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EVERGLADES



Natural Sciences Research Plan

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
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EVERGLADES NATIONAL PARK
NATURAL SCIENCES RESEARCH PLAN

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FOREWORD

Everglades National Park, this Nation's third largest National Park and the only National Park in North America established to save and protect a semitropical aquatic wilderness, has the dubious additional distinction of presenting the most serious preservation problem faced by the National Park Service today.

For many years, farsighted individuals such as the Park's first Superintendent, Daniel B. Beard, have warned of potential dangers to the delicate balance of the living natural resources which constitute Everglades National Park. These warnings pointed to the urgency for initiating massive research efforts to understand the intricate interrelationships of the complicated array of biological and physical components which produced and currently contribute to the complex of sensitive ecosystems for which the Park is famous. Attention was directed repeatedly to deterioration which appeared to have begun already in the Park's natural systems and to the tragic consequences likely to accrue from man's efforts to manage living resources in the absence of a sound understanding of their environmental requirements.

Man's continuing manipulation of the terrestrial environment in central and southern Florida resulted in ever-decreasing surface flow of fresh water into the Park and the living systems appeared to deteriorate further. Then, Nature compounded the Park problems with 3 or 4 successive years of below-normal rainfall. The cumulative effects were such that, in 1964 and 1965, the Park was so parched that some scientists believed the resulting damage to the living resources to be of a catastrophic nature--so severe that Everglades National Park could scarcely recover. By this time, newly appointed National Park Service Director Hartzog had launched extremely vigorous and persistent efforts to obtain an "adequate" surface flow of fresh water from extra-Park sources.

The truth of the years of warning concerning the need for natural science research in the Park began to become embarrassingly obvious at this point, for the Service found that it possessed little or no indisputable evidence with which to defend its appeals for a portions of the surface water available elsewhere in southern Florida. Who could say what constituted an "adequate" water supply? Indeed, who could prove that the severe desiccation of the Park was not a natural phase in the historical development of the Park biota? Fish skeletons in the dry basin of a pond and failure of bird populations to reproduce were certainly evidence that all was not as it

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should be at the moment but--who could show that these conditions were not simply normal facets of Nature's unending evolutionary measures? Who could demonstrate conclusively that other natural features of the Park biota had been critically damaged? It is a credit to Director Hartzog that, despite the necessity of entering the conflict with little live ammunition, the battle was joined with almost brazen aggressiveness and, aided by an aroused public, a victory was achieved--limited amounts of fresh water were permitted to flow into the Park from the north and additional steps were initiated to increase and perpetuate the surface water supply.

We may never know whether or not the resulting supply of fresh water would have been too little and/or too late because, by mid-1966, Nature had again taken a hand and drenched the Florida peninsula with above-normal rainfall to the point that, at this writing (September 1, 1966), the Park water situation appears to be reasonably good. However, much time will have to pass before we can determine the severity of damage which accrued to the Park resources as the result of the drought period. We don't know if all of the resources will recover and, if so--how much time the recovery will require. We still do not know how much water the Park resources require or with what periodicity. Certainly, we do not know why. Some have said that the Park has had a reprieve in the form of the sudden excess of rainfall. Let's hope so. Let's hope, too, that, given this additional chance, the Service has learned a lesson and will act promptly to assure that it will never again be caught with its data lacking in such resource situations that could readily develop in any of the areas for which it is responsible.

Not the least persistent of the voices that were raised in warning of impending disaster to the Park's living resources was that of Dr. William B. Robertson, Jr., who has served Everglades National Park in the role of Biologist or Field Research Biologist for more than 10 years. Despite great odds, enforced distractions and little support or encouragement, Dr. Robertson has managed to build an enviable record of research in the Park. Indeed, he has become recognized in the scientific community as being the foremost authority in the world on the overall biology of Everglades National Park. However, such an incredible amount of research needs to be done in the Park that even Dr. Robertson's magnificent contributions have been little more than a large drop in the bucket. A score of scientists of his ability could more nearly meet the Park's research needs.

Dr. Robertson has prepared, or obtained from other contributors, much of the material constituting the body of this Everglades National Park Natural Sciences Research Plan. In addition to the usual editorial duties, the editors have taken the liberty to modify the text such as to identify Dr. Robertson's research activities with prominence equal to that which he has accorded other individuals responsible for past or present research activities in the Park.

George Sprugel, Jr.
Chief Scientist

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INTRODUCTION

Natural science research in the National Parks requires unified planning in order to supply park administrators with the information they need for wise administrative decisions affecting the natural areas for which they are responsible. Such information is essential for the protection and interpretation of park resources.

The purpose of this Park Natural Sciences Research Plan is to outline the natural science research needed to meet the above-mentioned park requirements. In doing so, it identifies pertinent investigations underway, or already accomplished, establishes general patterns for obtaining additional needed information, and indicates the broad content and dimensions of the natural science research program required by the Park.

Everglades National Park differs in degree (though not in kind) from other major units of the National Park System in that its significant features primarily illustrate dynamic, biological systems of plant and animal populations which are predominantly aquatic. These systems comprise an intricate mosaic of marsh and estuarine communities which are situated at or near sea level at the seaward end of an extensive drainage system.

The present Natural Sciences Research Plan was prepared in accordance with the Service's Natural Sciences Research Handbook, which outlines in further detail the basic philosophy, and the specific procedures to be followed, in connection with the natural sciences research program.

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SUMMARY

I. PURPOSES AND OBJECTIVES

The various Acts of establishment, and related legislation, make clear that the primary purposes and objectives of the Park are to exemplify and maintain for posterity in a wilderness condition (1) the abundant native wildlife, including rare and colorful birds; (2) the extensive fresh-water and salt-water areas, open Everglades prairies, mangrove forests, and all other natural features, which collectively make this Park the only large subtropical wilderness remaining in the United States; and (3) certain archeological and historic sites illustrative of pre-Columbian cultures.

The substance of other pertinent documents indicates that management of the natural resources is to be oriented to: (1) assure a minimum of man-induced interference with the natural evolutionary processes, and (2) maintain or re-create the closest possible approximation to the natural habitat conditions that would now prevail in the Park if there had been no significant interference by European man.

One of the greatest values that visitors can derive from Everglades National Park is to experience, with adequate understanding, the complex interplay of land and water, and the diverse plant and animal life associated with this environment. The inter-relationship of plant and animal populations thriving under these conditions offers an unrivaled opportunity for resource interpretation, for visitor inspiration and education, and for scientific study.

II. RESOURCE CHARACTERISTICS

GEOGRAPHY

The east boundary of the Park lies within a few miles of the fringes of the Greater Miami metropolitan area which now has a population of about one and one-half million and continues to grow.

The Park's geography is characterized by extreme flatness and slight elevation; permanently submerged lands comprise at least half of the Park, and much of the rest is subject to seasonal flooding. The three principal geographic divisions are (1) the interior Everglades, (2) the coastal brackish zone, and (3) the marine coastal region.

Biogeographically, the Park is a meeting ground for temperate continental and Antillean tropical biotas, both of which are at the extremities of their respective ranges.

CLIMATE AND HYDROLOGY

Climate

Warm weather, light but persistent winds and ample but erratic rainfall, characterize the area. During the summer-fall wet season, hurricanes sometimes cause extensive damage to islands and coastal areas--particularly to mangrove forests, and in extreme cases to birds and other animals.

The more severe winter freezes cause heavy mortality among tropical fish and manatees, but only once or twice per century are such freezes severe enough to significantly damage mangroves and other tropical plants. However, the heavy downpours associated with the storm fronts, when followed by cold, have been known to break up water bird rookeries.

Hydrology

Although heavy rainfall is the principal source of water needed to maintain the Park's ecology, a vitally important additional supply of water is, or used to be, provided by overland flow. This additional supply must be in an adequate amount to overcome or minimize water shortage at all times, and particularly

during the extremely dry periods. In recent years this amount has not been sufficient. Underground flow from the north is impeded by the relatively low permeability of the limestone aquifer along Tamiami Trail.

Overland flow from Lake Okeechobee and the area north thereof was intercepted between 1881 and 1927 by canals which changed the runoff patterns in most of the area south of Lake Okeechobee, thereby diverting much of the water to the ocean.

At the time the Park was established in 1947 and subsequent thereto, some overland flow of water into the Park from the north continued. In 1948, Congress authorized the construction and operation of the Central and Southern Florida Flood Control Project which included development of three Conservation Areas north of the Park for storage and release of water for beneficial use. Conservation Area 3, directly north of the Park, is the main storage facility designed to hold water for release into the Park. However, the southward flow of water released into Conservation Area 3 from Lake Okeechobee and Conservation Areas 1 and 2 has been very slow because the average gradient is only about one-tenth foot per mile over the intervening distance of 40 miles to the Park. Existing canals in this region are relatively inefficient for conveying the necessary volume of water. Moreover, much water released into Conservation Area 3 is lost through evapotranspiration.

The National Park Service, the Central and Southern Florida Flood Control District, and the Corps of Engineers, have been coordinating efforts to determine means of improving the water supply for the Park. A study authorized for this purpose by the Congress is considering water needs of the entire area and is expected to be completed in the fall of 1967.

In addition, interim work now underway and planned should provide substantial relief to the Park until such time as more comprehensive measures can be considered under the more detailed study authorized by Congress.

GEOLOGY

Although the Floridian Plateau is a relatively ancient geomorphic feature, it has been largely submerged through most of its history and is blanketed by great depths of marine sediments.

The three surface formations of importance in determining the present topography and drainage characteristics of southern Florida are: the Miocene Tamiami Formation in the northwestern part of the Park; the Pleistocene Miami Oolite which underlies most of the Park area and forms the floor of Florida Bay; and, the Key Largo Limestone, an emerged Pleistocene coral reef which forms the present Upper Florida Keys. All are permeable marine limestones (in part, calcareous sandstone, in the case of the Tamiami Formation) highly modified by solution and thinly mantled by recent accumulations of marl and peat. Outcrops of these formations, such as Long Pine Key in the Park, form some of the present slightly elevated "uplands" of south Florida, profoundly affecting the occurrence of native vegetation types.

Evidence from the study of tides and coastal peat deposits indicates that the sea level has risen again in recent times. It appears probable that this sea rise is continuing, but the point is disputed by some authorities.

A number of the underlying strata of southern Florida are aquifers. Three--the Ocala of Eocene age, the Tampa and Hawthorn of Miocene age--carry artesian water and form the Floridian aquifer. Overlying the Floridian aquifer is a blanket of formations of low permeability (Floridian aquiclude) that confines the water in the aquifer and gives it artesian pressure. The Floridian aquiclude is approximately 600 feet thick in the Park area and forms a water-tight foundation for the important Biscayne aquifer.

The Biscayne aquifer occurs in rocks chiefly composed of the Miami Oolite and the Fort Thompson Formation and contains a pool of fresh water with the apex a few miles west of Hialeah. During the wet season, part of this pool is apparent as surface water.

Little on the Park's surface suggests a rather eventful geologic history. No explanation presently is available for the so-called Everglades "rock reefs" (not coral) which are conspicuous surface features. The formation of the keys (mangrove islands) in Florida Bay, and various coastal ridges, may have resulted from mangrove growth, but this hypothesis needs further study.

BIOLOGICAL COMMUNITIES

Despite the region's topographic uniformity, various combinations of environmental factors have acted on particular sites to

produce a number of distinct vegetation types. Striking changes in the vegetation, associated with slight differences in elevation, salinity or with variations in the effects of fire, often are encountered within short distances. Changes in the characteristic animal life associated with these different cover types often are equally well-marked.

The most distinctive biological communities are: sawgrass marshes and prairies, sloughs, cypress islands, bayheads, hardwood hammock forests, pinelands, estuaries and lagoons, mangrove swamp forests, coastal prairies, shell beaches, oyster bars, and turtle-grass shoals.

