively removed from former farmlands in the Hole-in-the-Donut of Everglades NP, and productive wetlands are replacing them on the managed lands (Dalrymple 1994a, Dalrymple and Doren 1998, Resources Management International 1998). The restoration methods can be used on hundreds more acres of abandoned lands, such as the Frog Pond, and on illegally rock-plowed and/or filled wetlands in the east Everglades (Dalrymple *et al.* 1993). The method involves removing the rock-plowed topsoil, and scraping the surface to the limestone bedrock (below grade). The surface of the site is lowered by this action, and therefore is more likely to have a longer hydropattern. This prevents future germination of Brazilian pepper, and promotes wetland plant and animal re-colonization of the areas (Dalrymple 1994a; Dalrymple *et al*. 1993, Dalrymple and Doren 1998).

Hydrilla and other aquatic pest plant species are controlled by herbicidal treatments, mechanical removal, and biological control agents. The majority of control efforts are in Florida's lakes, rivers and canals (Schardt, 1994). Without continued efforts to reduce focal points of runoff via canals and control structures and water impoundment in sub-basins, all marsh and wet prairie systems will continue to degrade while increasing millions of dollars are spent per year in programs to control and eradicate pest plant species (Center *et al.* 1994, Schardt 1994).

Exotic Fauna

There is an ever-increasing array and range expansion of exotic species (Schmitz and Brown 1994) including the walking catfish (*Clarias batrachus*), Asian swamp eel (*Monopterus albus*), the live bearing pike killifish (*Belonesox belizanus)*, and cichlids of the genera *Astronotus*, *Cichlasoma*, *Hemichromis*, and *Tilapia* in South Florida (Courtenay 1994, Dineen 1984, Loftus and Kushlan 1987, O'Hare and Dalrymple 1997). Native piscivorous fishes and larger fish species are generally uncommon in saw grass marsh. Loftus and Kushlan (1987) attributed this to a combination of the high density of plant stems, shallow waters that inhibit movement, and dissolved oxygen levels that are often low. The invasive Asian swamp eel could be an exception and this large piscivore appears able to expand into the saw grass marsh. Also, the relatively small piscivorous exotic pike killifish and the increasingly common Nicaraguan cichlid, *Cichlasoma managuensis*, (O'Hare and Dalrymple 1997) may have significant impacts on the future structure of the saw grass marsh community due to direct and indirect effects (Mathews 1998). The range of exotic animals, from invertebrates such as fire ants (*Solenopsis invicta*) to mammals such as armadillos (*Dasypus novemcinctus*), that have invaded Florida is still being evaluated, but it includes some species that have had severe impacts on native communities (see chapters in Schmitz and Brown 1994 for a review).

Management

As pointed out by Weller (1982) in his classic paper on the management of freshwater marshes for wildlife, the two main objectives are "the preservation of marshes in a natural and esthetically pleasing state with or without manipulation" and "to maintain high productivity of characteristic flora and fauna in freshwater marsh units."

A number of authors discuss a wide variety of management methods that can be employed to improve the design of marshes. The following management practices or principles are suggested (Weller 1982, 1994): (1) system management, rather than species-by-species management, results in widespread benefits to all wildlife and plants; (2) management to produce early plant successional stages results in longer-lasting benefits, and creates diverse habitat niches; (3) for improved habitat heterogeneity in wetland complexes, all units in an area should not be managed in the same manner at the same time; (4) wetland:upland ratios that preserve natural patterns should be used; and (5) natural or artificial simulation of drawdown is advised, especially within subregions of the system that will benefit productivity in marshes, littoral and limnetic zones (Fredrickson and Laubhan, 1994, Kadlec 1962; Meeks 1969, Williams *et al*. 1985).

Positive activities for freshwater marshes and wet prairies on existing and proposed managed lands in South Florida include the following:

(1) Re-establishment of seasonally variable hydropatterns to ensure a mosaic of freshwater marsh, wet prairie, and littoral zones with emergent and submerged (open water) vegetation.

(2) Re-establishment of sheet flow into freshwater marshes and wet prairies with a reduced reliance on canals to channel water between sub-basins.

(3) Development of water treatment marshes and stricter regulations, including Best Management Practices (BMPs) on agricultural land and adjacent managed lands. Enforce existing water quality standards and regulations.

