Impact of water management on wildlife in the Florida Everglades

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Resumen

Originalmente los Everglades ocuparon mas de 10 000 kilómetros cuadrados en el sur de Florida en los Estados Unidos. El agua se movia lento bajando en flujo por la ciénaga, pero en años recientes ha sido afectado por diques, compuertas y canales y por las políticas de las entidades a través de las cuales fluye. Los impactos sobre poblaciones de peces y animales silvestres pueden ser atribuidos primero al desecado de 65% de la superficie y segundo a la alteración de el patrón de fluctuaciones de los niveles de agua en lo que queda de pantanos.

La modificación hidrológica comenzó en 1907 a 1928 y fué completada hasta los 70s. Por lo tanto la alteración drástica del núcleo de los Everglades es un fenómeno relativamente reciente. Las respuestas biológicas de especies que son indicadoras de las condiciones hidrológicas pueden ser usadas para obtener estrategias de manejo apropiadas a humedales. En los Everglades, los efectos de las fluctuaciones de agua sobre las cigüeñas americanas, lagartos, peces y camarones de estuario, pueden ser usadas para establecer metas de manejo para áreas, tales como parques nacionales, que son zonificadas para mantenerlas en su condición natural.

Abstract

The primitive Everglades occupied more than 10 000 square kilometers of southern Florida, USA. Historically water moved slowly downgradient by marshflow, but in recent years has been affected by levels, gates, and canals and by policies of the several political entities through which it flows. Impacts on fish and wildlife populations may be attributed firstly to drainage of 65% of the surface area and secondly to alteration of the pattern of water level fluctuation on the remaining marsh.

Hydrologic modification, beginning in 1907 to 1928, was not completed until the 1970s. Thus the drastic hydrological alteration of the core of the Everglades es a relatively recent phenomenon.

The biological responses of species that are indicative of hydrological conditions can be used to develop appropriate management strategies in wetlands. In the Everglades the effects of water level fluctuation on Wood Storks, alligators, fish populations, and estuarine shrimp can be used to establish management goals for areas, such as the national park, that are zoned to be manitained in their natural condition. Management of the Everglades system as a whole, however, must take into consideration the needs of such potentially divergent goals as ecosystem preservation, wildlife management, flood control, and water supply. In the Everglades, strategies can be found to meet each of these goals.

Introduction

The Florida Everglades may be the best known of the great tropical marsh grasslands of the western hemesphere. This emergent wetland, historically occupying much of the southern third of Florida (Fig. 1.), is warmed by the warm Gulf Stream such that it has subtropical temperature and rainfall regimes despite lying north of the true tropics. Historically water flowed slowly downgradient from central Florida to the coastal estuaries; this flow is now controlled by leves and canals and determined by the management policies of several political entities, at Federal, state and local levels.

Much has much has changed in the Everglades, over 65% of it has been irrepairably altered by drainage. What is more surprising is that so much remains. It is the dilemma of managing the remanant which faces the responsible governmental entities. Yet, no where else that I am aware do 2,500,000 people live adjacent to such a vast marshland in relative harmony. Over the past decade it is become increasingly recognized that the land and water of the Everglades are resources critical to the many human interests of southern Florida, including agriculture, urban, and industrial concerns, for whom the Everglades basin provides water, flood control, and waste water renovation. Expectedly, the management of the remanant Everglades is characterized by conflicts and differences of opinion. This is as it should be because the most appropriate, and perhaps even the best management solution in an altered system will come from the knowledgable compromises of all parties.

In this paper, I discuss the specific impacts of hydrological alterations and management actions on wildlife in the Everglades as a case history that may have utility in tropical wetlands elsewhere, such as in the Usumacinta and Grijalva Delta. I will then discuss management approaches and compromises.

Everglades ecology

Historically the Everglades wetlands occupied an elongated basin of 10,000 km2, 65 km wide and 160 km long, extending from Lake Okeechobee to the southwestern edge of the Florida peninsula (Fig. 1). To the north, it originated at Lake Okeechobee, where water sometimes overflowed the lake berm into the marsh. To the west, it was confluent with the higher Big Cypress Swamp. To the east, water passed over and through higher limestone and sand ridges along the coast. The slight slope and thick emergent vegetation impeded water flow and water flow south. The Everglades differs from most similar tropical marshes in that it has no central river system. Rivers are short and supply localized outlets for surface water flow through the coastal mangrove swamps.