Glades. The open glades, which are wide reaches of sawgrass marsh dotted with scattered tree islands, dominate much of the interior of the Park. During the summer-fall rainy season they are largely covered with a sheet of water and provide breeding grounds for an abundance of small fish and other aquatic animals. Alligators, birds, and mammals feed in this ecological setting. The sizeable population of white-tailed deer which inhabits the sawgrass marshes takes refuge on the tree islands during times of high water.

With the onset of the dry season, runoff and evapotranspiration gradually lower the water table below the peat and marl soil surface into the underlying limestone aquifer. When dry, the glades support little higher animal life and frequently are swept by fire.

With the onset of early summer flooding, the production of tadpoles, crayfish larvae, and fresh-water plankton blooms is at a maximum. Gradually the populations of small fish and aquatic invertebrates build up, and these, in turn, are consumed by larger fish. Normally by the end of the wet season, a great amount and variety of aquatic life has been produced. Lowering water levels then concentrate this mass of aquatics, making it available for feeding birds, alligators, etc. However, prolonged wet or dry intervals in the normal cycles alter the composition of this aquatic food crop rather profoundly.

Sloughs resemble imperceptibly moving rivers. They hold a tremendous volume of water and food and provide the major runoff into the productive buffer zone between fresh and salt waters.

Cypress Islands. Where low spots in the glades provide sufficient soil and water, dense stands of large bald cypress form islands and may harbor air plants and epiphytic orchids.

Tree Islands or Bayheads. The marshy expanses of the Everglades are dotted with hundreds of small tree islands. Most of these are dense, low, tangled forests usually occupying deposits of woody peat. The vegetation is composed of relatively few species of trees which are adapted to slightly elevated sites. These tree islands contain an interesting assortment of animal life, including deer, marsh rabbits, cotton rats, and raccoons. Alligator holes in the woodlands generally are four or five feet deep at or near their center during the rainy season. In the dry season the holes and the deep alligator dens within them, serve as a vital last-ditch water refuge for fish and other aquatic animals from the surrounding open glades.

Hammocks. The dense, jungle-like hardwood hammocks contain a great variety of trees and occupy elevated sites that have not been recently invaded by fire. They are rich floristically and have an abundance of animal life. In addition to the larger animals such as bobcats, occasional panthers, raccoons, marsh rabbits and snakes, the hammocks harbor a large array of insects, some of them unique.

Pine Forest. A fire-maintained pine forest once occupied most of the limestone ridge along the southeastern coast of Florida. In recent years, real estate and agricultural development has proceeded so rapidly that the portion of Long Pine Key lying within the Park may soon be the chief surviving example of south Florida pineland. This vegetation type offers many aspects of ecological interest, particularly in regard to the role of natural fire in preservation of the pine type and the adaptations of many plant species to withstand fire. A large number of shrubs and herbaceous plants, and such bird species as the wild turkey, bluebird and pine warbler, are closely limited to pine forest areas.

Estuaries and Lagoons. For centuries the sheet of fresh water moving southward over the Everglades from Lake Okeechobee, flowed through sawgrass areas of the Park and entered the Gulf of Mexico through a labyrinth of mangrove-lined rivers and creeks. Where fresh water flowing out of the Everglades merged with salt water of the Gulf, a shifting zone of brackish water up to 12 miles wide has developed. The width of the brackish zone is dependent on the quantity of fresh water flowing seaward from the land, and hence is greatest in wet years and very restricted during drought.

No other area in the Park exceeds the brackish zone in terms of the gross productivity of organic material. Its fertility makes it highly important as a "nursery ground" for the young of many marine fishes and crustaceans, notably the economically important pink shrimp.

As understanding of the great production potential of estuarine communities grows, and as these communities become more restricted elsewhere, the importance of the rich and diverse series of brackish habitats within the Park becomes increasingly clear. However, this zone--even in the Park--is seriously threatened by the present interruption of the historic flow of fresh water.

Mangrove Swamps. The mangrove belt occurs along the coast of the Park and occupies most of the keys in Florida Bay, as well as the margins of the estuaries and lagoons. These swamps support the rookeries, notably at Cuthbert Lake and East River, where wood ibises, white ibises, egrets, anhingas, cormorants, and other birds raise their young safe from predators. White ibises, herons, egrets, and other birds roost at night on certain mangrove islands of the Gulf Coast, particularly during the summer. The white-crowned pigeon, roseate spoonbill, great white heron, reddish egret, and other water birds nest on many of the mangrove keys of Florida Bay. Some 55 pairs of bald eagles nest in coastal mangroves and on the keys of Florida Bay.

Coastal Prairie. The coastal prairie, which occupies most of Cape Sable and its hinterlands between the Gulf and Whitewater Bay, as well as the nonforested area along the northern coast of Florida Bay, is very important to the Park's wildlife. Marsh rabbits, cotton rats, raccoons, and bobcats are common there. The marl flats and ponds are major winter feeding areas for wading birds, waterfowl, white pelicans, and many shore birds. The remoteness of much of the prairie gives protection for rare animals, such as the panther. Of special interest is a small colony of gopher turtles that lives in the sand dune ridges adjacent to the Cape Sable Beach. This is a disjunct population, nearly 60 miles from the nearest outpost of the species.

Shell Beaches. Shell beaches occur along the shores of the Gulf of Mexico and Florida Bay, and on some of the Florida Bay keys. Larger beaches, such as Cape Sable and Highland Beach, support many plants and animals not found elsewhere in the Park.

One of the most important remaining rookeries of the Atlantic loggerhead turtle is to be found on the shell beaches of the Cape Sable region. Since other remaining loggerhead rookeries are being destroyed gradually by man's activities, preservation of the Cape Sable breeding grounds has become increasingly vital. Only the control of severe raccoon predation is required to maintain and even increase its productivity. Protection of the loggerheads automatically would give the greatly reduced green turtle, hawksbill, and leatherback populations a better chance to recover.

Crocodiles nest on some of the Park's beaches, such as those in the Madeira Bay section and on keys in northeastern Florida Bay.

Submerged Lands. Although nearly one-half of the Park area is permanently under salt water, most of which is quite shallow, it harbors a great variety of scientifically interesting and ecologically important marine life. Tidal flats and the mouths of rivers are significantly valuable feeding grounds for water birds. A variety of fishes, mollusks and crustaceans inhabit Florida Bay. Bottle-nosed dolphins and manatees occur in suitable areas of the submerged portion of the Park.

Fishes abound in Park waters. Fishing pressure is heavy, but present productivity appears to be sufficient to maintain the current catch per unit of effort. However, further and continued reduced flow of fresh water into the estuaries and Florida Bay may adversely influence this favorable ratio.

III. NEEDED RESEARCH

Research is needed to provide more adequate information on (a) the current status of the Park's natural resources; (b) the primeval condition of these resources; (c) the methods of restoring the resources as nearly as possible to the ecological conditions requisite for their continuing natural evolution; and, (d) incipient trends toward additional unnatural environmental situations. Once baselines of current or natural conditions have been established, periodic monitoring will reveal trends of deterioration. These can then be corrected at an early stage before severe damage occurs.

Research in the Park should build toward an eventual understanding of the organization and interrelationships of the various communities represented. Only through such understanding can effective management and interpretation of the Park resources be achieved.

Overall research objectives and programs for the Park should result in a body of information necessary for (1) restoration and maintenance of appropriate natural conditions of the environment, (2) more effective interpretive programs, and (3) a better understanding of visitor needs and preferences.

An analysis of 56 current Park problems is presented, together with research projects believed to be required for their better understanding and ultimate solution.

PURPOSES AND OBJECTIVES OF THE PARK

The Act of May 30, 1934 (48 Stat. 816), providing for the ultimate establishment of Everglades National Park, states in Section 4:

"The said area or areas shall be permanently reserved as a wilderness, and no development of the project or plan for the entertainment of visitors shall be undertaken which will interfere with the preservation intact of the unique flora and fauna and the essential primitive natural conditions now prevailing in this area."

The Act of 1947, specifically establishing the Park, and subsequent Acts of 1950, 1954, 1958, 1959, and 1960, which modified the Park boundaries, make clear that Everglades National Park is intended to exemplify and maintain for posterity (1) the abundant native wildlife, including rare and colorful birds; (2) the extensive fresh-water and salt-water areas, open Everglades prairies, mangrove forests, and all other natural features, which collectively make this Park the only large subtropical wilderness remaining in the United States; and (3) archeological and historic sites illustrative of pre-Columbian cultures.

Other documents repeat and enlarge on these themes. The Master Plan currently approved for Everglades National Park lists the following programs and objectives:

"To conserve and protect the Park's primary resource-- the natural features of a vast wilderness region unlike any other part of this country.

". . . to maintain Everglades National Park in its natural state by protecting ecological communities from influences that would change their appearance or threaten their very existence.

"To conduct research directed toward the management and preservation of biological and natural features with special attention to the concepts and recommendations of the Wildlife Management Report [Leopold, et.al., 1963] and the National Academy of Sciences Report [1963].

"To coordinate and conduct research necessary to assure the preservation of the Park's water resources. The complex problem of the effect of developments outside the Park on the flow of fresh water required to maintain the ecological communities of this area, must be studied to provide a factual basis for its solution."

Documents which define further the nature of the maintenance or restoration of natural ecological resources required in this and other National Parks, include National Park Service Fauna No. 1 (Wright, Dixon and Thompson, 1933); Secretary Udall's letter of July 10, 1964, to Director Hartzog concerning the Road to the Future; and the currently approved Wildlife Management Plan for the Park. Each of these documents indicates that management of the significant natural resources of national parks is oriented to: (1) assure a minimum of man-induced interference with the natural processes associated with the evolution and maintenance of the parks' wilderness features; and (2) maintain or, if necessary and feasible, re-create the closest possible approximations to the natural habitat conditions that would now prevail if human impact had remained as it was prior to influence of European man.

One of the greatest values that visitors can derive from Everglades National Park is to experience, with understanding, the complex interplay of land and water, and the diverse plant and animal life associated with this environment. In the field of interpretation, the Master Plan states that the objective is:

"To present to the public the natural heritage of the Everglades National Park. The Park's Interpretive Theme shall tell the complex story of the largest representative portion of the Everglades region, the only subtropical or tropical waterland area in the continental United States. The area preserves extraordinary biological communities created by a warm semitropical climate and nurtured by a slowly moving sheet of seasonal fresh water flowing to meet the sea. The interrelationship of plant and animal populations thriving under these conditions offers an unrivaled opportunity for resource interpretation, for visitor inspiration and education, and for scientific observation."

Essential to any park interpretive program is the acquisition, through research, of accurate knowledge concerning the identity, distribution and life history requirements of the terrestrial and aquatic fauna and flora; the physical and biological characteristics of terrestrial and aquatic ecosystems; the identity and origin of major geologic features; and, especially important, the interrelationships between these resources.

Although the living resources of Everglades National Park are extremely fragile, because of their dependence on large supplies of fresh water at seasonally critical times of the year, they are largely renewable and, with adequate water, may respond rather quickly to careful and correct ecological management. However, for such management to be fully effective, much more information is needed concerning requirements of individual species and the many factors that act upon them in the Park. Management must be based on such knowledge in order to determine which steps should or should not be taken to preserve the unique ecosystems of Everglades National Park.

While certain studies may be specifically designed with full expectation of offering immediate assistance to management programs, the nature of research often is such that results directly useful to management may be somewhat delayed in their appearance and recognition. A basic requirement in the solution of any research problem is the acquisition of sufficient information to permit identification of critical questions which, when answered, will provide for resolution of the parent problem. Though information obtained in the course of interdependent and supporting investigations may not be immediately applicable by management, it often can be assimilated into the interpretive program at once.