(4) Promotion of new funding sources at the State and Federal level to continue with the planned land acquisitions related to P2000 and Save Our Rivers (SFWMD 1998). Restoration or reclamation of adjacent forested swamp and upland habitat is needed to provide suitable habitat for water birds, wading birds, and raptors, and areas of dry land for basking and egg laying for most semi-aquatic animals.

(5) Acquisition, restoration, or reclamation of drainage basin elements to existing managed wetlands, and of upland travel lanes and cover for upland animals that would seasonally use the wetlands.

(6) Prescribed burning in many marsh systems to control pest plant species, and re-invigorate plant communities. As Birkenholtz (1963) and Weller (1994) have pointed out, herbivore population increases and fire schedules are effective means for altering encroachment of dense emergent sedge and grass marsh types into open marsh types.

(7) Management of lakes and rivers to enhance or restore littoral zone marsh systems is becoming more commonly practiced on a local and regional level. Weller (1994), as well as the State of Florida's water management districts and GFC, have emphasized the value of lake management techniques such as drying down of lake margins, removal of excess organic matter in basins and exotic plant control to promote more natural basin morphology and soil conditions for re-establishment of marsh/littoral habitat. Current examples managed by the SFWMD include the de-channelization of portions of the Kissimmee River, now canal C-38 (SFWMD 1995, 1998) and GFC projects in Lake Trafford (Lake Trafford Task Force Conceptual Plan document: Gail Gibson, personal communication 1998), Stick Marsh, and Tenoroc FMA (King and Cates 1994, King *et al.* 1994).

(8) Regulation of biomagnification of contaminants in the food chain. The current combined programs of "Eastward, Ho!" and Brownspace reclamation in inner cities help reduce pressure for westward development into the periphery of wetlands, especially the Everglades, and simultaneously help clean up existing areas of contamination.

The two greatest priorities for freshwater marsh and wet prairie ecological restoration are reduction to natural background levels of nutrients and re-establishment of natural levels of seasonal sheet flow to recover the greatest possible spatial extent of the communities. The increased spatial extent of the natural system is the most fundamental way to ensure the range of water depths and hydroperiods beneficial to the diversity of freshwater marsh and wet prairie communities and listed species with varying ecological requirements.

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Community-level Restoration Actions

Restoration of Freshwater Marshes and Wet Prairies

Restoration Objective: Restore natural water quality, increase the spatial extent, and restore natural hydropatterns and seasonal flows to freshwater marshes and wet prairies in South Florida.

Restoration Criteria

South Florida must restore and preserve the highly threatened Kissimmee River-Lake Okeechobee-Everglades drainage system, as well as freshwater marsh and wet prairie habitats that are associated with other lakes and creeks, and isolated freshwater marshes and wet prairies. The recovery of listed plant and animal species, and the continued existence of other species of concern, including the American alligator, apple snail, and migratory birds, depends upon the restoration of these communities. Restoration of freshwater marshes and wet prairies must also assure flood control and aquifer recharge for drinking water and agriculture.

The restoration objective will be achieved when (1) the Kissimmee River is restored to its natural basin; (2) Lake Okeechobee water quality and water storage are restored to more natural conditions; (3) the Water Conservation Areas, including the Arthur C. Marshall Loxahatchee NWR have water quality and sheet flow, and hydropatterns restored to more natural conditions; (4) Everglades NP and Big Cypress National Preserve have water quality, sheet flow and hydropatterns restored to natural conditions; (5) the Northeast Shark River Slough (NESRS) addition to Everglades NP and the eight and one half square mile area (8.5 SMA) of the East Everglades land purchases are completed and sheet flow is restored; (6) the lands currently identified by the COE, SFWMD and the National Audubon Society as Water Preserve Areas are added to the spatial extent of the system to provide additional natural wetlands, flood control, and aquifer recharge; (7) the SOR additions are made through the use of all possible conservation land funding methods (SOR, CARL and Federal financial assistance); (8) prescribed burning is restored to the management of the marsh and wet prairie systems; (9) exotic biota including Brazilian pepper, melaleuca, Australian pine, hydrilla, and water hyacinth are eradicated or controlled; (10) the integrity of the marshes and wet prairies are ensured and maintained through a sound water management program of delivery schedules, and water storage patterns to be derived from the Central and South ern Florida (C&SF) Restudy; and (11) the distinction between wet prairie and marsh habitat conditions,

1. **Restore the maximum spatial scale to the natural ecosystems.**

   1.1. **Support and accelerate land acquisition programs** by expanding funding and staffing for land transfers.