Precipitation is highly seasonal with and average of 75% of the annual rain falling in the summer and fall (Fig. 2). The wet-dry rainfall cycle plays an important role in the ecology of the Everglades in that it causes a seasonal fluctuation of surface water. At the beginning of the rainy season in June, a rapid increase in water depths begins that peaks in autumm. Water levels fall in late winter and spring to a low point in May. Throughout normal dry seasons the peat soil remaing damp, but standing surface water is absent from all but the deeper sloughs and ponds. Absence of surface water is typically a condition of short duration, lasting a month or less, another difference from most tropical marshlands. Marsh organisms must be able to cope with alternating flood and drought, a process that along with fire (Wade et al. 1980) is the dominating forcing function of the ecosystem.

Hydrology in large part determined by patterns and timing of water level fluctuations as constrained by history and fire (Hoftetter this symposium). Sawgrass marsh is the predominant plant community in the Everglades. Once covering 800,000 ha (Stephens 1974), it now accounts for about 70% of the remaining Everglades landscape (Loveless 1959a). Sawgrass (*Cladium jamaicensis*) and other plants must be adapted to fluctuating water conditions. The occurrence of various plant can be correlated to water depth and the duration of flooding during a year, with a strong historical component affecting the details of distribution along hydrologic gradients. Maidencane (*Panicum hemitomon*) grows in water inundated for relatively long periods, 78% or more of the time. Sawgrass grows on slightly higher ground, inundated less than 80% of the time. Wet prairie plants such as muhly (*Muhlenbergia fillipes*) grow on still higher ground having shorter inundation periods.

Recent studies have demonstrated the dominating role of fluctuating water levels in the ecology of the characteristic animal populations of the Everglades (Kushlan 1974a, b, 1975, 1976a, b, 1980, 1987, in press, Kushlan and Kushlan 1979, 1980). During the summer and fall period of high water, fish populations increase but when water levels fall, standing surface water becomes shallower, affecting initially the higher elevations in the marsh. As these begin to dry, fishes and other mobile aquatic organisms become concentrated in the remaining pools in the marsh. Maximum Fish densities increase until water reaches a depth of 25-30 cm. Thereafter it decreases until the marsh dries completely and fishes continue to concentrate in deeper water ponds within the marsh where they may survive the dry season. Reduction of fish populations by predatory activities, especially of birds can incrase the probability that the remaining fish can survive through remaining the dry season.

Many wading bird species (Ciconiiformes) take advantage of the seasonally abundant patches of food available in the marsh and its ponds to obtain food for reproduction, thereby accessing the productivity of the wetland for their own reproduction. In some species the relationships between water level fluctuations and nesting biology are crucial to nesting success (Kahl 1964, Kushlan 1976c, 1977, 1979a, 1986a, Kushlan et al. 1975). The white ibis (*Eudocimus albus*), for example chooses, its nesting colony sites near drying marsh patches. The wood stork (*Mycteria americana*) depends on aspecific rate of falling water for intiating nesting and successfully completing it.

The snail kite (*Rostrhamus sociabilis*) also exemplifies water level relationships (Sykes 1983a, 1983b). The snail kite is dependent almost entirely on a single species of aquatic snail (*Pomacea paludosa*), which achieves its highest populations in deeper-water sloughs and marshes that do not dry out completely (Kushlan 1975). Historically kites located these patches of snails by moving among marshes in the state.

A marsh bird having different hydrological requirements is the Cape Sable seaside sparrow (*Ammodramus maritimus*). It occupies higher marhes along the edge of the Everglades where it depends on short hydroperiods and recurrent fire (Werner an; Woolfenden 1983, Kushlan and Bass 1983a).

The dominant species of animal in the Everglades is the American alligator (*Alligator mississippiensis*) (Kushlan 1974a, Kushlan and Jacobsen in prep.). Its nesting success depends on the pattern of water level fluctuation in the wet season. The alligator places its eggs in mound that it constructs from available marsh vegetation at the beginning of the rainy season, and development takes place as water levels rise, which may put the eggs at risk to flooding. However the height the eggs are positioned above the marsh bottom depends on water levels at the time of nesting, which have a statistically predictable relationship with maximum water levels later in the wet season. Thus the alligator relies on an inherent predictability in the pattern of water level fluctuations during the Everglades wet season.

