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THE EVERGLADES: MANAGEMENT OF CUMULATIVE ECOSYSTEM DEGRADATION

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ABSTRACT

The Everglades was a 9300 km^2 hyperseasonal savanna occupying the lower third of the Florida peninsula. Historically it was characterized by slow down-gradient marsh flow of surface water and by an annual dry period during which surface water was confined to scattered ponds and deep marshes. Reclamation has reduced the area of the Everglades by 65%, the remnant wetland being compartmentalized into shallow reservoirs (the water conservation areas) and a natural area reserve (Everglades National Park). Other land uses of former Everglades include agriculture and residential development. The seasonal cycle of water level fluctuation is the dominating force determining the functional characteristics of the ecosystem. Indigenous plant and animal populations are adapted to the annual water level cycle, and disruption of this cycle has lead to the cumulative functional degradation of the ecosystem and disruption of constituent populations. Investigation of the relationships of water level fluctuation to the biology of certain sensitive populations, including fishes, alligators, wading birds, and shrimp has provided an understanding of the system's function and options for the active management of surface water. Knowledge is sufficient to undertake this management provided certain premises are accepted. These include that the loss of wetlands, the compartmentalized zoning of the remaining Everglades, and for the most part the deterioration of system function are irreversible. Furthermore the remnant Everglades must process more water than it did historically, e.g., the problem of water management with respect to the natural system is the management of too much water. In Everglades National Park, but not necessarily in the water

conservation areas, management must be aimed at perpetuating ecosystem processes to conserve distinctive plant and animal populations. Finally, the Everglades must be managed actively rather than by benign neglect. Mechanisms are available for active management that can preserve the Everglades ecosystem and needs of various groups dependent upon this wetland ecosystem. The cumulative loss of ecosystem function can be expected in wetland systems that have suffered reduction in size or alteration of critical ecological processes, such as the cycle of water level fluctuation.

INTRODUCTION

World famous as the River of Grass, the Everglades is neither a grassland nor a river, thereby suggesting a principal impediment to its appropriate management. The Everglades lives an allegorical life in the minds of both citizens and its managers, and is at once the most studied yet most misunderstood representative of the several subtropical hyperseasonal savannas scattered around the world. The plight of the Everglades has been a well-publicized concern of the conservation community since the beginning of this century, engendering the expenditure of hundreds of millions of dollars on management and research, while the cumulative impacts of management action progressively eroded its fundamental functioning as a wetland ecosystem.

Once, the Everglades was a wetland unified by the flow of surface water during the annual rainy season. It was characterized by seasonal droughts to which the indigenous plants and animals were particularly adapted. Now, the Everglades is compartmentalized by levees, interconnected by canals, and divided by the differing management policies of its political components. It serves the flood control and water supply needs of Florida's east coast, yet is perceived to be in competition for these waters. It is unsurprising that conflicts should abound.

Such conflicts are yet resolvable. Sufficient knowledge exists to begin appropriate management of the Everglades once fundamental premises are accepted. First, the compartmentalizing of the Everglades is not only a fact but is inevitable and not necessarily undesirable. It essentially represents zoning into land use areas for water management, recreation, wildlife, agriculture, development, and a natural area preserve. It follows that multiple management strategies are now or eventually will be in effect. Second, the cumulative degradation of the Everglades is a fact, and it can never be restored to its presettlement condition. The character of the Everglades prior to a time just a few years ago is unknowable in any detail. Third, the Everglades is presently a remnant of its former expanse, and the remaining wetland must process more water than did that same area historically. The fundamental management problem is not one of prolonged man-effected drought. Rather, the problem is that there is too much water in the Everglades. Fourth, Everglades National Park, managing southern tail of the Everglades, was charged by law to preserve the distinc animal and plant populations of the Everglades and by Bureau policy to pres ecosystem processes. Management should, therefore, be aimed at preserving t processes by reference to the effects of water management on its constitu natural biological populations. What is critical is not the amount of wa but its ecological impact. Fifth, the Everglades will always need to be man actively. It would be inappropriate to conserve the Everglades through rem of management mechanisms, followed by the benign neglect of having nature its course.

In this paper I will explore the implications of cumulative ecosy degradation in the Everglades to its management, based upon the results o series of studies on the effects of water level variability on Everglades an populations.