   Current land acquisition programs (P 2000, CARL, SOR, *etc*.) are guided by highly sophisticated gap analyses to set priorities (Cox *et al*. 1994, 1997), to improve core areas for listed species and reduce habitat fragmentation to increase the likelihood of long-term metapopulation survival.

   Combined Federal and State programs have been enacted to acquire the Northeast

Shark River Slough (NESRS), the Frog Pond, and the Addition Lands to the Big Cypress National Preserve. The Save Our Rivers Program (SFWMD 1998) has acquired or plans acquisition of lands associated with the Frog Pond, L31N, Corkscrew Regional Ecosystem Watershed (CREW), C-111, East Coast Buffer Strip (also called the Water Preserve Areas (see below), Kissimmee Prairie Ecosystem, Kissimmee River upper and lower lake basin watersheds, Kissimmee Chain of Lakes, Shingle Creek, Everglades Agricultural Area stormwater treatment areas (STAs), Indian River Lagoon, Lake Lizzie, Lake Walk-in-Water, and boundary modifications for the Southern Glades and Model Lands Basin, Loxahatchee Slough, and North Fork St. Lucie River. The Save Our Rivers program also includes completion of outstanding land interests in the water conservation areas (WCAs). Critical to the continuation and completion of these land acquisition programs at the State level is renewing the funding sources to extend a program similar to P2000 into the 21st century.

The acquisition of the remaining NESRS lands, Water preserve area (WPA) lands for a buffer strip and additional water storage capacity for implementation of the Modified Water Delivery plan to Everglades National Park has fallen behind schedule, and the current period of high waters (1994 to 1998) has created conditions that make it very clear that the SFWMD is beyond its capacity to store water. Massive amounts of water are being shunted out through the Caloosahatchee River, St. Lucie drainage system, and the remaining canals to the estuaries in the coastal areas. Also, the water deliveries to Everglades NP continue to be drained toward the west, which damages the wet prairies through flooding, and the eastern prairies and marshes by over-drying.

The high water levels in Lake Okeechobee endanger the Lake's natural marsh littoral zones, as well as the structural integrity of the Herbert Hoover Dike. An accelerated rate of purchase of peripheral wetlands for inclusion in the WATER PRESERVE AREA buffer system is recommended.

The GFC has developed a sophisticated set of documents to evaluate the criteria and priorities for land acquisition for federally and state listed species (Cox *et al*. 1994, 1997). The priorities are based on a complex effort that coordinates all available information on listed species, and critical habitats or vegetational community types to identify strategic habitat conservation areas (SHCAs) in relation to current managed lands, as well as lands identified as critical by other agencies, or institutions (*e.g.* CARL, SOR, P2000, FNAI). The results of these reports are of great significance in identifying the geographic gaps that need to be acquired or protected (*e.g.* by less-than-fee methods) to preserve listed species, vegetational community types, and ecosystems.

Cox *et al.* (1994, 1997) have pointed out that the land cover types most well represented in current publicly managed lands are wetlands, including marshes and wet prairies. They point out that these cover types are, in a sense, over-represented in the current publicly managed land system, and made strong arguments for the need for land acquisitions in other cover types or vegetative communities, such as scrub, and pine flatwoods. But the high percentage of wetlands in public ownership, and the current and planned land acquisitions of additional wetlands are consistent with local State and Federal wetland protection legislation, and critical for a very large number of federally and state listed species associated with these cover types.

1.2. **Manage acquired lands for ecosystem benefits.** A major problem is not how many hectares of marsh and wet prairie are currently listed as managed areas or how many more hectares are acquired, but how they will be managed. Many land acquisitions do not end up being used to increase the spatial extent of the ecosystem, but rather are used for water treatment. A current example of this problem involves Miami-Dade County's Environmentally Endangered Lands and The Nature Conservancy lands between Biscayne NP and the Homestead Air Base. These lands may be used for stormwater retention and treatment with the planned privatization and commercial expansion of the airbase (SFWMD 1997b, U. S. Air Force 1994).

Some water management alternatives that are currently being discussed are counterproductive to maintaining water quality and natural system structure and function. For example, one option to implement a water control system around the eight and one-half square mile East Everglades residential area (8.5 SMA) will require back-pumping water that will lower water quality in the North East Shark River Slough.