The Everglades fish community also depends on water level fluctuations (Kushlan and Lodge 1974, Kushlan 1976a, 1980, Loftus and Kushlan in press). The community is dominated under usual conditions by the mosquitofish (*Gambusia affinis*), which can account for 60% of the fishes present. Other livebearers and killifishes make up most of the other fishes present in the marsh. Larger fishes are rare in the fluctuating marsh. Naturally sunfish, gar, and bullheads occur primarily in ponds and the deeper water lily marshes. Under typically fructuating conditions the larger fishes suffer high mortality whereas the smaller species are able to repopulate the marsh following a dry period.

Deer (*Odocoileus virginianus*) that occur in the Everglades are distinguished by their small size and aquatic habits (Loveless 1959). They wade through water that can be shoulder deep to obtain forage, particularly water lilies, various emergent herbaceous plants, and woody swamp plants especially willows.

In any segment of the Everglades marsh, the extent and timing of water level fluctuation depend on two factors, local rainfall and surface water inflow from higher areas. Historically water moved through the shallow marsh very slowly in that it eas blocked by stand of dense plants. Surface water flow from upstream marshes in essential to the ecology of any particular patch of marsh.

Changes and their impacts

Historically 30% of the land area of Florida was covered by wetlands, much of this emergent marshes. The first canal dredging began in southern Florida in the late 1800s at Lake Okeechobee and along the coasts (Blake 1980). These efforts, however, had little effect on the Everglades. Everglades drainage commenced with the activities of a local drainage district from 1907 to 1928, during which period four canal were dug in the Everglades, and Lake Okeechobbe surrounded by levees. The drainage scheme was most effective along the coast, leading to salt water intrusion into the surficial water table as the head of fresh water dropped. The central core of the Everglades proved exceptionally difficult to drain in the wet season, so these areas remained wetlands. The lack of control of both seasonal and catastrophic high water on nearby lands led to the establishment of another flood control district in 1949, which began the process of enclosing the remaining virtually undrainable Everglades and isolating it from reclaimed lands to the north and east, a process not completed until 1967.

The alteration of Everglades marshes may be attributed to two related factors, drainage and alteration of the extent and timing of hydrological events. The fundamental cause of the ecological degredation of the Everglades has been the dewatering of a large portion of its expanse, a process that reflects the history of marshes in Florida as whole in which 76% of the historic marsh area has been lost (Hefner in press). The second factor had been the alteration of water level fluctuations on the remaining marsh.

By the 1980s, 65% of the original Everglades marsh had been irretrievably drained. Most of the loss was to agriculture. The largest loss of habitat in the core of the Everglades followed the recognition that the northern Everglades marsh could be made suitable for farming. This lead to the reclamation of the swamp and marsh inmediately south of Lake Okeechobee. Reclamation of the Everglades-like marshes northeast of Lake Okeechobee was nearly complete, except for a few small reservoirs. Additional land was reclaimed east of the Everglades, between the central core of the basin and the higher ground along the coast, a loss primarily of wet prairie and sparse sawgrass associations. Over 80%, about 1,300 km 2, of these marshes have been drained in one are (Birnhak and Crowder 1974). Most of the southeastern Everglades is under agriculture (Hull and Meyer 1973).

A more insidious effect superimposed on the dramatic loss of higher marsh habitat was that resulting from flood control and water management within the remaining marsh. Much of the change in the remnant Everglades is caused by use of the marsh for water storage and its release for flood control. This has been accomplished by the enclosure of the northern Everglades in five shallow reservoirs called water conservation areas. One of the low areas southeast of Lake Okeechobee is both a reservoir and a national wildlife refuge. The southernmost compartment is Everglades National Park and the undeveloped wet prairie to the east, recently named the East Everglades. The intended functions of the conservation area reservoirs are to provide flood control for the developed east coast and municipal and agricultural water supplies, prevent the intrusion of salt water into the aquifer, supply water to the southern Everglades, and conserve fish an wildlife habitat. Presently about 3500 km2 of Everglades marsh is encompased by five interconneting pools of the conservation areas holding a maximum regulation storage of over 1,600,000 acre feet of water.