THE EVERGLADES WETLAND RESOURCES

Historically, the Everglades wetlands occupied an elongated b covering over 9300 km^2, extending from Lake Okeechobee to the mangrove swamp the southwestern edge of the Florida peninsula. On the north it originate seasonal water which flowed out of Lake Okeechobee. To the west it confluent with the more intermittent swamps and marshes of the Big Cyp Swamp. To the east water exited over and through the limestone and formations of the Atlantic coastal ridge. Such underground water movement sufficient to cause freshwater springs to flow in adjacent east coast bays. the southwest water moved seaward via a network of streams that coalesced several short rivers before entering the Gulf of Mexico. Historically, li water moved south because of natural levees inland of the mangrove swamps. result, Florida Bay on the southern tip of the Peninsula is and probably al has been highly saline, with little connection to the Everglades. The main of water through the marsh followed a shallow gradient of 3.6 cm/km fro elevation of 5.2m to sea level.

The Everglades is underlain by peat and peaty-marl, deposited by vasc plants and epiphytic algae. The characteristic vegetation is sawgrass (Maris *jamaicensis*), covering 70% of the present Everglades. Lower sites contain a sedge and grass community, the surface of which is usually covered by floating plants, especially bladderwort (*Utricularia*) and water lily (*Nymphaea*). The deepest basins are ponds maintained by the American alligator (*Alligator mississippiensis*), the dominant animal of the ecosystem (Kushlan, 1974).

Water depths are shallow, averaging less than one meter. There is no evidence that historical water depths were any greater than they are today in the remnant Everglades. Although downward seepage is impeded by the marl and peat substrate, the surface water is in direct connection to the ground water. Along the southeastern edge of the Everglades this connection is to the highly permeable Biscayne aquifer.

The fauna of the Everglades is a relatively depauperate temperate one, having reached south Florida through the sieve of an elongated peninsula. The fauna and aquatic flora are predominantly temperate North American in origin. Hardwood vegetation on the scattered tree islands varies in character along the long axis of the Everglades. Southern tree islands, especially elevated ones, have some trees of tropical West Indian origin, which drop out of the more northern communities.

Management of the Everglades is divided among public agencies and private landowners (Figure 1). Most of the remnant Everglades is encompassed by three shallow reservoirs called Conservation Areas, which are surrounded almost completely by levees and interconnected by gated structures and canals. The southern tail of the Everglades, known as Shark River Slough, is part of Everglades National Park. The wetland east of the park is in both public and private ownership.

ECOSYSTEM STRUCTURE AND FUNCTION

Seasonal fluctuation of water level is the primary driving force in the functioning of the Everglades ecosystem. The Everglades is a seasonal wetland and thus experiences alternating periods of flood and drought caused by seasonal rainfall. On the average 85% of the 1250mm annual rainfall occurs in the six month rainy season from June through December (Figure 2). Increasing evaporation and transpiration in the spring leads to increasingly rapid