A. GEOGRAPHY

Everglades National Park is primarily an aquatic area which occupies about 2100 square miles of the extreme southern and southwestern portion of the Florida peninsula, including adjacent inshore waters. Lands permanently submerged by Florida Bay, portions of the Gulf of Mexico, and numerous brackish lakes, bays, and rivers near the coast constitute at least half of the Park. Much of the rest of the area is subject to seasonal flooding. The east boundary of the Park lies within a few miles of the fringes of the Greater Miami metropolitan area which now has a population of about one and one-half million, and continues to grow with no indication of slackening in the immediate future.

The Park may be considered to have three principal geographic divisions: (1) the interior Everglades, (2) the coastal brackish zone, and (3) the marine region which comprises the outer coast, inshore waters, and keys. Vital ties of dependence link these divisions. The geography throughout is characterized by extreme flatness with only slight elevation, the highest point being less than 10 feet above mean sea level.

Biogeographically, the Park is a meeting ground for temperate continental and Antillean tropical biotas, both of which are at the extremities of their respective ranges. Marine forms show a mixture of West Indian and North American species, the latter predominating in most groups. The upland terrestrial flora is predominantly Antillean with temperate species becoming of greater importance at interior sites.

The fauna of terrestrial and fresh-water invertebrates and small vertebrates (such as lizards and frogs) includes many West Indian species, but comprises only those that could be effectively distributed across a sea barrier by winds or currents. The land birds with a few exceptions, and the land mammals without exception, are widespread North American forms. However, several species of West Indian land birds have colonized southern Florida recently and a few North American species that formerly nested in the area are no longer present.

B. CLIMATE AND HYDROLOGY

Climate

The climate of southern Florida is strongly influenced by the proximity of maritime waters. The surrounding seas and the low altitude and latitude of the area produce the prevailing condition of warm weather, light but persistent winds, and ample though erratic rainfall nearly twice the national average of 29 inches. Rainfall is of the summer-wet, winter-dry "tropical savannah" pattern which results in a predominance of seasonal fresh-water marsh in the interior and a brackish zone of seasonally fluctuating extent where drainage from the interior meets tidewater. Thunderstorms occur frequently during the summer and fall.

During the summer-fall wet season, tropical storms from the Caribbean hurricane belt, with accompanying winds approaching 200 miles per hour and heavy rainfall, sometimes cause extensive damage to the coastal Everglades biota where large areas of mangrove forest have been destroyed. When coastal regions and low islands of this part of the Park take the full brunt of hurricanes, they may be completely submerged by the sea surge that accompanies the more severe storms. Populations of birds and aquatic animals suffer heavy mortality during such storms. By contrast, only about 20 percent of the Park's rainfall occurs during the winter-spring period.

Continental storms produce the most eventful winter weather. The flow of cold air introduced by the lead of a high-pressure storm is especially impressive and may result in freezes and sustained northwest winds. The more severe freezes may cause heavy mortality among tropical marine fishes, manatees, etc., but only in the case of record freezes that have occurred at a frequency of one or two per century is there extensive damage to mangroves and other tropical plants. However, the storm front preceding these northwest blows may produce heavy downpours of rain which, when followed by cold, have been known to result in a breakup of water bird rookeries. Wood ibis and roseate spoonbill are especially subject to such losses.

Hydrology

Everglades National Park is at the southern periphery of an extensive hydrologic system that assists in furnishing fresh water to southern Florida. Although rainfall is the principal source of

water needed to maintain the Park's ecology, an important additional supply of water is provided by overland flow. This additional supply must be in an amount adequate to overcome or minimize local rainfall shortage at all times, and particularly during the extremely dry periods. In recent years the overland flow has not been sufficient. Underground flow from the north is impeded by the relatively low permeability of the limestone aquifer along the Tamiami Trail.

Overland flow from Lake Okeechobee and the area north thereof was intercepted by land reclamation efforts of local interests between 1881 and 1927. Canals constructed during this period changed the runoff patterns in most of the area south of Lake Okeechobee, thereby diverting much of the water to the ocean.

As a result of the heavy loss of human life and property damage caused by hurricane-induced flooding, the Corps of Engineers, starting in 1928, began enlarging the levees around much of the Lake and constructing the Okeechobee waterway, which involved the existing St. Lucie Canal, the Lake, and the Caloosahatchee River.

At the time the Park was established in 1947 and subsequent thereto, some water continued to flow overland into the Park from the north. In 1948, Congress authorized the construction and operation of the Central and Southern Florida Flood Control Project. Considerable detailed information concerning the purposes of the project is contained in House Document No. 643, 80th Congress, 2d Session.

With specific reference to the Everglades National Park, the Central and Southern Florida Flood Control Project works include construction of three Conservation Areas (see map) north of the Park for storage and release of water for beneficial use. Conservation Area 3, directly north of the Park, is the main storage facility designed to store water for release into the Park. As a part of this Conservation Area, the Corps, in 1962, constructed a levee (L-29) for approximately 10 miles along the northern edge of the Park. This levee contains five sets of gates through which water can be released from the Conservation Area into the Park. Completion of L-29 and the five control structures, S-12 (A, B, C, D, and E), when closed, effectively obstructed the overland flow of water from the north.

At present (August 1966), several other factors make supply of water to the Park difficult. The southward flow of water released into Conservation Area 3 from Lake Okeechobee and Conservation Areas 1 and 2 has been very slow because the gradient averages only

one-tenth foot per mile in the intervening distance (40 miles) to the Park. Existing canals in this region are relatively inefficient for conveying the necessary volume of water.

Gravity discharges from Lake Okeechobee into Conservation Area 3 are limited by canal capacities between the Lake and the Conservation Area and are further impeded by the head of water which accumulates in the heavy sawgrass at the northern end of Conservation Area 3. Much water released into Conservation Area 3 is lost through evapotranspiration. Like the Park, the principal normal source of water for Conservation Area 3 is direct rainfall. Unfortunately, several successive years of below-normal rainfall have compounded the problem of collecting water to fill and maintain reasonable levels of storage in the Conservation Areas.

Tests conducted in 1965 indicate that the release capacity (for the benefit of the Park) of the existing system can be improved by the use of project pumps. Funds for this purpose have not been available heretofore. In an emergency, to safeguard life and property to the north when heavy rainfall persists and the hurricane season is imminent, it may be necessary to discharge excess water to the ocean instead of to the Park despite the maximum use of the Flood Control District's pumping capability.

Current water releases from Conservation Area 3 through the L-29 gates into the Park are limited to an interim water release schedule established by the Central and Southern Florida Flood Control District. The Flood Control District maintains that the control of such water resides in the State. However, the Corps of Engineers assumes responsibility when water levels reach flood stage.

For a number of years the National Park Service, the Central and Southern Florida Flood Control District, and the Corps of Engineers have been cooperating in efforts to determine means of improving the water supply for the Park. A study authorized for this purpose by the Congress will consider the water needs of the entire area and is expected to be completed in the fall of 1967.

In the meantime, emergency procedures for correcting present difficulties are being explored within existing and expanded authorities. Some work (construction of the second diagonal levee, L-67C) within Conservation Area 3 was started in September 1965. This additional levee is expected to reduce seepage losses to the east and thereby increase surface water for distribution to the Park. Additional construction (L-67 extension) consisting of a

levee and canal along the east boundary of the Park to distribute water to the Park was commenced during the spring of 1966.

Another plan has been proposed for the transfer of water from Lake Okeechobee to the Park during periods when Lake levels permit. The plan suggests enlargement and extension of the North New River Canal downstream from the agricultural area to a junction with the Miami Canal and the borrow canal for L-67, enlargement of the Miami Canal downstream from the agricultural area to the same point, and the enlargement of the L-67 borrow canal from the Miami Canal to the Park boundary. To move water from Lake Okeechobee through these canals into the Park will require the operation of two existing pumping stations for extended periods of time.

The work now underway and planned should result eventually in substantial interim relief to the Park. These measures represent a practical approach to the problem until such time as more comprehensive measures can be developed following the detailed study authorized by the Congress.

Water losses from the Park occur by runoff through estuaries bordering Florida Bay and the Gulf of Mexico and by evapotranspiration. Overland flow through the Everglades, even under natural conditions, is at a very slow rate and offers a long period of exposure for evapotranspiration before the fresh waters reach the sea. Water levels in the Everglades recede slowly, and antecedent levels influence the expected magnitude of recession into dry periods. Thus, if the water level is three feet deep at the beginning of the dry season, the period during which the water level remains above the ground surface will be much longer than that if the water was only one foot deep initially.

C. GEOLOGY

Little of the geological story of the Park is evident from surface features. The present peninsula of Florida is the emerged portion of the Floridian Plateau, an elevated area between the deep basins of the Atlantic Ocean and the Gulf of Mexico. Although the plateau is a relatively ancient geomorphic feature, it has been largely submerged through most of its history and is blanketed by great depths of marine sediments. Throughout its geological existence, southern Florida has alternately been flooded by shallow seas and exposed beyond present shores as sea levels changed in relation to a stable land mass. Sedimentary strata laid down during the marine invasions were reworked by solution and erosion during subsequent emergence.

The three surface formations of importance in determining the present topography and drainage characteristics of southern Florida are: the Miocene Tamiami Formation in the northwestern part of the Park; the Pleistocene Miami Oolite* which underlies most of the Park area and forms the floor of Florida Bay; and, the Key Largo Limestone, an emerged Pleistocene coral reef which forms the present Upper Florida Keys. All are permeable marine limestones (in part calcareous sandstone in the case of the Tamiami Formation) highly modified by solution and thinly mantled by recent accumulations of marl and peat. Outcrops of these formations, such as Long Pine Key in the Park, form some of the present slightly elevated "uplands" of south Florida, profoundly affecting the occurrence of native vegetation types.

South Florida emerged during each glacial period of the Pleistocene and was submerged by each interglacial sea. The Key Largo Limestone and Miami Oolite* were deposited during the third interglacial stage, the latter formation as a calcareous ooze that accumulated in protected waters behind the coral reef. After the deposition of these formations, south Florida emerged in the following period of glaciation, was flooded to the 25-foot contour during the fourth interglacial stage and was exposed again during a still later period of glaciation.

Shoreline features resembling drowned karst, and submerged caverns at inland localities suggest that the extent of the late "Wisconsin" emergence may have been considerably beyond present shores. Evidence from the study of tides and coastal peat deposits

*See Appendix No. IV.

indicates that the sea level has risen again in recent time. It appears probable that this sea rise is continuing, but the point is disputed by some authorities.

Approximately 14,000 feet of sedimentary deposits, primarily limestone, overlie the basement metamorphic rocks in south Florida. A gentle doming of these rocks has exposed the Eocene Ocala Limestone 150 feet above sea level in central Florida. Lifting of this limestone and more recent Pliocene and Pleistocene deposits caused these rock layers to dip gently southward throughout south Florida.

A number of the underlying strata are aquifers. Three--the Ocala of Eocene age, the Tampa and Hawthorn of Miocene age--carry artesian water and form the Floridian aquifer. Overlying the Floridian aquifer is a blanket of formations of low permeability that confines the water in the aquifer and gives it artesian pressure. This confining layer, called the Floridian aquiclude, is approximately 600 feet thick in the Park area and forms a water-tight foundation for the important Biscayne aquifer.

This nonartesian aquifer--the Biscayne--occurs in rocks chiefly composed of the Miami Oolite* and the Fort Thompson Formation. It contains a pool of fresh water with the apex a few miles west of Hialeah. During the wet portion of the year, part of this pool is apparent as surface water, but during the dry period it is often completely below the surface.

Little on the Park's surface suggests a rather eventful geologic history. No explanation presently is available for the so-called Everglades "rock reefs" (not coral) which are conspicuous surface features. The formation of the keys (mangrove islands) in Florida Bay, and various coastal ridges, may have resulted from mangrove growth, but this hypothesis needs further study.

*See Appendix No. IV.

D. BIOLOGICAL COMMUNITIES

General

On the subdued topography of southern Florida the different types of plant cover provide variety in the landscape. Despite the region's topographic uniformity, various combinations of environmental factors have acted on particular sites to produce a number of distinct types of vegetation. Striking changes in the vegetation, associated with slight differences in elevation, salinity or with variations in the effects of fire, often are encountered within short distances. Changes in the characteristic animal life associated with the different cover types often are equally well-marked.