Actually before the early 1960s, except for the drainage of the Everglades agricultural area and peripheral wetlands near the coast, the flow of surface water was relatively unimpeded in the remanant core of the Everglades. But in the 1960s, the levees caused substantial changes in the water patterns in the Everglades. The eastern levees of the conservation areas, blocked the flow of water eastward, thereby increasing the amounts of water in the remaining Everglades marsh and directing it southward (Leach et al.

1972). The western levees of Conservation Area 3 kept water in the Everglades from flowing westward into the southern Big Cypress Swamp, retaining it in the Everglades marsh. Transverse levees caused substantial changes. Water flowing southward, especially via canal flow, piled up behind the transverse levees flooding the marsh in the southern ends of the conservation areas. Southward flowing water left the higher northenmost marshes drier than previously.

The southern transverse levees also caused considerable disruption in the southern Everglades of Everglades National Park. In December 1962, the gates in the newly completed transverse levee north of the park were closes and remained closed for two years except for a few short politically-inspired openings. This action cut off surface flow into the southern Everglades, which aggravated the dry conditions of the drought years causing widely publicized fires.

In 1970 a public law guaranteed certain amounts of water to Everglades National Park, flows that approximated the median monthly amounts found in the available historic record. No provisions had been made in the design of the water conservation areas for the discharge of water to the south by any means other than directly into the park. The result was the extra discharge of water into the park whenever upstream levels exceeded that set by regulations. This water was from previous rainfall or surface flow, the release of which was delayed until required for water management purposes in the conservation areas.

A natural drought in 1971 reinforced the decades-old perception of a drying Everglades (Ward 1972). Neither this or subsequent well publicized droughts had any lasting adverse impact on the southern Everglades marsh. In fact no drought related effects are noticable in the core of the southern Everglades since the institution of the water delivery schedule. However, the excess water in the now reduced Everglades and its unnaturally timed release has led to changes in the patterns of water level fluctuations both north and south of the transverse levees, resulting in the extensive system disruptions documented in the Everglades in the last 15 years. Recent studies have especially documented how alteration of water levels has markedly affected wildlife.

Sykes (1979, 1983) demostrated that the decrease in the Florida population of the snail kite was the result of drainage projects that destroyed much of its marsh habitat and secondly the modification of the wetlands that remained. Under natural conditions within the broad expanse and scattered distribution of Florida s marshes, the kite in most years located marshes suitable for foraging sites. Presently mangement of the core Everglades and of Lake Okeechobee, in providing long-term water level stability, has benefited the kite population. Thus the stabilization of high levels in parts of the remaining core Everglades marshes compensated for the loss of marsh habitat elsewhere in Florida.

On the other hand, this same stabilization of high water levels in the conservation areas and discharge south into the southern Everglades have adversely affected the wood stork, a species that has experienced nesting failure because the flooding of its feeding marshes. As a result the southern Everglades wood stork population has decreased by 75% from 1967 to 1982 (Kushlan and Frohring 1986). It of interes to note that we have no evidence of a substantial decrease of wood storks or of other wading birds in southern Florida prior to the recent period of water management. Although contrary to most published accounts we found no credible evidence for the existence of millions of wading birds or hundreds of thousands of wood storks in Everglades. However there is no doubt that population decrease during the past two decades of water management have been substantial.

White-tailed deer suffer periodic mass mortality caused by high waters in the Everglades. These die-offs are certainly directly caused by water management, but surely have precedents in the natural ecosystem. It is likely that the deer herd now builds up in the drier northern ends of the conservation areas but sucumbs when those areas flood. The catastrophic mortality appears to be due ultimately to declining condition because of the lack of dry ground rather than a lack of browze per se, which is present in the marshes in abundance. Generally under these conditions the management response to curtail hunting and access to the area is to avoid additional strees on the animals. It may be more useful to encourage hunters to take these animals at just this time, to service one of the several groups that have a special interst in using Everglades resources.

The normal fish community of the Everglades requires the maintenance of fluctuating water conditions. Where water fluctuations are stabilized, substantial changes occur essentially turning the Everglades fish community into on more resembling that of a lake, dominated by large predatory fishes (Kushlan 1976a). Clearly alteration of the patterns of water level fluctuations will and have changed the relative and absolute abundance of fish communities.