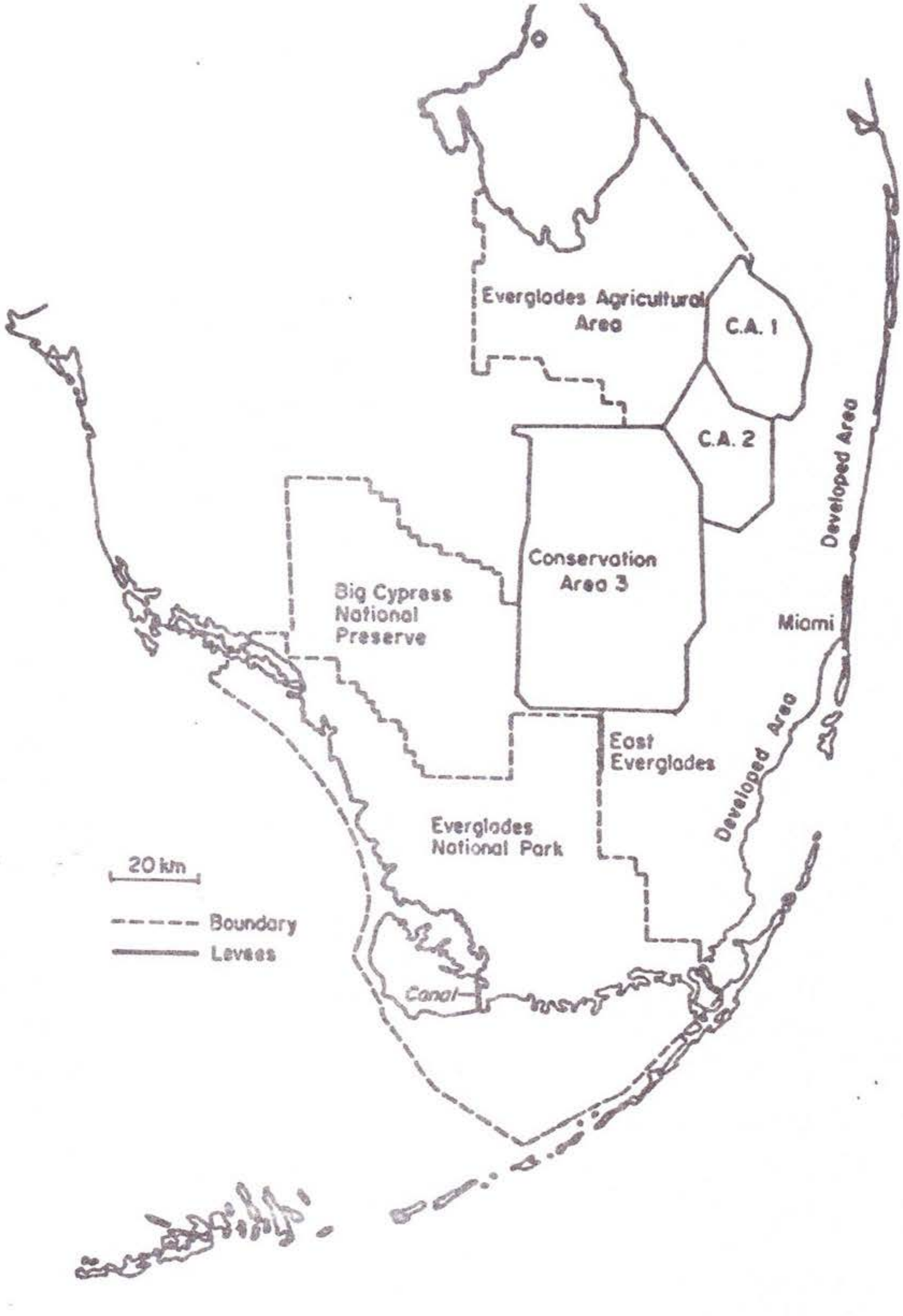

Figure 1. Map of southern Florida showing the land use and political divisions of the interior wetlands.