The most distinctive biological communities are: sawgrass marshes and prairies, sloughs, cypress islands, bayheads, hardwood hammock forests, pinelands, estuaries and lagoons, mangrove swamp forests, coastal prairies, shell beaches, oyster bars, and turtle-grass shoals.

Fresh-Water Glades

The open glades, which are horizonwide reaches of sawgrass marsh with scattered tree islands, dominate much of the interior of the Park. The stretches of sawgrass are interspersed with shallow intermittent pools. Sparse stands of aquatic sedges and grasses generally occur in the pools. A significant feature of such areas is the great seasonal fluctuation in environmental conditions. The glades are largely covered with a sheet of water during the summer-fall rainy season and provide breeding grounds for small fish and other aquatic animals. Alligators, birds and mammals feed in this ecological setting. A sizeable population of white-tailed deer inhabits the sawgrass marshes, the animals taking refuge on the tree islands during times of high water.

With the onset of the dry season, runoff and evapotranspiration gradually lower the water table below the peat and marl soil surface into the underlying limestone aquifer. When dry, the glades support little higher animal life, and frequently are swept by fire.

The dominant biological microcommunity in the glades is the periphyton complex. Periphyton, as applied to the Everglades, consists basically of interlaced filaments and individual cells of

algae, microscopic animals, and precipitated calcite that forms a thick felt-like mat around the submerged portions of plant stems and on the water-covered ground.

Green periphyton coats all submerged objects, especially the stems of the omnipresent spike-rush. This type also grows heavily on purple bladderwort in continuous floating mats which may cover acres. In the rockland sawgrass areas, blue-green periphyton may cover all submerged surfaces, including the bottom. The greatest development of this periphyton mat occurs on the bottom of the open pools, where the shading effect of vegetation is minimal. Periphyton is chiefly responsible for the fluctuating chemical composition of the water.

The biological productivity of the flooded glades appears to be enormous. The huge expanse of shallow water, flooded with subtropical sunlight, is an ideal medium for the production of aquatic life. However, the underlying marls and limestones are almost pure calcium carbonate, and nearly constant flooding has leached the marls of most of the important minerals and nutrients necessary for life. This factor is somewhat compensated for by the rapid turnover of metal ions and the transport through the glades--under natural conditions--of necessary minerals by the flow of water from beyond the Everglades.

Some research on glades productivity has been undertaken, but thus far these studies have posed more questions than they have answered. Very little indeed is known of the true phytoplankton and zooplankton in Park waters, of their population dynamics or their interrelationships with other physical and biological phenomena of this particular environment.

The glades life exhibits an abundant variety. The occurrence of peak populations of various animal species is dictated by numerous, complex food chains. Thus, at the onset of early summer flooding, the production of tadpoles, crayfish larvae, and fresh-water plankton blooms is at a maximum. Gradually the populations of small fishes and aquatic invertebrates that feed on the tadpoles, etc., build up, and are in turn utilized by such larger fishes as sunfish, bass and gar. Normally by the end of the wet season, a great amount and variety of aquatic life has been produced. Lowering water levels concentrate the mass of aquatics, making it available for feeding birds, alligators, etc. However, prolonged wet or dry intervals in the normal cycles alter the composition and abundance of this aquatic production rather profoundly.

Inventories of the aquatic populations from season to season and from year to year, will be needed to assess drought damage, to plan ecological management, and to support interpretation.

Populations of wet glades fishes, frogs, crayfish, and various reptiles and aquatic mammals, such as the round-tailed muskrat and otter, adapt in many ways to the dry periods. Many migrate to deeper waterholes and sloughs. Some, such as frogs, turtles, and crayfish, burrow into the muck or seek refuge in rock cavities.

Excavation of crayfish holes has revealed the presence of a number of aquatic species, including small fishes, that find the burrow entrances, perhaps by chance. Little is known of the survival success of the aquatics that remain in burrows or solution holes for several months of the year. Questions arise concerning the ability of these animals to lower their metabolic rate and thus decrease their oxygen demand. The extent to which such animals prey upon one another in this state of extreme confinement is another question to which we have no answer. Information is lacking, too, on the length of time these animals can survive under the physiological stresses of a stagnating and restricted environment.

Sloughs. By definition a slough is a large wet or marshy area, but the sloughs in the Park are more like slowly moving rivers whose flows are generally imperceptible to the human eye. The major slough of the Park is the Shark River Slough; others are considerably smaller, with channels less distinct. Deeper sloughs, to which aquatic animals resort in times of drought, usually are surrounded by willow and custard apple trees.

The Shark River Slough, holding a tremendous volume of water and organisms in its areal extent of 125,000 acres, plays the important role of providing the major runoff into the productive buffer zone (ecotone) between fresh-water and marine communities.

Taylor Slough is of importance in that several of its ponds and environs are wildlife showplaces for the public. When sufficient fresh water flows through Taylor Slough, the resulting discharge into central Florida Bay helps to ameliorate the lethal hypersalinities that often are found there.

Cypress Islands. The fresh-water glades of the Park also contain a variety of stands of bald cypress. These cypress heads are of considerable magnitude and density in those areas where low spots provide sufficient soil and water. A scattering of dwarf cypress

dots the land within the area circumscribed by the rock reef. These trees do not occur in clumps or heads and, though aged, do not reach great size. Many of the cypresses bear air plants and occasional clumps of epiphytic orchids.

Tree Islands or Bayheads. The marshy expanses of the Everglades are dotted with hundreds of small tree islands. Most of these are bayheads--dense, low, tangled forests usually occupying sites of woody peat deposits. The vegetation is composed of relatively few species of trees adapted to slightly elevated sites, and includes bay, wax myrtle, and holly. The form and orientation of the tree islands is influenced by the direction of drainage, fire, and irregularities in the underlying limestone surface.

Dry season fires may completely remove tree islands from the landscape by burning the forest and the peat deposit beneath it. The location of some tree islands has been partially explained on the basis of accumulation of woody peat on top of sawgrass peat. Others appear to have formed on slight elevations which remained as surrounding limestone surfaces eroded more rapidly. However, this vegetation type needs additional study before it can be interpreted with greater confidence.

The tree islands contain an interesting assortment of animal life. Deer browse some plants and find cover here, as do marsh rabbits, cotton rats, and raccoons. Snakes often reside in isolated tree islands, as do other reptiles such as box turtles and anole lizards.

Alligator holes, which often occur in these woodlands, frequently approach a circular shape but may vary considerably in size and configuration. During the rainy season, they are generally four or five feet deep at or near their centers. Excavation and root-tearing by alligators play the major role in preventing plant succession from filling the holes. Peat that has been pushed out by the reptiles forms a low bank around some of the sites. In the dry season these holes and the deep alligator dens within them, serve as a vital last-ditch water refuge for fish and other aquatic animals from the surrounding open glades.

Hardwood Hammocks. These are hardwood forests containing a great variety of trees and occupying elevated sites that have not been invaded recently by fire. Hammocks are found in the Park as islands of dense jungle in the pinelands of Long Pine Key; at a few

places in the open glades; and on the marl ridges, shell beaches, and Indian mounds of the coastal areas. They show great variations in appearance and specific composition associated with regional climatic gradients.

In the northwestern part of the Park such temperate species as hackberry and red maple are prominent components of the hammocks, but further south, most of the hammock trees are species characteristic of the West Indian tropics, such as mahogany. In areas where annual rainfall is high, as at Paradise Key, the hammocks take the form of moist, dense forests of tall trees with a profusion of ferns and vines, and many epiphytic orchids and bromeliads. Southwestward toward Cape Sable along the gradient of decreasing annual rainfall, the hammock forests become less luxurious; many of the trees are deciduous in the dry season; and large cacti occur in relative abundance. Such colorful tropical animals as the zebra butterflies and tree snails (Liguus) are closely associated with hammock growth.

The domelike profile and tight canopy of mature hammocks give them considerable protection from the blast of frontal storms and hurricanes. Their density also provides insulation from frost and encourages the presence of tropical vegetation. In recent years, however, Mahogany and Royal Palm Hammocks, both important in the Park's interpretive story, have suffered extensive hurricane damage. This damage may have been aggravated by trail construction which initially broke the canopy and evidently encouraged wind channelling. The protective canopy of the Mahogany Hammock was further opened by the "once in a century" intense wind force of Hurricane Donna. This exposed it to still greater damage by the lesser storm, "Betsy." Considerable time and favorable environmental factors will be necessary to restore conditions that were present in these impressive forests when Everglades National Park was established.

The Royal Palm Hammock, once considered an outstanding botanical jewel, has suffered from at least two fires and both of the above-mentioned hurricanes. Much of the original canopy and most of the larger trees, especially oak, have been destroyed. The abundance of epiphytic plants, such as orchids, has been reduced to an occasional few. Many of the very tall, old Royal Palm trees are gone. However, some replacement growth is present in the Hammock, and time and protection ultimately may restore the Hammock to a condition similar to that of two decades ago.

Hardwood hammocks are rich floristically and also have an abundance of animal life. Besides the larger animals, i.e., bobcat, occasional panthers, raccoons, marsh rabbits and snakes, there is a large array of insects. Although no thorough inventory of the Park insect fauna has been made, the growing number in the Park's study collection gives some indication of the great wealth of insect species to be found here. Of particular interest to lepidopterists is the *Atala* hairstreak butterfly. Except for one small colony outside the Park, this once common insect has become extinct in Florida. The last individuals collected in the Park area were taken in 1935. Two attempts at reintroduction were nullified by untimely storms.

For some time the U. S. Public Health Service has been collecting and studying mosquitoes and small mammals from certain Park hammocks. The sylvatic reservoir for tropical encephalitis virus (VEE) found there may be of some potential importance as a source of the disease in man.

Pinelands. A fire-maintained pine forest once occupied most of the limestone ridge along the southeastern coast of Florida. In recent years, real estate and agricultural development has proceeded so rapidly that the portion of Long Pine Key lying within the Park may soon be the chief surviving example of south Florida pineland.

This pine area was cut over shortly before the establishment of the Park and hence is not at present an imposing forest. However, it does offer many points of ecological interest, particularly in regard to the role of natural fire in preserving the pine type and the adaptations of many plant species to withstand fire. A large number of shrubs and herbaceous plants, and such bird species as the wild turkey, bluebird and pine warbler, are closely limited to pine forest areas.

Other animals, though present in different habitats, frequent the pinelands. Bobwhites, raccoons, opossums, gray foxes, and small rodents are common. Bobcats, deer, and even panthers are sometimes seen there. Rattlesnakes, indigo snakes, and black snakes are at home in the rocky terrain of the pinelands. Sinkholes of various sizes present most interesting botanical microhabitats. Bordering hammocks, and hammocks within the pinewoods, increase the variety of habitat available to plants and animals.

Plant succession following fire is dramatically exhibited at Long Pine Key, especially in the areas where the Service has carried out controlled burning.

Poaching is destroying important Park values. Hammocks enclosed in the pine forest contain the last known wild Florida specimens of tropical maidenhair fern and the epiphytic orchid, Brassia caudata. These and wild turkey and deer are endangered by poachers who gain entrance from the nearby Park road and from the "Hole in the Donut" area (private inholding). Feral animals, especially cats liberated by campers and those originating from nearby farm areas, are destructive influences on the animal ecology of the pine forest.

Brackish Zone

For centuries the sheet of fresh water moving southward over the Everglades from Lake Okeechobee, has flowed through sawgrass areas of the present Park and entered the Gulf of Mexico through a labyrinth of mangrove-lined rivers and tidal creeks. Where fresh water flowing out of the Everglades meets the salt water of the Gulf, a shifting zone of brackish water up to 12 miles wide occurs.