The relationship between alligator nesting success and water levels in the wet season is clearly based upon the predictable fluctuations of water levels (Jacobsen and Kushlan in prep.). We have found that hydrological predictability disappeared during the current period of water management. As a result the flooding of alligator eggs in the southern Everglades has increased five-fold during the current period of water management. Concurrently in the southern end of Conservation Area 3 pool, persistent high water levels have led to the near elimination of reproduction.

Drainage of peripheral marshes has had salutatory effects on some species that prefer drier wet prairie. One of these is the Cape Sable seaside sparrow. Reduced water levels in the Taylor Slough headwaters and the consequent encroachment of muhly marsh into the area has led to an increase in the species from a point where it had been thought to be nearly extinct (Kushlan and Bass 1983a). Thus this species has benefited from the reduction of water tables along the periphery of the main core of the Everglades.

To the south of the Everglades marsh, lay estuaries and lagons that support important wildlife populations. The flow of water from the Everglades into the Gulf of Mexico estuaries is certainly an important determinent of productivity in this area and on the Tortugas shrimping ground (Browder 1985). It is likely however that the lagoon system of Florida Bay may never have been much affected by upland water flow because of its large size and tits small upland catchment area. Population censuses in Florida Bay have suggested that decreases in populations of brown pelicans (*Pelecanus occidentalis*) and osprey (*Pandion haliaetus*) have occurred (Kushlan and Bass 1983b, Kushlan and Frohring 1985). Simultaneously, Powell (1983) demonstrated reduced reproductive success of Great Blue Herons (*Ardea herodias*) nesting away from developed areas in the bay. It would appear that the most straight-forward explanation for impacts on all three of these fish-eating species is a change in the seasonal availability of their fish prey. It is not known if the decreases in birds or prey have any relation to the alteration of the upland drainage in the Everglades.

Management options for the Everglades

The direct hydrological and biological effects of drainage and water management demonstrate the differing, and sometimes subtle, responses of various plant and animal populations. In total these are certainly indicative of substantial disruptions to the natural functioning of the Everglades ecosystems. To some extent the species discussed above can serve as indicators of natural ecosystem function, and one can expect that other unstudied system components are being adversely affected as well. The insidious alteration of population sizes and ecological relationships has no doubt resulted in substantial, although undocumented, changes in the pathways and control of energy flow throughout the ecosystem.

The reversibility of the various changes in the Evergldes system cannot be determined. Many if not most changes are irreversible. It is likely that a return to more natural fluctuations would result in an approach to but not a complete return to pre-existing system function in small areas. There is no evidence that any species has been eliminated from the Everglades wetland, despite the dramatic population changes observed in some.

The trends in water management in southern Florida have had a number of specific impacts. These include the loss of wetland habitat to drainage, which in turn requires continued drainage and protection of resulting residential and agricultural areas. Flood control and water supply considerations have resulted in the compartmentalizing of the once confluent marsh, reducing its capacity to buffer local hydrologic events. However it has also permitted some degree of management.

One result is the disruption of the natural predictability of hydrological fluctuations. The natural rainfall-driven pattern of water level fluctuation provided inherently predictible sequences of events to which natural populations could accommodate. The timing and speed of water level decrease in the dring season, maximum submergence periods, and the percentage of time submerged all affect the survival and reproduction of the plant and animal populations. The imposition of management has altered the natural relationships of rainfall to consequent water level fluctuation, thereby causing substantial changes in the population size, distribution, and ecology of the plant and animals characteristic of the Everglades. It has also led to political conflict among agencies and citizens over control of the water supply.

Management of the remanant Everglades in a natural ecological condition requires not only maintenance of the essential marshland character but also production of some very exacting requirements with respect to patterns of water level fluctuation. Such management requires the active manipulation of discharge and water levels through structural means such as levees, gates, and spillways. It must be remembered that the core Everglades is only a fraction of it former size, and there is more water over the remnant basin than was present on that same area historically. Along the higher periphery of the Everglades, drainage has resulted in less water being present than historically and the consequent increase in fires and the spread of exotic plants (Hofstetter, this proceedings).

Because of past management decisions, including its reduction in size, the entirety of the Everglades can no longer be managed as a naturally functioning ecosystem. Presently the Everglades is zoned for different uses. Some of it has been drained for agriculture; some is occupied by residences. Most of the remnant is encompassed by three shallow reservoirs, which are nearly surrounded by levees and connected by gated structures and canals. The southernmonst portion is part of Everglades National Park, a natural area reserve.