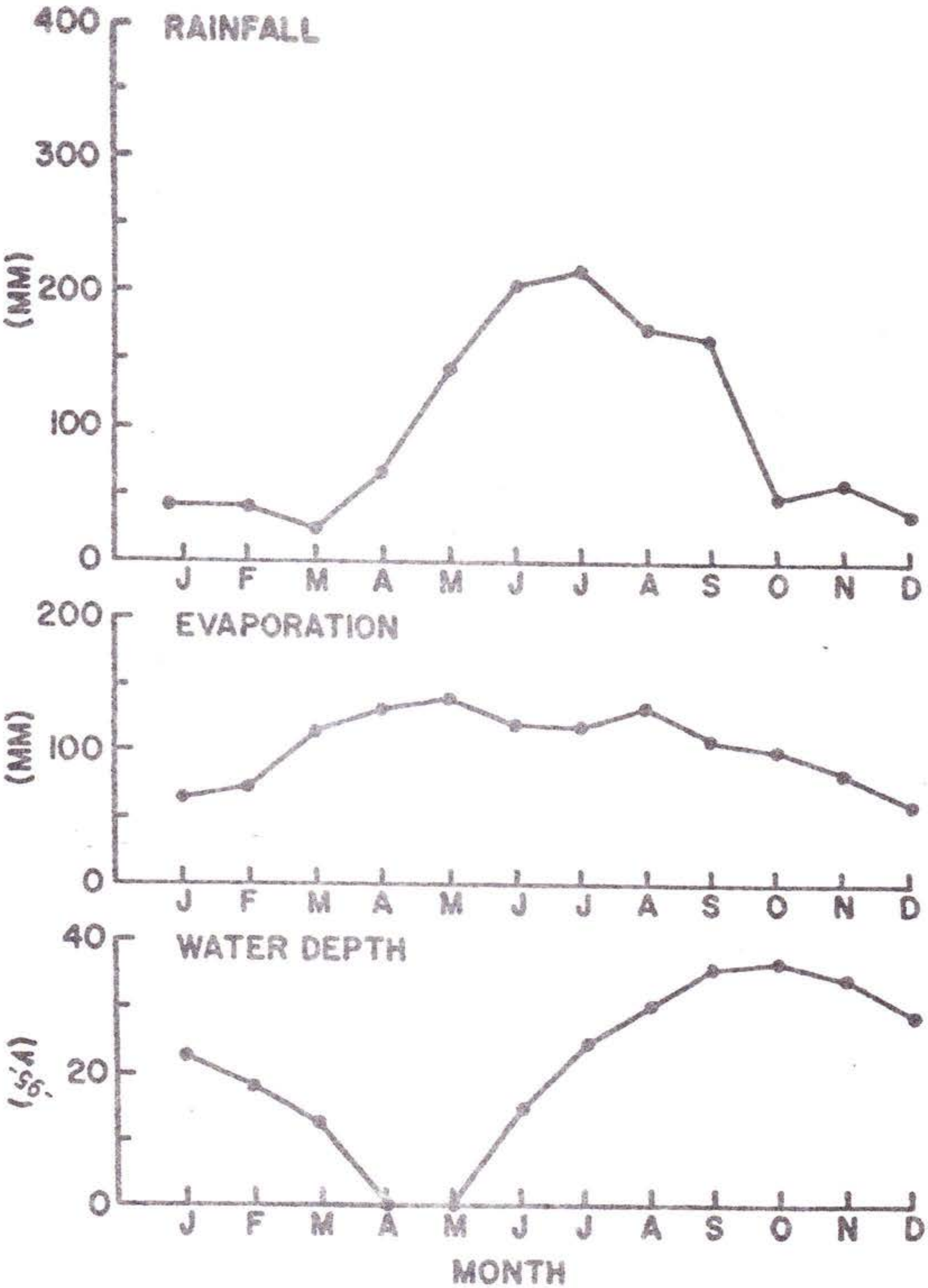

Figure 2. Average rainfall, evaporation, and water depth in the southern Everglades.

decreases in water levels. By the end of the dry season in late May, water i typically absent from the marsh, remaining only in the deeper alligato maintained ponds. When rainfall resumes, the water level rises rapidly flooding the marsh.

Plant and animal populations surviving in the Everglades must have bee able to accommodate seasonal changes in flood conditions and yearly deviation from the norm. Their life cycles are attuned to the predictable variability o the system. The extent of these adaptations have been demonstrated in a serie of studies (Browder, in press; Jacobsen and Kushlan, in press; Kushlan, 1974 1976a, b, 1977, 1979a, 1980; Kushlan and Jacobsen, in prep.; Kushlan et al. 1975; Ogden et al., 1978).

The working of the system can be visualized through a model of ecosyste function, the alligator pond (Figure 3). The pathways of energy flow are to large extent controlled by water fluctuations. During the drying season, fishe and many aquatic invertebrates move into the remaining deep-water ponds as th marshes dry. Their survival depends on the occurrence of compensatory mortalit from predation by birds and alligators. Without this mortality, fish kill occur, which divert energy flow into scavenger and detritus food chain: Colonial wading birds adjust their nesting seasons to take advantage of th seasonally superabundant food supplies found in drying marshes and ponds. Th undertake seasonal movements covering most of the Everglades as it drie: feeding in a succession of ponds and marshes as the drying conditions make th available. The birds use this food supply for nesting. The deep water refug are maintained through the work of the alligator.

The relationships between the animal populations and the pattern of wat level fluctuation are complex but predictable. The character of the Evergladı freshwater fish community is determined by the multiyear pattern of water lev fluctuation (Kushlan, 1976, 1980). Specifically, the typical fish communi dominated by small live-bearers and top minnows requires seasonal dry period When dry periods do not occur, survival of larger-bodied fishes chang community structure to one resembling a lake rather than a marsh.