In order to replace the pattern of rapid pulsed discharges and reversals of water levels with more natural attenuated sheet flow, land must be acquired to permit the wider areal extent of rainfall to drain off and water management releases to occur. The SFWMD stormwater treatment areas will also be used to redirect water flows from the northern Everglades EAA region. The releases will be designed to expand and enhance sheet flows to the water conservation areas (WCAs)

1.3. **Restore existing freshwater marshes and wet prairies**. The SFWMD (1998) in cooperation with other State, local, and Federal agencies should include the "Lower East Coast Buffer Plan" in the C&SF Restudy recommendations. The restudy is intended to develop water budgets and delivery schedules for all of southeast Florida. The projects under consideration include the Lower East Coast (LEC) buffer or water preserve areas as a series of wetlands along the development boundaries between the WCAs and Palm Beach, Broward, and Miami-Dade counties to serve as water preserve and storage areas. Some of the portions of this system of water preserve areas (WPAs) have been identified as having significant biological value (*e.g.* the Pennsuco Everglades in Miami-Dade County), and will be considered as valuable areas for ecological restoration of the spatial extent of the eastern peripheral freshwater marshes and wet prairies of the southeastern Everglades.

The Keys Environmental Restoration Trust Fund rehabilitated several acres of freshwater wetlands on Big Pine Key that are important to Key deer, Lower Keys rabbit, alligators, Key mud turtle (*Kinosternum bauri bauri*), wading birds, and other species. Restoration was achieved through fill removal and blockage of non-natural tidal influence.

Many other examples of laudable restorations exist and should be supported. The ecosystem restoration plan currently being enacted for Lake Trafford (Lake Trafford Task Force Conceptual Plan document, Gail Gibson, written communication 1998) is an excellent example of a plan to restore lake and marsh hydrology, reduce nutrient loadings, control phytoplankton blooms and *Hydrilla*, improve fisheries and wildlife habitat, and integrate the restoration into the Corkscrew Regional Ecosystem Watershed (SFWMD 1998). Another example is the restoration of short hydroperiod and marsh conditions on approximately 4,000 ha (9,880 acres) on former farmlands in the Hole-in-the-Donut of Everglades NP (Dalrymple 1994a, and Dalrymple and Doren (1998). This restoration prevents future germination of Brazilian pepper, and promotes wetland plant and animal re-colonization of the areas (Dalrymple 1994a; Dalrymple *et al*. 1993, Dalrymple and Doren 1998, Resources Management International 1998). All of these efforts will increase the spatial extent of functional wetlands for in a wide range of hydropatterns.

1.4. **Support modeling efforts** to evaluate plans and progress for ecosystem restorations. The USGS ATLSS modeling program (USGS 1997) is one of several initiatives to develop a landscape level model for evaluating future water delivery scenarios, as well as for evaluating impacts to single species, and entire trophic levels. This program should be supported because it is the only modeling program that incorporates both single species models and multi-species models in a spatially explicit landscape.

Additional support for the Natural Systems Model and the modified water deliveries (“Modwaters”) C-111 Project efforts are needed.

Modeling efforts are needed for predicting rates of success of stormwater treatment of agricultural runoff (Moustafa 1997). Modeling efforts to develop the best possible program for use of the proposed Water Preserve areas and the WCAs must include assessments of studies of seepage rates from WCA2. Alternative water storage technologies including Floridan aquifer storage and retrieval methods should be supported.

1.5. **Support reclamation programs that expand the spatial extent** of marshes and prairies and lake and riverine littoral zones. The easiest way to begin improving on current conditions is to selectively modify current design characteristics that are most amenable to both water management and habitat enhancement. For example: besides structural modifications for improved simulation of natural hydropatterns to regional lakes, rivers, and marsh systems, a number of additional actions should be considered for wildlife habitat improvement. Such actions include increased peripheral forested land, especially upland habitat, including native tree islands and littoral edge tree stands to improve ecotones between marsh and upland/forested habitat. Inclusion of island systems in artificial lakes and reclaimed rock mining pits, where native macrophytes and trees will be recruited, will promote water and wading bird foraging, roosting, and breeding habitat. Such areas would be isolated from human disturbance and mammalian predators (also see Hammond and Mann 1956, Sargeant 1982). King *et al.* (1985) have developed a series of guidelines for habitat reclamation on phosphate-mined lands, *e.g.* Tenoroc FMA near Lakeland, Florida (also see King and Cates 1994). Effective plans have also been developed for restoration of the Peace River and especially the Upper Saddle Creek (DEP 1997, and King *et al.* 1994). Construction of points of land, isthmuses, or spits of land along shorelines will be beneficial to overall productivity, habitat diversity, and maintenance of upland-wetland species requirements (Newman and Griffin 1994).