It is crucial to realize that the management goals of the several compartments of the Everglades must differ, and that the differing needs of the various users must be taken into consideration. In southern Florida the conflicting interests might seem to represent irreconcilable positions. But aparent conflicts are to a large degree technically resolvable. Sufficient knowledge exists now to manage the Everglades for the benefit of all users once the fundamental premises of its being an already altered system area accepted.

There is little doubt that the preservation of the entirety of the Everglades would have been a most worthwhile goal one hundred years ago. However, the compartmentalization of the Everglades is not only a fact but may have been inevitable in an unplanned human occupancy of southern Florida. It essentially representes zoning into use-areas for water management, recreation, wildlife, agriculture, development, and a natural area preserve. Thus it follows that various management strategies will be in effect. In addition, it must be realized that with respect to preserving water supplies and providing flood control the compartmentalization and management of the Everglades has been a resounding success. With respect to preserving natural ecological processes, it has not (Kushlan 1979b).

Within the zone of the Everglades included in Everglades National Park, it is appropriate to manage to preserve the distinctive animal and plant populations, as required by law. Management there should, therefore, be aimed at preserving ecological processes by reference to the effects of water management on its constituent natural populations. What is critical is not so much the amount of water entering the park as its ecological impact. In order to provide some approach to reinstituting a naturally functioning ecosystem, management should involve restoration of meteorologically-based patterns of water level fluctuations.

Such restorations cannot be effected in the entirety of the Everglades if flood control and water supply requirements are going to be met (Kushlan 1987). Thus management of the conservation areas must be very different from that of the natural area zone. The eastern levee system keeps surface water from flowing eastward over former Everglades land, which has now been developed and is no longer available as wetland. The Everglades thus provide flood protection during seasonal and storm-derived periods of high rainfall. On the water supply side, the Everglades is the recharge area for the Biscayne Aquifer, which provides water to the populated Florida east coast. Water conservation requires the withholding of water that would otherwise be lost to the ocean and the continued positive drainage of former wetlands. It also requires its movement in the dry season to the coast via canals in order to maintain a hydraulic head against the intrusion of salt water, a process that also recharges the well fields. These considerations suggest that relatively high water levels need to be maintained in the conservation areas. Such a situation would deviate substantially from natural conditions. Nonetheless it would preserve the marsh character, enhance habitat for certain wildlife, and provide recreation opportunities.

Neither the maintenance of high water levels in the conservation areas nor their use for water quality restoration need adversely affect the natural area compartment, Everglades National Park, so long as it did not result in water quality changes or the high or unseasonal discharge of water to the south. This can be avoided by using a rainfall-driven delivery system to determine timing. The amount of water must be determined by its downstream effects. Managed water flows should not cause water level fluctuations that would adversely impact sensitive plant and animal populations. These impacts can be used to form the basis for establishing hydrobiological criteria for water deliveres (Kushlan 1987).

None of these measures need necessarily conflict with other uses of nearby land. For example, farming adjacent to Everglades National Park has not resulted in the movement of contaminents into the park (Requejo et al. 1977). It should be possible to use traditional agricultural practices for row crops in the former marshland next to the Everglades, and to farm such land during the low water periods, which happens to correspond to the growing season. What is required however is an acceptance by farmers of the seasonlity of their farming and the risk of failure due to high waters. Similarly housing developments already in existance can be protected by levees and drainage without any expectation that this would further impact the Everglades marsh within the national park.

It is important to realize that managing for an approach to reproducing natural conditions in the southern Everglades will not necessarily restore all species to their place in the wetland ecosystem. Management goals assigned to each zone determine the future ecological potential of all zones. To maintain some endangered species it may be necessary to establish additional management zones, for single-species wildlife refuges. Once a decision is made that water supply or waste water renovation is the most important use of a wetland, the preservation of natural system function will be sacrificed. The important concern is to make such decisions aware of the potential their potential effects.

That these compromises are possible reflects in large part on accepting the premise that most of the Everglades no longer exists and that already existing development and land uses constrain management options. It is an acceptance of a highly altered system, that will be managed differentially to various ends. Had the planning process begun prior to the irretrievable committment of capital, the ultimate management strategies could have been more robust. Under the condition of a naturally-functioning system, management manipulations could have been minimized. As it is, the management of this wetland will require continual expenditures of tens of millions on dollars per year. With such expenditures, appropriate management of the remanant Everglades becomes possible.