The wading bird most sensitive to water level fluctuations is the wo

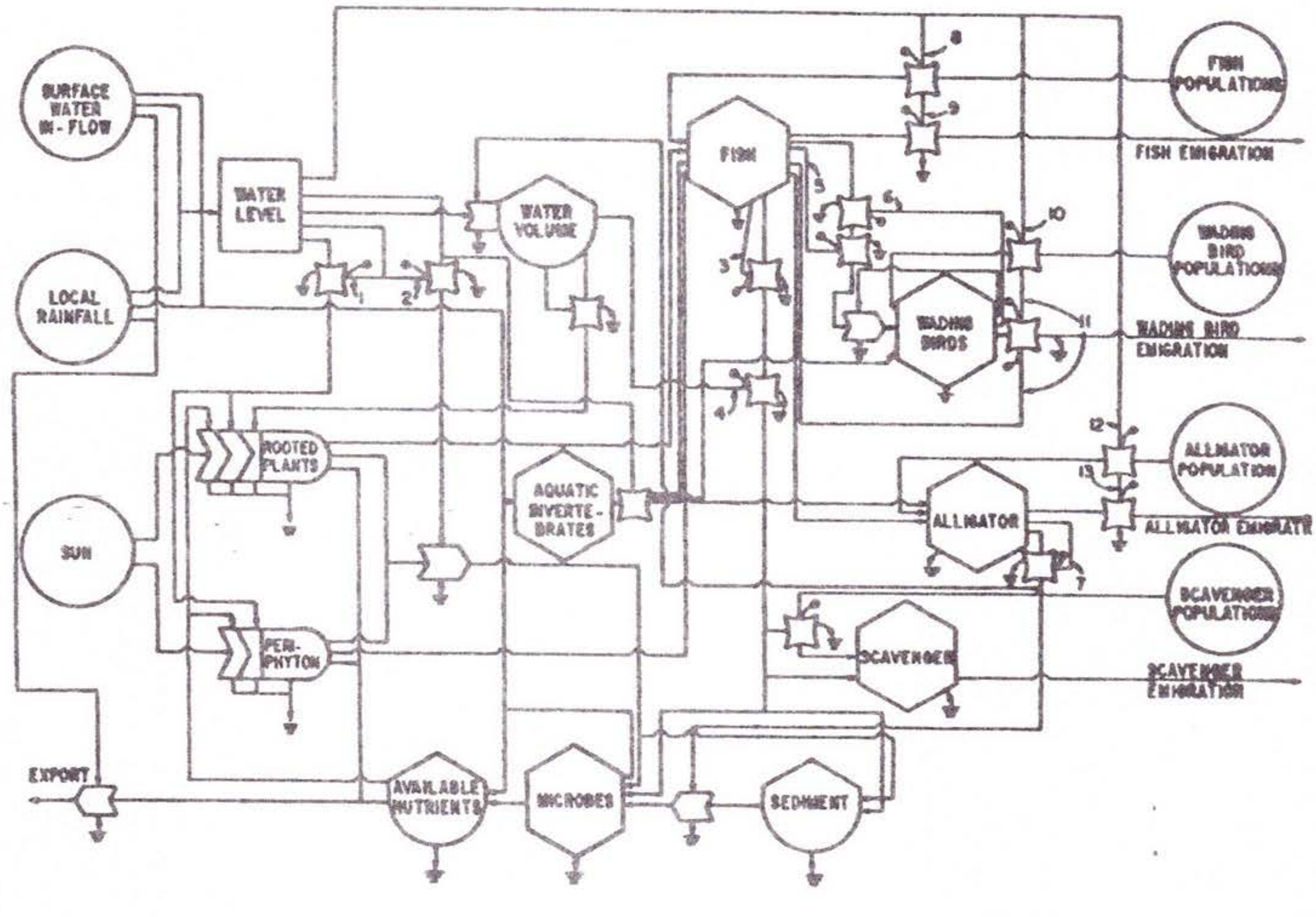

Figure 3. A functional model of an Everglades alligator pond, using Energy Circuit Language (Odum, 1983).

stork (Mycteria americana). I have found a predictive mathematical relationsh between the timing of wood stork nesting and the rate at which the souther Everglades dries in the drying season (Kushlan et al., 1975). The faster th drying rate the earlier the storks nest. This is of importance because th nesting season has been delayed in recent years, such that in most cases nestir is not completed before the beginning of the next rainy season; as a result th nesting effort is abandoned. The repeated nesting failure of souther Everglades wood storks, which have had two successful years in the past 18, ma be attributed to the alteration of hydrological conditions in the souther Everglades, particularly the maintenance of higher dry season water levels an slower drying rates.

The relationship between rising water levels in the wet season an alligator nesting success is just as compelling (Kushlan and Jacobsen, i prep.). The primary cause of alligator nesting failure in the Everglades i flooding of eggs by rising water levels. Alligators can, however, accommodat to water conditions by elevating the level of their eggs above the marsh bottom We found that the height of the clutch is predictable from the water level a the time of egg deposition in the early summer. We also found that historicall this water level was a good predictor of the maximum height water achieved during the following two months. Maximum water levels threatening to alligato nesting were predictable from water levels at the time of nesting. We have found also that this relationship disappeared during the current period of wate management, thus suggesting that the inherent predictability of the hydrological cycle in the Everglades has broken down. As a result, the loss of alligator eggs to flooding in the southern Everglades has increased fivefold during the current period of water management.

Water flow through the marsh also has important effects in the downstream estuary. Browder (in press) found that water depth in the marsh in the fall was a predictor of harvest on the Dry Tortugas fishing grounds of shrimp known to originate in the Everglades estuaries. Thus it appears that high wet season discharge enhances estuarine shrimp production. There was no relation between dry season water depths and shrimp production. These findings demonstrate the need for high surface water discharges in the fall, during the historic season of high flows. However, the findings do not support a need for increased dry season discharges into the estuary. From our marsh studies, we find no adverse biological effects of high discharge in the fall.

High water levels also have affected plant communities. The plant communities in the southern end of the Conservation Areas have changed markedly during the current period of water management. At the southern end of the reservoirs there has been a loss of sawgrass and low tree island communities in favor of deeper water habitats such as water lily sloughs. The northern upstream part of these same areas have experienced the replacement of marsh vegetation by shrubby swamp trees due to increased drying. This has also occurred in drained Everglades land in the east Everglades, meaning that both extended high and extended low water levels have changed plant communities in the Everglades.