Estuaries and Lagoons. The width of the brackish zone is dependent on the quantity of fresh water flowing seaward from the land, and hence is greatest in wet years and considerably reduced during drought. Generally, the brackish zone occupies the estuaries and lagoons and merges with or is adjacent to the mangrove belt, for mangroves thrive in areas having some salt and tidal action. The entire mangrove coastal area of the Park is, in fact, more or less a drowned river estuary and comprises a complex situation that cannot be defined easily; its origin, and even the processes presently active there are little known.

The brackish zone is most extensive during the fall when the high ocean tides of the autumnal equinox combine with peak rainy season runoff to produce extensive inundation of the coastal marsh. This zone of mixing water is characterized by high biological productivity. It traps land-derived nutrients and produces tons of organic material through rapid chemical recycling of these nutrients. No other area in the Park exceeds the brackish zone in terms of gross productivity of organic material.

Although conditions for life in the fluctuating brackish zone appear to be severe, certain specialized organisms thrive there. They feed on the abundant organic material and are, in turn, fed upon by larger organisms. Killifish are the dominant fishes of the high marshes of the brackish zone; these fishes convert the lower

forms of life into food suitable for a host of larger predators such as the wading birds. Anchovies and mullets fulfill the same function in deeper, more open water areas of the brackish zone by serving as prey for large carnivorous fishes.

The fertility of the brackish zone makes it highly important as "nursery ground" for the young of many marine fishes and crustaceans, notably the pink shrimp.

As understanding of the great production potential of estuarine communities grows, and as these communities become restricted elsewhere because of pollution, bulkheading, and filling, the importance of the rich and diverse series of brackish environments within the Park becomes increasingly clear.

However, this zone--even in the Park--is seriously threatened by the present interruption of the historic flow of fresh water. Perhaps more than any other area of the Park, it is extremely sensitive to both too much and too little fresh water.

Additional studies of the organization and production of estuarine communities should be undertaken to supplement those already underway.

Mangrove Swamps. The mangrove belt which occurs along the coast of the Park and occupies most of the keys in Florida Bay, as well as the margins of the estuaries and lagoons, consists of four dominant woody species: the red, black, and white mangroves, and the buttonwood (Conocarpus). These species may occur either singly or in mixed stands and produce communities which may vary in structure from a savannah of scattered shrubs to closed forests of tall single-stemmed trees reaching 80 feet in height. The best developed forests are located on islands in the mouths of rivers of the Park's Gulf Coast. Large portions of this forest area, however, were devastated by Hurricane Donna in September 1960.

The rough bark of buttonwood trees encourages the growth of epiphytic plants, such as orchids and bromeliads. Inaccessibility and remoteness make the mangrove forest a last refuge for the panther. Also present are deer, bobcats, raccoons, mangrove cuckoos, diamond-back terrapins, mangrove water snakes, and various crustaceans and mollusks. Waters in mangrove-lined creeks are stained with humic acid and pungent with hydrogen sulfide. Fish, especially mullet, redbfish, snook and tarpon, abound.

Of special interest are the several wading bird rookeries, notably at Cuthbert Lake and East River, where wood ibises, white ibises, egrets, anhingas, cormorants, and other birds raise their young relatively safe from predators. Tens of thousands of white ibises, herons, egrets, and other birds roost at night on certain mangrove islands of the Gulf Coast, particularly during the summer. The white-crowned pigeon, roseate spoonbill, great white heron, reddish egret, and other water birds nest on many of the mangrove keys of Florida Bay. A population of about 55 pairs of bald eagles nests in mangroves along the Gulf Coast and on the keys of Florida Bay.

Mangrove areas produce huge swarms of mosquitoes. The eggs of this insect are laid on exposed mudbanks and hatch when inundated. Thus, emergent broods occur after floodtides as well as after abundant rains.

Coastal Prairie. Strictly defined, the coastal prairie is a narrow belt of slightly elevated marl soil just back from the coast in the region of Flamingo and Cape Sable, with vegetation composed of salt-tolerant grasses and herbaceous halophytes. However, the coastal prairie is often considered in a broader sense to include all of Cape Sable and its hinterlands between the Gulf and Whitewater Bay, as well as the nonforested area along the northern coast of Florida Bay. The region is a complex mosaic of communities, including: marl flats that are inundated by summer rains or high tides; salt marshes dominated by switchgrass (Spartina); sawgrass marshes with many small ponds; tree islands of buttonwood, cabbage palm, and various tropical hardwoods; the low dune ridges of Cape Sable proper; considerable areas of mangrove swamp; and a number of sizeable lakes, some of which are saline (Lake Ingraham), while others are brackish (Fox Lakes and Cattail Lake).

While the present distribution of plant communities in the coastal prairie region can be partially explained on the basis of variations in elevation and soil salinity, the reason for the existence of grassland in an area where forest types generally predominate, is not altogether clear.

The widespread occurrence of shells of Liguus tree snails, and of buttonwood stumps in areas that now are open country, suggest that grassland and marl flats have become more extensive at the expense of forest. Probably both fire and hurricanes have figured in the reduction of forests in this area. Although no fires of consequence have occurred here within the history of the Park,

extensive fires were recorded in pre-Park days. Most were probably man-caused, either started accidentally from farming and charcoal-burning activities in the area, or deliberately set by hunters. The accessible stands of buttonwood were probably greatly reduced by cutting for charcoal, an enterprise practiced on a relatively small scale around Flamingo for more than 50 years, and as late as the middle 1930's.

Several recent storms have demonstrated the dominant role of hurricanes in the ecology of vegetation in the coastal prairie area. The net effect of these massive storms on vegetation seems likely to be reduction of forest area and extension of open areas. After 30 years, some mangrove forests killed by the intense storm of September 1935, are still bare marl flats with standing dead snags and little sign of forest recovery. Pre-1935 photographs also suggest that marl flats replaced some areas of Spartina prairie, as a result of this storm. Similarly, some mangrove stands killed by the hurricane of 1960 apparently are being replaced by herbaceous halophytes, particularly Batis maritima.

Hurricanes in this region also affect vegetation by depositing marl and thereby increasing land elevation. The marl ridge along the south coast probably is a storm-built levee. These storms drive quantities of sea water inland. Because the coastal ridge blocks return flow, much of this water is trapped and evaporates, contributing to buildup of soil salinity. Bare marl flats result when soils become too saline to support even the highly salt-tolerant halophytes.

The ecological bases for the existence of the coastal prairie are obscure. Fire may have been a factor in its origin. Although the marl soil was at least partially deposited by storm waves or hurricanes, much of it has been precipitated. However, tides penetrating the coastal prairies through manmade canals may be carrying marl to the sea, as well as bleeding off fresh water. Evidence left by the Labor Day hurricane of 1935 and Hurricane Donna of 1960 suggests that areas formerly covered by mangrove may become additional prairie and not return to the mangrove forest climax.

The coastal prairie area is important to the Park's wildlife. Marsh rabbits, cotton rats, raccoons, and bobcats are common there. The marl flats and ponds are major winter feeding areas for wading birds, waterfowl, white pelicans, and many shore birds. The remoteness of much of the prairie gives protection for rare animals, such as the panther. Of special interest is a small colony of

gopher turtles that is situated in the sand dune ridges adjacent to the Cape Sable Beach. This is a disjunct population, nearly 60 miles from the nearest outpost of the species, but the animals show some morphological similarity to the gopher turtles of peripheral colonies on Marco Island and in the Cutler Ridge area of Dade County. It is not clear whether these gopher turtles are native to Cape Sable, or were introduced there by Indians or early white settlers.

Marine Region

The marine area of the Park includes beaches and other high land along the coast and the littoral zone, islands, and shallow inshore waters of Florida Bay and the Gulf of Mexico. Much of the water area is shallower than three feet and is characterized by extensive mudflats and turtlegrass flats that are important feeding areas for birds and fish. Oyster bars, especially at river mouths, are a prominent feature of the upper Gulf Coast of the Park.

Diurnal tides range from two to three feet along the Gulf to a few inches in much of Florida Bay, where wind tides are responsible for most of the variation in water level. Central portions of Florida Bay have poor circulation of water and are subject to conditions of hypersalinity during extended periods of drought. At times the salinity may reach levels twice that of normal sea water. Such levels are lethal to many of the animal forms present. Many of the islands of Florida Bay have water bird colonies of major importance, and, as stated earlier, the marine area also supports a large breeding population of bald eagles and ospreys.

Shell Beaches. Shell beaches, composed principally of shell fragments, occur at a number of places along the shores of the Gulf of Mexico and Florida Bay and on some of the Florida Bay keys. The series of paralleling dune ridges revealed following denudation by Hurricane Donna, raise the question of the balance between aggregation and degradation of the beaches. Larger beaches, such as at Cape Sable and Highland Beach, support many plants and animals not found elsewhere in the Park.

The continental United States contains the most important remaining rookeries of the Atlantic loggerhead turtle which is on the verge of becoming a threatened species. The best of these rookeries are situated along the middle east coast of Florida from Palm Beach to Melbourne, on some of the Georgia sea islands, and in

the Cape Sable region. Commercial and housing development is rapidly encroaching upon the first two areas and, therefore, the Cape Sable breeding ground has become of vital importance. Only the control of severe raccoon predation is required to maintain and even increase its productivity.

Three other species of marine turtles--the green turtle, hawksbill, and leatherback--formerly nested at the Cape, and it is probable that a few emergences still occur there each year. Protection of the loggerheads would automatically provide these vestigial colonies of the other species an opportunity to recover.

Some of the Park's beaches, such as those in the Madeira Bay section and on keys in northeastern Florida Bay are used by crocodiles for nesting sites.

Submerged Lands. Nearly one-half of the Park area is permanently under salt water. Most of this water area is quite shallow and harbors a great variety of scientifically interesting and ecologically important marine life. Tidal flats and the mouths of rivers, including turtlegrass shoals and oyster bars, are important feeding grounds for roseate spoonbills, reddish egrets, and a large number of the more common water birds. Spiny lobsters, blue and stone crabs, and many other crustaceans and mollusks inhabit Florida Bay. Bottle-nosed dolphins are commonly seen along the Gulf Coast, in Ponce de Leon Bay, and elsewhere. Manatees seem to be most numerous in Whitewater Bay and rivers entering it, and around the Ten Thousand Islands.

A great variety of fishes abound in Park waters. Fishing pressure from commercial and sport fishermen is heavy, but studies indicate that, so far, present productivity appears to be sufficient to maintain the current catch per unit of effort. On the other hand, the Park fishery may be adversely affected by further and continued reduction in the flow of fresh water into the estuaries and Florida Bay.

HISTORY OF PARK RESEARCH EFFORTS

By the time Everglades National Park was established, the region had already been changed by 40 or more years of man-caused disturbance within the area as well as in the drainage basins above it. Far from being remote, the Park site was within a few miles of a major metropolitan area which, even then, was experiencing rapid and relatively uncontrolled growth. Until recently, little detailed biological information, other than natural history, was available on the Everglades area and, even today, the interrelationships of its natural features are far from well understood.

Although the necessity for a comprehensive natural history research program in the Park has long been obvious to many individuals, implementation of specific research efforts has lagged far behind recognition of the need. Nevertheless, a substantial amount of useful work has been completed through one means or another. Recently, the value of natural science research has been given greater official recognition.

Everglades National Park is unusual in the Service in having had a resident Research Biologist on the staff throughout its history. Occupants of the position have been able to complete and publish results of some research and carry other projects various steps toward completion. In response to the recently increased support of natural history research by the Service, the Research Biologist produced important summaries of research objectives and detailed outlines for many specific research projects that are needed for proper management and interpretation of the Park resources.

Because of the unusual features of the area, Everglades National Park has attracted Park Rangers and Naturalists who were interested in natural history research. A few have persevered against difficulties to produce worthwhile studies. In addition, some non-Service Biologists have become associated with the Park as National Park Service Collaborators. Notable among these is Dr. Frank C. Craighead, Sr., who, in an association of nearly 15 years after formal retirement, has forged a second productive research career (in addition to his earlier one as an Entomologist) in studies involving the botany of the Park.