Another lesson from the Everglades experience is that relatively slight alterations of a critical forcing function can lead to system disruption nearly as drastic as that of drainage. Both the environmental changes and the biological impacts can be subtle, and unrecognized without detail study, and perhaps unrecognizable within the limits of current technology. Slight delays in the timing of surface water discharges can destroy a wood stork or alligator nesting season. Repeated alterations, only moderately noteable themselves, can readily affect such population sizes and even persistence of species. Nonetheless the end result is a change, usually a degradation of ecosystem processes, as clearly as if the wetland had been drained. Whether such a change is appropriate is a matter for careful and learned consideration.

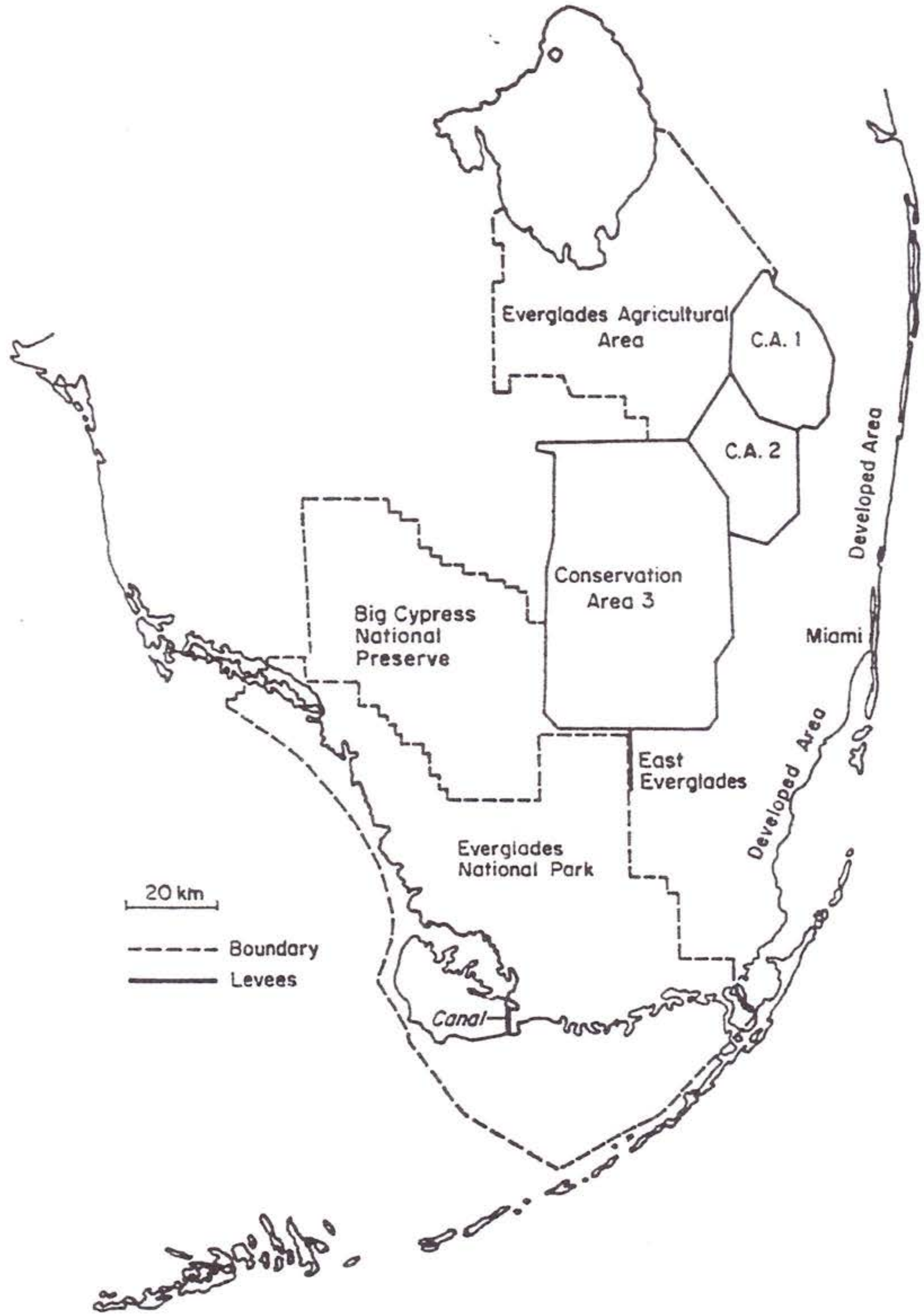

Figure 1. Political features of Southern Florida.