Alteration of the natural patterns of water level fluctuation, especially maintaining water at too high a level, results in fundamental alteration of the functioning of the wetland ecosystem. These effects have been gradual and cumulative; some are reversible, some are not. Reduced nesting success in the wood stork in the southern Everglades and of the alligator in the southern Consrevation Areas has lead to a long term decrease in populations occupying these areas. The southern Everglades wood stork population has decreased by 80% from 1967 to 1982 (Kushlan and Frohring, in press).

It is of interest to note with respect to cumulative effects that we have no evidence of a substantial decrease of wood storks or of other wading birds in southern Florida from the early part of the century. Contrary to most published accounts, there is no credible evidence for the existence of millions of wading birds or hundreds of thousands of wood storks in southern Florida. The maximum documentable wood stork nesting population was in 1967, from which it has dropped gradually as nesting failures multiplied. This decrease need not have been accompanied by a decrease in the overall wood stork population as it is likely that unsuccessful storks gradually moved out of the southern Everglades.

Such population decreases should raise less concern for the wood stork per se than for what the declines imply about the functioning of the Everglad ecosystem. The functional characteristics of the Everglades have been alter by changes in the pattern of water level fluctuations in each of its prese compartments. These alterations have lead to a progressive deterioration of t ecosystem, demonstrated by the responses of sensitive indicator species.

ECOSYSTEM SERVICES

The Everglades is vital to the maintenance of the urban-agricultur development of southern Florida, especially with respect to water supply, flo control, and pollution abatement. Other well known functions performed by t Everglades, although clearly of lesser economic importance, include recreatio tourism, and aesthetic values.

The Everglades is the recharge area for the Biscayne Aquifer, whi provides water for two and one-half million residents of the Florida east coas their industry and agriculture. Holding surface water in the Conservation Ar reservoirs maintains aquifer recharge. From the Everglades the water flo underground toward the southeast, where it is recoverable by pumping. Duri the drying season surface water from the Everglades is displaced coastward v canals in order to maintain a hydraulic head against the intrusion of saltwate This canal-delivered water also recharges the well fields. The reservoir last resort is Lake Okeechobee, from which water can be moved in the dry seas via leaky canals toward the populated coast.

The eastern levee system of the southern Everglades keeps surface wat from flowing eastward over former Everglades land which has been developed a is no longer available as wetland. The levees were constructed principally f purposes of controlling flood waters and retaining such waters in t Everglades. The Everglades thus provide flood protection during seasonal a storm derived periods of high rainfall.

Ewel and Odum (1984) have demonstrated the efficacy of using wetlands f renovation of wastewater. The Everglades is a nutrient poor system that c absorb nutrients within a short distance from their insertion point. Where canals may move such water rapidly through the system and into otherwi unaffected areas of the Everglades, marsh flow is relatively slow, allowing t removal of nutrient loads. Thus, the Everglades could serve for wastewater renovation provided such water were not allowed to be transported quickly by canals to inappropriate locations.

TRENDS

Cumulative impacts have resulted from two sources: drainage and flooding. Thus, there have been two dominant trends in changes of the Everglades, the loss of wetland and functional alteration of the remaining marsh. Impacts began with the drainage schemes of the early part of the century, which have been well documented (Blake, 1980). The initial impact of the drainage was the drying of areas of the Everglades, at least seasonally. In most cases, the gains of land were compromised by short periods and years of high water conditions. Long term irreversible impacts were felt first along the coast where drainage was most effective. Such effective drainage gradually moved inland, but the central core of the Everglades was probably not overdrained in most normal and high rainfall years.

Actually, with the exception of the removal of agricultural land south of Lake Okeechobee from the system (Figure 1), flow of surface water was relatively unimpeded before 1962. In the 1950's and early 1960's the coastal canal systems were controlled by salinity structures near their mouths. Thereafter they have been used primarily for drainage of the developed coastal ridge and not of the interior Everglades. Water was moved into the canals from the Everglades only when required to maintain their hydraulic head. In the early 1960's the levees of the Conservation Areas were completed. The eastern levees blocked the flow of water eastward and thereby opened up consistently drained land west of the coastal ridge. The levees also increased the amounts of water in the remaining Everglades marsh to the west (Leach et al., 1972), in that water now moved southward instead of southeastward. Levees along the western edge of Conservation Area 3 have a large breach that collected water drainage from the Big Cypress Swamp. The levees south of the breach kept water from flowing westward back into the southern Big Cypress Swamp, retaining it in the Everglades marsh. The southern transverse levees caused substantial disruption. In December 1962 the gates in the newly completed transverse levee were closed 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. One result was to inspire the enduring impression that the Everglades was too dry. But even at the same time, water piling up in the Conservation Areas was beginning to cause system alterations there.