Increasingly successful attempts have been made to interest university scientists and those from other agencies to conduct

research in the Park at no major cost to the Service. In June 1957, a 3-day conference of nearly 100 Biologists was held in the Park to discuss its natural history research needs. From this meeting came a clearer recognition of the Park's value for research in many areas of science.

It has become quite obvious that this Park, like others in the System, can serve as a unique natural research laboratory for the world's scientific community. The 1957 meeting led to the Park's present close and productive association with research personnel of the Institute of Marine Science of the University of Miami, with the Florida State Board of Conservation, the U.S. Bureau of Commercial Fisheries, the U.S. Bureau of Sport Fisheries and Wildlife, the University of Florida, the University of South Florida, Pennsylvania State University, and several major U.S. petroleum-producing companies. The latter have long recognized the immense value of the Park, particularly the Florida Bay area, for teaching in the field of calcium deposition and the formation of marine limestones.

Eventually, as various specific management problems of the Park became recognized, some of the Service's meager research funds were devoted to the support of a few modest, problem-oriented investigative efforts. Since 1958, a substantial part of the slender National Park Service budget for natural history research has been allotted to analyze the vital fishery resources of Florida Bay and adjacent waters. Since the late 1950's, when the ecologically serious consequences of fire exclusion from the Park's pinelands became evident, other small funds have been devoted to experimental controlled burning.

By the 1960's, critical problems resulting from a reduction in the fresh-water supplies of the upper Everglades drainage basin had reached an acute stage. Consequently, certain funds were diverted from other accounts to support basic hydrologic and, more recently, modest ecological studies being done for the National Park Service by the U.S. Geological Survey. After the wholesale devastation of coastal areas by Hurricane Donna in 1960, meager support was provided to Dr. Craighead for the conduct of a modest but thorough study of vegetation recovery following the passage of intense storms.

In summary, while Everglades National Park is in a class by itself with respect to the scope and urgency of its natural sciences research needs, the Park also is unusual within the Service for the amount of research of a modern, quantitative nature in progress and completed. The efforts of the Park staff have figured directly or indirectly in most of these investigations.

GENERAL RESEARCH OBJECTIVES AND CRITERIA FOR THE PARK

A sound resource management and interpretive program must be based on adequate knowledge of at least four kinds: (a) the current status of the Park's natural resources; (b) the primeval condition of these resources (as defined by the Leopold Report and in Chapters I and II of this Research Plan); (c) the best and most feasible methods of restoring the resources as nearly as possible to the ecological conditions requisite for their continuing natural evolution; and (d) incipient trends toward additional adverse (i.e., unnatural) environmental situations. When baselines of current or desired natural conditions have been established, periodic monitoring will reveal trends toward deterioration or improvement of the situation. With early identification, steps can be taken to correct deterioration before severe or irreparable damage occurs.

Some of the most obvious existent changes from the original natural conditions have been described, together with indications of specific shortcomings in our knowledge relative to the natural resources of the Park. The sharply seasonal and widely variable rainfall, and the occurrence of many of the Park's living resources at the extremes of their geographic ranges have been mentioned, as has the dominant role of recurring natural disturbances such as fire, flood, freeze, drought, hurricane, and salt intrusion.

These factors make for rapid and continual change in the Park's living resources--annual change from wet season to dry season; change governed by the time-space distribution of natural disturbances; changes in relation to long-term pulses of rainfall and hurricane intensity; possibly even visible change resulting from processes such as climatic amelioration and sea level fluctuation that ordinarily are thought to operate only over long periods of geologic time. Clearly, the ecological manifestations of these changes remain largely undocumented, and even less understood. Moreover, even if Everglades had been acquired as a remote and pristine area whose ecology was understood in minute detail, the problems of protection and interpretation would have offered quite a challenge to the best efforts of the Service.

It should be quite clear that, when we have identified the conditions which prevailed in the various ecosystems of the Park before European man came, the next step should be to ascertain how these conditions would have become modified through normal natural

processes had man's influences not interfered. Upon identification of what the present natural state should be as opposed to that which exists, it follows that the manipulative practices necessary to achieve the optimal condition must be determined. If the required management steps are known and recognized, they should be implemented at once. For the most part, however, our state of knowledge is such that the procedure is not likely to be quite that simple. Considerable research will be required to identify: (a) the nature of the original (before European man's interference) resource conditions; (b) the original and present natural influences in detail and the biological response to these influences; (c) the present state of the natural resources; (d) what the present resource conditions would have been had only natural influences obtained; (e) the manipulation of present influences or the development of additional effects necessary to produce and hasten the transition from the resource conditions of (c) to those of (d).

An ideal approach--provided time, funds and the availability of interested, qualified personnel were unlimited--would be institution of simultaneous studies to produce the information required for (a), (b) and (c). With such information in hand, research could proceed to (d) and thence to (e). Unfortunately, funds adequate to purchase the necessary research by university scientists or by investigators from other arms of the Government are not available to the NPS and the Service does not itself have the requisite number and kinds of highly trained scientists required to meet the needs of a vigorous and comprehensive research program. Moreover, natural resource conditions in the Everglades appear to be such that corrective steps must be taken now rather than after the many years that will be required to conduct the exhaustive studies actually needed to produce the wealth of understanding upon which assuredly sound management practices can be based. The lesson obvious from hindsight is that we are some 20 years late in the depth of our concern about effective management of the fragile living resources of Everglades National Park. If the impact of this lesson is sufficiently great, it may be possible to initiate suitable steps to avert similar crises in other units administered by the Service.

Wherever situations exist which threaten irreversible deterioration of resources unless promptly checked, priority should be given to projects that have a direct and immediate bearing on the survival of the features which the Park was established to preserve. Insofar as possible, the present report attempts to indicate those crucial projects which relate particularly to fresh-water drought

reactions, threatened estuarine and inshore marine environments, special dangers to rare and vanishing species, evaporation rates, effects of different kinds of vegetation on water flow, succession dynamics, fresh-water biological productivity, and the effects of pesticide residues.

As suggested earlier, the most massive and immediately critical living resource problem in the Park stems from fresh water, its supply and management. If an unlimited overland supply could be assured in the amounts and with the periodicity that Nature programmed centuries ago, we would have no problem. Unfortunately, we do not know what Nature's program was or how it brought about the biological features which are thought to have existed in the Everglades before the influence of European man was felt there. We can be relatively sure, however, that these uninhibited natural phenomena are not likely to obtain again while man inhabits the Florida peninsula.

If the primeval conditions which characterized Everglades National Park are to be restored and/or maintained, the program will be accomplished only through man's manipulation of environmental factors to achieve this objective. This requires a clear and detailed understanding of the objective and of the direct and indirect contribution of each natural variable to it. We will need to know about water (both fresh and saline)--how much of what kind is needed when and where to induce responses directly upon the biota immediately at hand as well as indirectly upon other facets and organisms of the biological complex at a later time. We will need to know what happens to the water in the Park--its source, where it goes before it is lost to our use, and the time required to follow this course. In short, fresh water will have to be budgeted and manipulated to produce desired results just as it is managed in irrigation systems to produce various crops or in other aquatic systems to serve specifically designed purposes.

Similarly, we will need to know how and when to use fire as a management technique in the Everglades. Substantial information is already available on this subject but we must know considerably more before most effective use can be made of this tool.

Although the Service is not now in a position to undertake all of the desired Everglades research, some steps can and must be taken at once. Certain of these must be undertaken by professional scientists; others can be accomplished by Naturalists and Rangers in conjunction with or as substitutes for some of their presently

assigned duties. Indeed, increased use of such competent uniformed staff has already begun. A multitude of valuable additional observations on such features as water levels, numbers and species of birds, fish and other animals at various geographical locations and changes therein, unusual mortality of animals and/or vegetation, evidence of frost damage, etc., can be made and recorded during the course of routine or special patrols. If taken accurately and frequently and then routinely funneled to a central receiving point in the Park for evaluation by possibly more specifically trained individuals, data so amassed may provide important clues to the solutions of some of the natural resource problems. Certainly, widespread and frequent observations will provide a much better general picture of the day-to-day and long-term response of the Park's living resources to the current and changing environmental conditions.

Concerted efforts must be made to assure that all published and unpublished literature which may have a bearing on natural science problems in the Park has been reviewed and analyzed. Needless to say, raw observational data that have been accumulated but not studied, must be developed and analyzed. All available historical writings, old photographs and other records must be scrutinized for clues that will help to establish a more complete understanding of the early state of the Park's resources and environmental influences. In short, we have to be sure that all sources of existent natural science information relative to the Park and its resources have been fully explored and exploited.

Priority must be given to careful observation and recording of subtle, as well as marked changes which take place in the distribution and well-being of vegetation and animal populations in relation to fresh-water supply--both local rainfall and overland flow from outside the Park. Equally important are frequent and careful observations of the distribution and movement, both rate and pattern, of fresh water from external sources and local rainfall.

Long-range research efforts in the Park should build toward an eventual understanding of the organization and interrelationships of the various communities represented. Such understanding will contribute significantly to the effective management and interpretation of Park resources. The kinds of studies required fall into several general categories, as follows:

1. Continuation of floristic and faunistic studies: plant and animal lists and censuses.

2. Descriptive habitat studies: landscape inventories in terms of biotic makeup and physical substrate.

3. Autecological studies: a gradual accumulation of life cycle data on as many of the Park animals and plants as possible.

4. Synecological studies: investigations of the organization of limited sections of communities; studies of separate food chains and webs, particularly food chains in selected aquatic areas (such as Shark River) which exhibit gradations from fresh to saline conditions. Food chain research involving wading birds and young shrimp would be especially significant as would investigations of special mutualistic relations. Examples:

- a. The origin and ecology of alligator holes.
- b. The roles and ecology of drought refugia, including crayfish burrows and alligator holes which may be of critical importance during severe dry periods.
- c. Game trails as stream precursors in grassland and sloughs.
- d. Productivity studies: quantitative investigation of basic production and energetics of glades cycles.

With the exception of the emergency situations mentioned, the course of the natural sciences research program in the Park, for the foreseeable future, appears most likely to be determined by such factors as: productive avenues opened by preceding research; availability of talent; amount, source, and earmarking of funds from non-NPS sources; and, amount of NPS funds available. It is hoped that after present Park crises have been resolved, more time can be devoted to obtaining and digesting the vast potential of information that could be used to give the ordinary visitor a better understanding and appreciation of this unique Park.

Finally, it is important that a clear distinction be made between natural history surveys and research. Surveys are necessary to establish an accurate initial inventory and baseline of the Park's natural history resources, their distribution and current status (population levels, indications of overgrazing, water levels, salinity levels, incidence and levels of pollution, etc.).

Similar well-planned studies are useful, as well, when undertaken periodically to identify changes or deviations from the earlier baseline surveys. Such changes may be the first clues to developing problems of deterioration in the well-being of a resource. However, survey activities beyond the initial baseline studies must be considered to be more in the province of housekeeping duties of management than research. Hence, suggestions to carry out surveys should be carefully scrutinized, and, beyond initial baseline studies, should not be listed as part of the research program.

In summary, the overall research objectives and programs for the Park should result in a body of information necessary for (a) restoration and maintenance of appropriate natural conditions of the environment, (b) more effective interpretive programs, and (c) a better understanding of visitor needs and preferences.

INDIVIDUAL STUDY PROJECTS

The following summary of management problems, together with proposed research remedies, is arranged according to broad fields of study (e.g., Geology, Botany). The paragraphs introducing each field indicate the general state of knowledge in that field as it relates to the Park. The large fields such as Botany are subdivided into less comprehensive groupings like Floristic and Vegetational Studies. More logical categories of research are thus provided. Within the various categories, specific problems and projects are arranged to some degree according to urgency, and to the present status of the work: work in progress is listed first, and newly proposed studies follow. The most crucial projects or needs are so identified.