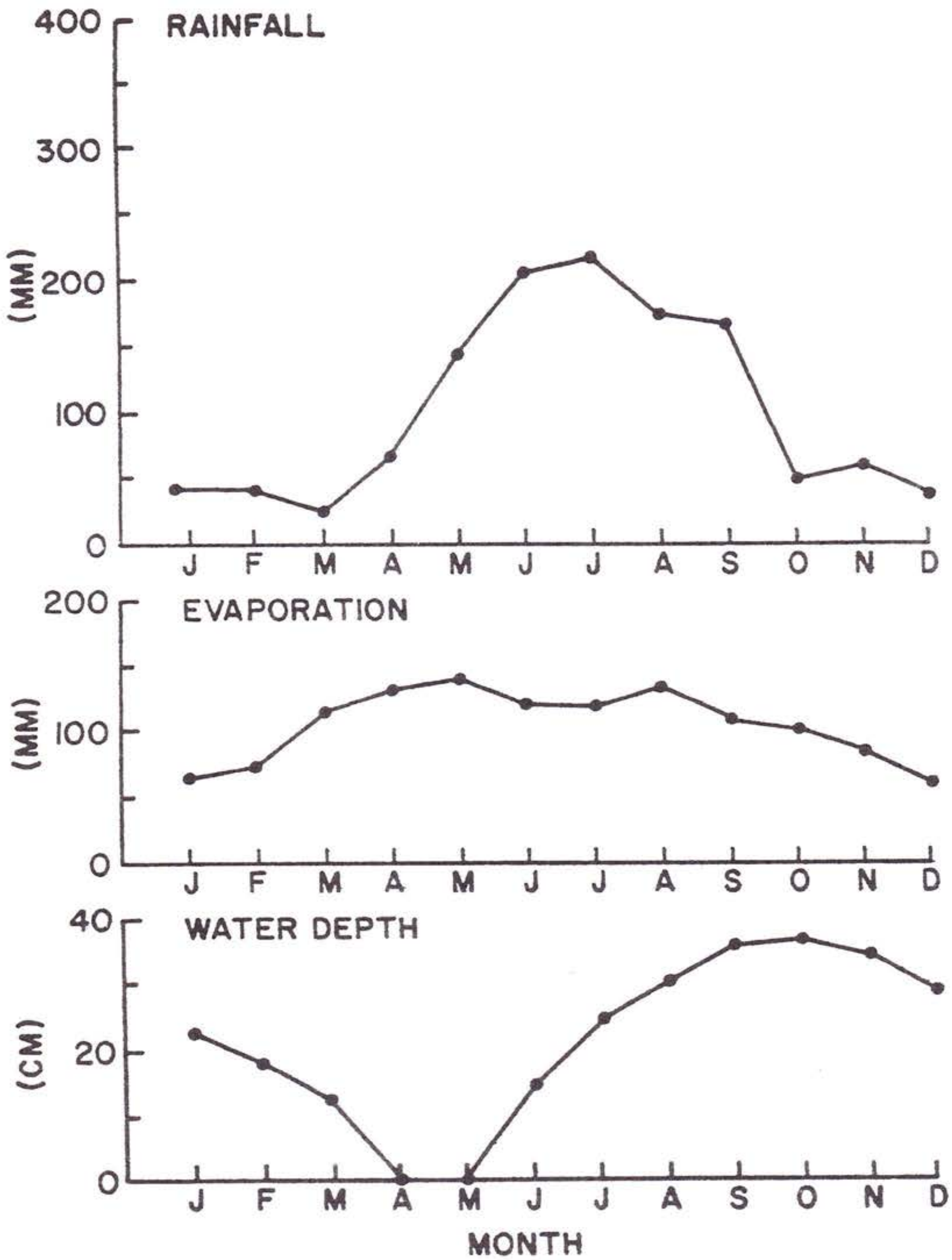

Figure 2. Average rainfall evaporation, and water level fluctuations in the everglades.

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