In 1970 a public law guaranteed certain amounts of water to Everglades National Park, flows that approximated the median monthly amounts of historic record over the entire drainage cross-section. Because no provisions had been made in the design of the Conservation Areas for discharge of water to the south through any means other than directly into the park, a method of releasing excess water was required. The National Park Service agreed to accept any excess water that might be made available. The result was the extra discharge of water into the park whenever upstream levels exceeded regulation. 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 decade old perception of a drying Everglades (Ward, 1972). Neither this nor subsequent well-publicized droughts had any lasting adverse impact on the Everglades marsh. In fact no drought related effects are noticeable in the southern Everglades since the institution of the water delivery schedule. However, the excess water in the areally reduced Everglades and its unnatural timing of release has lead to changes in the patterns of water level fluctuation both north and south of the transverse levees. This has resulted in the extensive system disruptions seen in the Everglades in the last 15 years.

SYSTEM IMPACTS

Trends in water management in southern Florida have had the following specific impacts:

1) The loss of wetland habitat to drainage followed by the need for continued positive drainage of newly formed residential and agricultural areas. The loss of Everglades wetland is about 65% of the original marsh area.
2) The compartmentalizing of once confluent marsh. This has reduced the

capacity of the system to buffer local hydrologic events but has als permitted some degree of management, which is most effective in smal controllable areas.

3) The loss of natural predictability in hydrological fluctuations. The natura rainfall-driven pattern of water level fluctuations provided inherentl predictable sequences of events to which animal populations coul accommodate. The imposition of management has altered the natura relationships of rainfall to consequent water level fluctuation.
4) The decrease in the populations of wood storks nesting in the southern Everglades, owing to the changes in the dry season water regime.
5) The decrease in the nesting success, and in some areas, population levels o alligators owing to changes in the wet season water regime.
6) Political conflict among agencies and citizens over control of the wate supply.

The direct biological impacts noted above are those that are understood because of the discovery of predictive relationships between water conditions and life history responses of several sensitive populations. However, to the extent that these populations serve as indicators of natural ecosystem function, we expect that other system components are being adversely affected as well. The insidious alteration of population sizes and relationships has no doubt resulted in substantial, although presently undocumented, impacts on the pathways and control of energy flow throughout the ecosystem. The reversibility of the various impacts in the Everglades system cannot be determined. It is likely that a return to more natural fluctuations would result in at least an approach to but not a complete return to pre-existing system function. Many changes are undoubtedly not reversible. There is no evidence that any species has been eliminated permanently from the Everglades wetland, despite the drastic population changes observed.

INFORMATION AND MANAGEMENT

The Everglades is in the unusual position of being the subject of an extensive research effort by many agencies over 20 years. Unfortunately, most of the information collected is not relevant to management of the system. In fact, much of it consists of data collected with minimal regard to answering specific questions of water management. Thus the existence of large masses of data on the Everglades is of little or no value. There is a reluctance to use the results of several specific management studies that run counter to long held beliefs about the Everglades. The problem in the Everglades is not the need for more information, but rather the acceptance of realistic premises and the implementation of management schemes derived from the information that does exist.

It is crucial to realize that management goals for each of the several compartments within the Everglades must differ, and that the differing needs of the particular users must be taken into consideration. Starting from this baseline the path to management action is in no way unclear.

The primary management goals of the water Conservation Areas must be water supply management and flood control. These goals require the withholding of water in the reservoirs during the dry season to preserve water supply and its movement to the coast via canals. They require the venting of water during the latter part of the wet season to avoid hurricane overspill of the levees. They also require the conservation of water that would otherwise be lost to the coast and the continued positive drainage of former wetland now developed. 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 marsh character and be especially useful for certain wildlife and recreation considerations, particularly the conservation of the endangered snail kite (Rostramus sociabilis) and freshwater fishing. Such a policy would require the continuation of most of the present levee system, especially the transverse levees, that impede the southward flow of water.

Such policies would also permit the use of the Conservation Area marsh for water renovation. It would be necessary to prevent the rapid downgradient displacement of such water requiring the blocking of all southward flowing canals. This would permit the slow movement of water down the marsh.

The maintenance of high water levels in the Conservation Areas would not adversely affect the natural area compartments in Everglades National Park, so long as it did not result in the high or unseasonal discharge of water to the south. This can be avoided by using a rainfall-driven delivery system. In that it is not the amount but the effect of the water delivery that is crucial, the resulting flows should not exceed levels that would adversely impact sensitive plant and animal populations. These impacts can be used to form the basis for establishing biological criteria for water deliveries (Kushlan, in press). Certain structural modifications would be necessary including the breaching of the southwestern levees of Conservation Area 3 and the filling of the delivery canal on the eastern boundary of the national park. It also would require the delivery of water over the entire width of the Everglades, including that area to the east of the park.