Existing proposals, reports, or publications are referred to without extended comment on the problem or the research needed. In the case of investigations that involve several major fields of natural science, the list cites the more important areas in which interdisciplinary approaches, or synthesis of findings from several lines of research, seem specially desirable.

In general, all reasonable and feasible efforts will be made to plan and support Park study projects in accordance with the logical sequence of steps outlined by the Leopold Committee Report as reflected in this Park Research Plan.

Additions to the project list are to be expected as understanding of the essential features of the Park's hydrology and ecology improves through studies in progress or proposed here. Undoubtedly, our present concept of the nature and dimensions of some problems will change as studies advance, and problems not now recognized become revealed.

A. CLIMATE AND HYDROLOGY

Climate

The results of recent freezes suggest that locations of certain plant communities in Florida are limited by frost incidence. Although certain species of both plants and animals were largely eliminated by the great freezes of 1958 and 1962, this significant mortality has received only casual and fortuitous study. It deserves the attention of a comprehensive and well-designed and supported research program. Such an undertaking would require the establishment in the Park of numerous weather stations at realistic heights above as well as on and in the soil for continuous recording of various climatic features including temperature, wind velocity and direction, relative humidity, barometric pressure, rainfall, etc., as appropriate. The optimal arrangement would include a strategically located network of automatic stations which could telemeter the data to a central recording station on command.

Hydrology

The major objective of proposed hydrologic investigations is a complete fresh-water budget for the Park drainage systems that would reveal accurately how much input and outgo by each route occurs over a given period of time and how much is needed from external sources at critical periods to reestablish and maintain the original natural conditions of the Park.

The hydrologic research currently being conducted by the U.S. Geological Survey consists of many types of studies, each contributing in some manner to the fulfillment of the objectives stated below. The hydrology and ecology of Everglades are complex and are so different from that of other areas that, in many instances, methodology to solve the problems must be developed through experimentation.

Objectives of the Geological Survey studies include the provision of geographic, geologic, hydrologic, and hydrobiologic data to serve as bases for the allocation, development, conservation and management of the water resources of Everglades. These studies are being correlated with other concurrent natural science investigations. Major lines of research effort are as follows: (a) analysis of the hydrology of the Park to define the historical water situation;

(b) evaluation and monitoring of hydrologic changes resulting in the Park from present and proposed water control works; (c) identification of the relations that exist between various conditions of water and the biology of the Park; (d) determining the botanical changes that have occurred since 1940 and establishing the cause of variance; and (e) evaluation of potential sources of water within and outside the Park's bounds. More accurate and extensive monitoring of hydrologic changes is particularly needed to better reveal the depth, distribution and duration of water cover throughout the year.

Hydrologic and biologic data are being gathered continuously at many locations in Everglades. These data include: streamflow, water level, rainfall, water temperature, specific conductance, air temperature, relative humidity, pan evaporation, wind movement, water samples--for analysis of various chemical constituents, and populations of aquatic plants and animals. Additional studies are seeking to establish the occurrence, movement, and storage of water and how it may be best utilized under varying conditions of flood and drought. These correlated investigations should assist in the provision of a quantitative measure of the water needed to maintain adequate biological populations.

Other studies underway include (a) Photo-interpretive observation of the botanical changes that have occurred since 1940. The known differences in the water situation will be analyzed in relation to the botanical data to determine whether or not the water levels were the likely cause of the vegetative variance; (b) Determination of the effect of mineralized, artesian water on the fresh-water biota of a test plot to ascertain whether artesian waters might be used as a supplemental supply in limited areas; and (c) Calculation of the rate of fresh-water discharge through Buttonwood Canal.

Some of the hydrologic or hydrobiologic problems that require continuing or new research include:

PROBLEM: To facilitate management of the Park's fresh-water budget, much more detailed and reliable data on evapotranspiration rates under various conditions are critically needed, particularly at seasons when rate of growth of sawgrass, beak rush, spike-rush, and maidencane are rapid.

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	RSP	Rel. RSPs
Although precise data on the enormous amounts of water lost through evapotranspiration are exceedingly important to an understanding of water management, little is known regarding differences in evapotranspiration rates among the principal types of marsh and wet prairie vegetation. Can a suitable means of direct measurement be designed; or is it possible and sufficient to approximate the evapotranspiration loss indirectly, since it appears to be the only major outgo not being measured at the present time? <u>RESEARCH NEEDED:</u> In some of the smaller ponds walled in with red mangrove scrub, there are indications that daytime water levels fall appreciably from transpiration alone and recover somewhat at night. Precise transpiration rates of mangroves should be determined under differing natural field conditions but, pending the initiation of such complex studies, it is possible that worthwhile general data on mangrove transpiration (excluding evaporation) can be obtained through the use of accurate water level gauges in comparative studies of some of the small, circular ponds near the Flamingo Highway. Investigations of both evaporation and transpiration need to be high on the Park's priority list as long as man-caused water shortages remain acute or are a threat. <u>PROBLEM:</u> An accurate <u>topographic map</u> with contours delineating ground elevations within one-half foot would make possible a much needed revision of the drainage pattern maps of the Park and would facilitate quantitative determinations in all natural science studies. The present drainage maps, made some years ago by the U.S. Geological Survey, portray fairly well the waterflow at high-water stages, but are not satisfactory at medium water stages, when a great portion of the water area of the Park is impounded, i.e., flow is obstructed by levee-like structures along the		NW-2

	RSP	Rel. RSPs
landward shores of the chain of lakes and bays that cross the Park. These ridges of ground--6 to 18 inches or more higher than the surrounding area--may be of extreme importance in maintaining a vast lake of fresh water for many months after normal flow has ceased. <u>RESEARCH NEEDED:</u> In addition to preparation of a medium water stage map, another important need is determination of the seasonal rate, volume and direction of the so-called "flow of water," particularly through the Shark River Slough. Actually, there may be no movement in this large body of water when it is at medium depth, other than the humping of water under local showers or from wind effects. Medium depth (when the water is not flowing over the levees) appears to be sufficient to maintain normal wildlife activities. These are high priority projects. <u>PROBLEM:</u> At times in 1964 and 1965, water levels east of the Flamingo Highway appeared to rise somewhat without relation to known local rainfall. While levels were being recorded of water impounded in this area during the period November 1964 to July 1965, increases of as much as 0.10' between morning and evening readings seemed to coincide with the influence of strong east winds. Wind action may well be the answer in this instance but the possibility, though remote, of an unrecognized source of fresh-water supply to the area should be examined carefully. <u>RESEARCH NEEDED:</u> Investigate the possibility that groundwater may be entering the impounded area from the aquifer under Long Pine Key or from some area further to the north. <u>PROBLEM:</u> An accurate knowledge of the expanse and location of surface water areas under different conditions of water supply is necessary for suitable management of the Park water budget and (in drought		NW-2

	RSP	Rel. RSPs
periods) for identification of vegetation-hidden waterholes which can be more effectively utilized to facilitate survival of the Park's wildlife. <u>RESEARCH NEEDED:</u> Determine whether or not aerial photography utilizing infrared techniques can provide surface water area information not available from present sources. Might it not be possible, given a sufficient number and distribution of accurate reference points for depth of surface water, to make a sensitive contour map in effect by determining, through infrared photographs, the size of the flooded area at a graded series of water levels? This is a high priority project. <u>PROBLEM:</u> The present sparse distribution of water level and rainfall measuring instruments is inadequate to provide readily available information on a scale needed for the optimum management of the Park's fresh-water budget, particularly as it permits prompt knowledge and accurate analysis of the water situation throughout the Park at any one time. <u>RESEARCH NEEDED:</u> Determine how the present system of stations can be supplemented and where new stations should be located to produce the desired coverage. This system might be tied in with the climatic stations discussed earlier. Determine how the data from the presently available water and rainfall stations can be utilized more effectively to meet current needs. High priority. <u>PROBLEM:</u> It has been suggested that Perrine-Flamingo marl deposits may form an effective seal in pond bottoms and thus prevent loss of surface water to the underlying limestone. If this can be demonstrated to be true, the information will be a significant contribution to our understanding of the Park's fresh-water cycle.		

NW-11

	RSP	Rel. RSPs
RESEARCH NEEDED: Develop and follow through with test installations of the "two well system" described by Tabb (1963) to establish the sealing qualities of Perrine-Flamingo marl. At the same time, investigate, from this point of view, some of the natural wells that occur in the marginal pineland between the glades and the higher pineland. Such wells extend through the surface marl, as do many of the ordinary solution holes, and form excellent survival pits for aquatic life. High priority.		
PROBLEM: Seepage out of the Conservation Areas via the Biscayne aquifer is not well understood. This is demonstrated by the existence of L-67 and the fate of the Park's projected Tamiami Trailside sump.		
RESEARCH NEEDED: Determine the amount of water that leaves the system via seepage to the Biscayne aquifer, the relative importance of such loss, and the desirability and feasibility of reducing it. Determine whether seepage water from the Conservation Areas to the north actually is supplying water through the aquifer into the Shark River Slough and under Long Pine Key into the Everglades and mangrove marshes south of this rock ridge. Very high priority.		
PROBLEM: It is essential that we have a better understanding of the quantitative hydrologic parameters of the various Park drainages in order to be able to predict how much fresh water is going to be where and at what time. Suitable water management procedures must be based upon a sound knowledge of the source, rate, volume and pattern of flow under different conditions of supply and depth level of fresh water entering or leaving each drainage system.		NW-3
RESEARCH NEEDED: Suitable instrumentation and techniques should be employed to obtain, by actual measurement, this data for the Park's major drainage		

	RSP	Rel. RSPs
systems. The initial concentration of effort should be directed to the Shark River Slough watershed because of the current upstream water control and the impending development of the Big Cypress drainage. Equally important is a similar undertaking in the Taylor Slough system because of its relation to the water supply of the important visitor exhibits in the Royal Palm Hammock area. Important, too, is an evaluation of the fresh-water supply entering Florida Bay--especially northeastern Florida Bay--from the hinterlands of the Park. Limited aspects of these studies are currently being undertaken by U.S. Geological Survey personnel. Upon evaluation of the data obtained, it should be possible to determine the additional individual studies necessary to clarify these hydrologic questions in the Park. Very high priority.		
PROBLEM: Greater knowledge of the various estuarine processes is necessary if we are to understand the role of these waters in the Park's natural environment. Many of the physical, chemical, geological and biological interrelationships involved need exploration and definition. Our present day understanding of estuarine flow and its consequences is most inadequate. Very high priority.	NW-7	
RESEARCH NEEDED: 1. Estuarine mixing results from fresh-water outflow, tides, and wave action. The manner in which tide and wave action behaves in the many estuaries and inland bays of Everglades needs examination. Stratification at the fresh-water salt-water interface requires substantial investigation because of its importance in determining the kinds and well-being of the great biological populations associated with it. Priority. 2. Water, serving as a transporting vehicle, disperses solids and solutes in oceans, bays, and		

estuaries by mechanical and chemical action. The dispersal processes need analysis because they create, among other effects, changes in dissolved oxygen which in turn may be a controlling factor in the biology of the area. Further, knowledge of dispersal processes is of paramount importance in understanding the potential effects of water-borne pollutants which may be introduced to these areas. High priority.

3. The above basic, closely correlated information is required before investigators can undertake additional research, including: the mechanics of delta formation; the mechanics of bedding; the physico-chemical properties of marine sediments; the littoral sediment transport as related to shoreline formation; and the damping characteristics of bays. All of these processes influence the marine habitat and, in turn, the biological processes associated therewith.

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RSPs

B. GEOLOGY AND SOILS

Geology

The physical and historical geology of southern Florida and the characteristics of the younger strata as they affect the hydrology have been studied extensively and are considered to be reasonably well known. As indicated in an earlier section, the area's geological structure suggests a rather unspectacular history, principally involving deep sedimentary accumulations that show little evidence of vertical displacement, and changes in land-sea relationships related to Pleistocene glaciation.