1.6. **Promote legislative initiatives** that improve on water use practices. State of Florida reform legislation was enacted in the 1972 Water Resources Act (Chapter 373) including amendments to insure more appropriate water budgets to multiple users, including the natural systems (Gsteiger and Loftin, 1997). Most importantly, the legislation protects natural systems by requiring Florida’s water management districts to ensure the sustainability of the natural systems and to establish minimum flows and levels for these systems. Scientific peer review for validating the data used in developing minimum flows was also required. The law should prevent wasting water by limiting the duration of water use permits, providing guarantees to current water permit holders when new users apply for limited water resources, providing equity in evaluation of water use permits, and providing certainty of water supply to existing and anticipated uses by requiring planning and water resource development technologies.

While there are still some controversial issues to be resolved in finalizing the best legislation, including the role of agricultural users that have not required permits previously, the most important issue regarding protection and enhancement of the spatial extent of functional marsh and wet prairies is the identification of minimum flows and levels. This and future legislation must recognize that a range of flows and water levels are required to sustain the largest spatial extent and most diverse range of marsh and wet prairie conditions, and that no single minimum flow level will be adequate to ensure long-term health of the natural systems.

2. Restore natural water quality to the system.

2.1. Provide initiatives for water quality improvement in relation to agricultural practices. SFWMD is developing six stormwater treatment areas (STAs) between the EAA and the WCAs in order to channel agricultural runoff away from Lake Okeechobee, and the WCAs. An experimental version, at a smaller scale, known as the Everglades nutrient removal project (ENR) has been operating since 1994. The ENR is a 1667 ha (4,000 acre) marsh retention area where runoff is held and phosphorus is absorbed by marsh plants. The ENR is experimental and intended to determine if the STAs will meet the Phase One goal of reducing phosphorus levels to 50 parts per billion (ppb) in water released into the WCAs. This is the largest constructed wetland designed for agricultural runoff in the country. To date, the SFWMD estimates (SFWMD 1997a) phosphorus reduction of 83 percent, estimated as a reduction to 22 ppb of phosphorus, which exceeds the expected Phase One level goal. SFWMD is continuing land acquisition and development of the full scale STAs. Debate remains over the actual success of the pilot nutrient removal. The agreement between the State and Federal agencies allows for continued acquisition and construction while these permitting and technical issues are clarified. STA 6 “section one” is operating now. STA-1 West, STA 2, and STA-5 are to be operating by early to mid 1999. The remaining STA element will not be operating until 2002 and later (SFWMD 1997a).

The ultimate goal is that water delivered to South Florida should not cause an imbalance of natural populations of flora and fauna. At the Phase Two level of this project agricultural phosphorus outflow concentrations should be down to 10 ppb or less when they leave treatment areas and enter the WCAs. The SFWMD is also proceeding with required evaluation of alternative technologies for phosphorus reduction, including chemical additives, STAs with chemical pre-treatment, and a method requiring passing STA water through an area of submersed vegetation with limerock for further filtration of phosphorus (SFWMD 1997a). The Miccosukee Tribe has promulgated water quality standards to protect tribal lands which include a large portion of the Everglades.

Similar efforts are underway in other portions of South Florida including the Kissimmee River drainage system. In Boney Marsh (Highlands County) a 0.48 sq. km (0.19 sq. mile) wetland was constructed to evaluate the role of overland flow in relation to phosphorus removal (Moustafa 1997). Much of this work is oriented to the development of larger projects throughout the SFWMD.

2.2. **Support public education** regarding proper disposal of hazardous wastes, and continue studies of the sources and effects of mercury and other contaminants and their relations to diseases and chronic sublethal effects in plants and animals in wetland food chains. The potential long-term food chain impacts from the wide range of contaminants and their relation to human activities may be the most underfunded and serious problem we face in the future.

3. **Support and increase funding for eradication and control of exotic pest species.** As reviewed above, funding and support is required to continue to control the expansion of exotic pest species of aquatic plants, trees, and animals in wetlands (Center *et al.* 1994, Jordan 1994, Schardt 1994, Thayer and Ferriter 1994). In particular, follow-up field studies of the effectiveness of biological control agents for melaleuca will require significant funding. Expanded quarantine facilities to permit more elaborate and detailed evaluations of other biological control agents are severely needed. Finally, some significant effort must be made to coordinate the agencies and inform the public regarding the elimination of exotic species of plants and animals.