None of these measures need conflict with other uses of nearby land. For example, farming adjacent to Everglades National Park has not been shown to result in the movement of contaminants into the park (Requejo et al., 1977). It should be possible to return to more traditional agricultural practices in the lowland next to the Everglades, and to farm such land during the low water periods which correspond to the growing season. Similarly, housing developments already in existence need to be protected by levees and drainage, but there is no reason to expect that this would further impact the Everglades marsh within the national park.

CUMULATIVE IMPACT MANAGEMENT

The long-term effects of drainage and water management in the Everglades have substantial lessons for the management of such impacts in other systems.

An important lesson can be gained from looking at aerial imagery of southern Florida. It is obvious that wetlands cover most of the southern tip of the Florida peninsula, and most of this has now been brought under government management. Yet despite the preservation of much of the massive south Florida wetlands, the functioning of these systems has been severely compromised (Kushlan, 1979b). The preservation of wetlands is insufficient without maintenance of processes or a conscious decision to accept their alteration.

Another lesson is that the loss of wetland function often is time dependent. The cumulative impact of all changes and management in and near wetland may take time to express itself. Because time spans on the order of t generation times of the plant and animal species are involved, such populatio seldom respond with a massive die-off. Rather, when their accommodati abilities are exceeded, population changes occur gradually; and as they d other coupled system functions are affected. Thus, cumulative impacts c radiate through an ecosystem as populations adjust to changes in forci functions and in the other populations with whom they interact.

To some extent the cumulative loss of ecosystem function in remna wetland patches is irreversible. The restoration of dominant forcing functio such as inflows of water will probably not restore the ecosystem to pre-existi conditions. Wetlands are open systems and probably have numerous steady state Just as the trajectory of change due to impacts is unpredictable, so is t trajectory of retrochange when impacts are removed. Thus, it is unlikely th management action should return the marsh to a totally natural steady stat Nonetheless, restoration and management of dominant functions such as wat inflow can restore some semblance of system processes. The processes may then preserved, even if the end result may differ from the starting condition.

Management for natural processes is an appropriate strategy for a natu area reserve. However, not all of the Everglades need to be so manag Appropriate management of a water Conservation Area may sacrifice natu processes for other higher priority goals. Is it much better to preserv wetland for water supplies and flood control, even if functionally altered, t to compromise those values in the search for an unattainable naturalne Restoration of ecosystem function in the natural area component of Everglades may still be the most one can hope for. In other systems it important to consider what amount of functional degradation is acceptable bef it becomes desirable to discontinue preservation efforts. Would an Evergla without wood storks be unacceptable? The stork is a highly specialized predator, and its loss would be an expected early consequence of ecosys degradation (Kushlan, 1979b).

It is important to realize that once zoning is enacted, the managem goals assigned to each unit will determine the future ecological potential of each component. Once a decision is made that water supply or wastewater renovation is the most important use of a wetland, the preservation of natural system function will be sacrificed. The important concern is to be aware of the potential cumulative impacts of a decision when making a decision.

Relatively slight alterations of a critical forcing function, such as the slight delay in water deliveries, can lead to system disruption as easily, albeit more subtly, than drainage. Thus it becomes crucial to understand the important forcing functions at each wetland system and the cumulative impacts of altering these functions. Research, therefore, should not be aimed at the near mindless gathering of ever more data, but rather should address specific questions of concern to conservation and management. For example in the Everglades it is of no direct management value to continue to survey wading bird numbers in various places, as this information cannot uniquely answer any question of water management interest. An applicable research question is, what is the long-term impact of a specific alteration of water deliveries (the forcing function) as mediated by water level fluctuations (a critical system process) on a population parameter of interest. The responses of sensitive species to system processes can serve as indicators of those processes, and can be used to derive hydrobiological criteria to guide and constrain water management actions. Only with such understanding of the dynamics of the system can appropriate decisions be made to either preserve or not preserve the functioning of the wetland ecosystem.

CONCLUSIONS

Cumulative impacts have resulted in degradation of ecosystem processes in the Everglades and have adversely affected plant and animal populations dependent on seasonal fluctuations of water levels. Both the environmental changes and the biological impacts can be subtle, and unrecognizable without addressing appropriate research questions. Slight delays in the timing of discharges may affect such population characteristics as nesting success and nest placement. Population effects may take generations to reveal themselves. Nonetheless, the end result is a change, usually a degradation of ecosystem processes, as clearly as if the wetland had been drained. Such impacts may be to some extent irreversible, requiring the imposition of management goals appropriate to the area. The goals of Everglades National Park and Water Conservation Areas need not be identical. The proper management of the Everglades requires the realization that the basic problem is that there is and will be an excess of water and that this wetland must be managed actively.

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