Some geological studies necessary for a better understanding of Park problems are suggested below. Additional projects of broader implication which have been completed recently, are in progress, or are proposed, involve work by geologists or utilize the techniques of geology (see problems included elsewhere in this chapter under the categories "VEGETATION" and "ANIMAL LIFE").

	RSP	Rel. RSPs
PROBLEM: The Biscayne aquifer is the sole known source of fresh ground water in southeastern Florida and forms the natural storage reservoir for fresh water in Everglades National Park. The areal extent, thickness, permeability, and complete geologic characteristics of this aquifer are poorly known.		
RESEARCH NEEDED: 1. The geometry of the Biscayne aquifer throughout the National Park area needs to be determined. A series of exploratory core-drill holes, perhaps on 2-mile centers, may provide adequate information for this purpose. The core holes should penetrate through the aquifer into materials of low permeability. Hydrologic testing done during the drilling will furnish information on changes in permeability with changes in depth. Once the variation in permeability of the rocks is known, estimates concerning the rate of ground-water movement can be made. High priority.		

A D D E N D U M

Subsequent to the preparation of the Everglades National Park Natural Sciences Research Plan, Dr. J. Edward Hoffmeister, Institute of Marine Science, University of Miami, informed the Division of Natural Sciences Studies (August 25, 1966) of a paper he and his co-workers have submitted for publication in the Bulletin of the Geological Society of America. The paper reports the findings of the authors' latest research on the geology of southern Florida and provides information directly pertinent to a number of the questions raised in the Everglades Research Plan relative to the "Miami Oolite." An abstract of the paper is included herein as Appendix IV - The Miami Limestone of Florida and Its Recent Bahamian Counterpart.

In separate correspondence, Dr. Hoffmeister has called attention to the necessity for additional research on the distribution, thickness and composition of the formations underlying the Miami Limestone (Miami Oolite).

	RSP	Rel. RSPs
2. From a thorough study of the rock cores obtained in (1) above, it should be possible to construct a series of contour maps which will depict the thickness or the elevation of the bottom of the Miami Oolite; the configuration and elevation of the bryozoan zone at the bottom of the Miami Oolite*, the thickness or the elevation of the bottom of the Fort Thompson Formation; the elevation of the bottom of the Biscayne aquifer; and the configuration and persistence of major layers of hard, dense limestones within the aquifer throughout the Park area. Hoffmeister and Multer (1961 and 1964) and others have obtained cores in the vicinity of the Park.		
3. Determination of the origin and environment of deposition of the bryozoan zone* and the hard, dense limestone layers.		
4. Studies to determine the effectiveness of the shallow, hard and dense layers of limestone in reducing the downward movement of surface water to the permeable sections of the aquifer. The dense layers tend to form two separate flow systems within the Biscayne aquifer. The origin and perpetuation of the Everglades may be closely related to the near-surface occurrence of limestone of low permeability that appears to underlie all of the Park south of the latitude of Miami. High priority.		
5. Study of the cored material to determine whether there is a sequence of fresh-water and marine limestones to conform with fluctuations of sea level during Pleistocene times.		
6. Determine the nature of the contact zone between the Pleistocene rocks (Miami Oolite and Fort Thompson Formation) to the east, and the Tamiami Formation (Miocene) to the west in the western part of the National Park. Olsson (1964) has suggested new stratigraphic nomenclature for shallow sediments in the vicinity of the western part of the Park and northward.		

*See Appendix IV.

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7. Determine the relationship between ponded water in shallow lakes in the southern coastal prairies of the Park and the ground water. Reportedly, water stands in these ponds even when the surrounding areas have been dry for many weeks. Is there upward movement of ground water into these ponds or are the ponds so floored with dense material that the water remains perched? High priority. <u>PROBLEM:</u> Observations suggest that mainland and island shores in several areas of the Park are changing rapidly through erosion and redeposition. These changes are most noticeable in the Cape Sable area, the lower Gulf Coast, on some Florida Bay keys, and along parts of the north shore of Florida Bay. Craighead (1964; 1962 with V. C. Gilbert) reported that Hurricane Donna (September 1960) markedly altered the Cape Sable beaches, reducing East Cape by at least 25 feet while Middle Cape and Northwest Cape were extended appreciably. A series of 24 beach ridges on Northwest Cape apparently represents successive storm deposits, the storm ridge of Donna lying nearly 75 feet seaward of the pre-storm shore. The same author noted that the beach between Middle and Northwest Capes was badly eroded and seemed likely to disappear. Park Naturalist Sloane (MS report in Park files) reported similar erosion of the beach arc between Middle Cape and East Cape. Spackman (Spackman, Scholl and Taft, 1964) pointed out the rapid erosion of mangrove peat which is occurring along the shores of Little Sable and Big Sable Creeks. These streams are cutting into peat beds, large amounts of peat are carried out on receding tides, and some is redeposited on Cape Sable. Farther east (of Cape Sable), lime mud shores of Florida Bay are being eroded along a considerable linear extent of the coast and are marked by a marl "bluff" several feet high.		

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Areas being lost by erosion are of considerable importance, since some plants occur in the Park only at shore sites. Moreover, the Cape Sable beaches are a major nesting ground for Atlantic loggerhead turtles. For these reasons, and because of the theoretical importance of understanding present processes in order to interpret earlier sediments more adequately, a comprehensive study is much needed. RESEARCH NEEDED: It should be determined from comparison of existing aerial photos of different ages whether or not the beach at Cape Sable <u>has</u> been eroded and, if so, at what rate. If significant erosion is evident, index markers should be established along the beach in order that the future course of the erosion can be gaged. Field studies should be made to identify the erosional factors, assess their importance, and provide information from which suitable control measures can be developed. Possible sources of erosion include hurricanes, along-shore currents, currents generated by tide races in the uncontrolled East Cape and Middle Cape Sable Canals, and rising sea level if such is occurring. Craighead and Gilbert (1962) have indicated the widespread deposition of marl along the fringe of the mainland during Hurricane Donna in 1960. Deposition during catastrophic events of this nature may be the chief source of such materials as those observed along the fringe of the Park and in Florida Bay. Bench marks should be established in these areas to permit measurement of the accumulation of sediments and analysis of their effects. PROBLEM: Low, linear ridges of limestone, some of which are many miles long, occur in several areas of the Park. The existence of others is suspected from features visible in aerial photographs. These so-called "rock reefs" (<u>not</u> coral) provide conspicuous topographic relief on the virtually featureless plain of southern Florida. They have not been explained or, apparently, even discussed in the geological literature.		

RESEARCH NEEDED: Careful field examination should be made of known rock reefs to determine their structural characteristics and orientation in relation to adjoining rock strata and to local drainage patterns. Existing aerial photographs (1965 series) need to be analyzed and the known reefs, along with other linear features that may be reefs or reef remnants, accurately located on a map of the area.

Features suspected to be reefs should be examined from the air and on the ground, with particular attention being directed to the possibility that reefs which have been reduced by solution and collapse and, thus, no longer exist as rock elevations, may still be identifiable from present patterns of drainage or vegetation.

It is hoped that such studies may provide an explanation which adequately accounts for the existence and location of the reefs. Some of the reefs seem to separate areas of markedly different hydroperiods. Possibly these structures determine (to some extent) the local patterns of surface drainage. Since the "reefs" may be composed chiefly of algal material which can indicate areas of old shorelines, microscopic analyses of the rock materials should be made to determine their structure and composition.

Soils

PROBLEM: Soils throughout much of the Park have not been classified other than in very broad categories. There is reason to suspect that deposits of organic soil in the interior of the Park have been reduced considerably by fire since the last available soil survey in the 1940's. Correlation of certain botanical and hydrologic phenomena with particular soil conditions is suspected but has not been verified in the Park and, certainly, is not understood.

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RESEARCH NEEDED: A systematic probing and sampling of soil types should be made at various depths throughout the Park and their physical and chemical characteristics determined. Samples need to be taken at different seasons at geographical points where it is suspected that soil characteristics important to plant growth may change seasonally. Particular effort is necessary to assure the availability of data relative to the influences of fire and hurricanes in determining changes in soil characteristics and vegetation.

A series of permanent index stations needs to be established to record soil changes in relation to differences in water availability. The soil survey must extend through the areas of mangrove peats. In addition, a series of soil samples should be collected throughout the Park to determine the range in ages of organic soils. Preferably these ought to be collected at the bottom of the organic sediments. Finally, one or more contour maps need to be prepared showing the configuration of the top of the limestone layer and the thickness of the soil blanket.

A standard soil survey and map, based on the relationships found to exist between soil characteristics and plant cover, needs to be made from aerial photographs in the manner outlined in the "Soil Survey Manual" and the "7th Approximation of Soil Classification" of the U.S. Soil Conservation Service.

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C. VEGETATION

Because of the Park's geographical location and physical characteristics, the vegetation of the area has features of unusual interest and botanical data have particular significance in management and interpretation. The vegetation shows the most convincing evidence of the Park's affinities to the West Indian tropics, as illustrated by such features as mangrove swamps; abundant wild palms; mahogany, strangler figs, and other tropical hardwoods; and, epiphytic orchids and bromeliads. On the subdued topography of southern Florida, the natural plant cover determines the appearance of the scenery to an unusual degree. The major theme of interpretation of the Park to visitors is in terms of vegetation-determined landscape types and the natural forces that affect their occurrence.

Changes in plant cover are perhaps the most sensitive indicators of the effects of drying and of salt water intrusion, because minute differences in elevation are of critical importance to the occurrence of particular plants in this area. Knowledge of fire and hurricane effects upon various vegetation types, and of patterns of vegetation recovery from disturbance by these natural factors, is also of critical importance to management. While the botany of the Park area and of southern Florida has been extensively investigated, there remains an acute need for greater general information and more precise data on many aspects of the vegetation of this region.

Floristic Studies

Largely through Dr. Frank Craighead's efforts, the Park possesses a substantially complete herbarium of vascular plants. Botanical studies have been hampered because the only available identification manual (Small, 1933a) is long out-of-date in both its nomenclature and taxonomy. Recent publication of a checklist of plants for the three southern counties of Florida (Lakela and Craighead, 1965) makes current names easily available, and work on a manual for the same area is proceeding well. A popular guide to the epiphytic plants of the Park (Craighead, 1963) has been published. Similar material dealing with other groups of general public interest, such as common wildflowers and woody plants, is greatly desired.

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<u>PROBLEM:</u> Botanical studies in the Park have been hampered considerably by the lack of an up-to-date and easily used manual for the identification of the local flora.		
<u>RESEARCH NEEDED:</u> Botanists at the University of South Florida, Tampa, are preparing a manual of the plants of Dade, Monroe, and Collier Counties, Florida, which include the Park. In support of this project, provision should be made for botanical exploration of sections of the Park where the flora has not yet been collected thoroughly. These sections include parts of the interior Everglades and particularly the upper Gulf Coast areas acquired as a result of the 1958 boundary adjustment. The manual now in preparation is almost certain to be the standard source for identification of the Park flora for many years to come. Thus, the Service must assure that coverage of the Park flora is as complete as possible.		

Phytoplankton and Periphyton

The clear, warm and shallow waters of the Everglades are usually considered to be highly productive, with phytoplankton constituting the major primary source. However, preliminary investigations of measured samples of phytoplankton have failed to yield sufficient producers to account for the diurnal physico-chemical fluctuations observed. On the other hand, attention directed to the periphyton revealed the presence of producer algae in numbers adequate to produce the fluctuations noted.

As described earlier, Everglades periphyton is considered to include that material which consists of precipitated calcite and microscopic organisms and is attached to the macroflora and grows over the bottom sediments.¹ The microscopic organisms have an extremely active metabolism and serve as food or (under certain conditions) may be toxic to larger animals. Whether toxic species occur in the Everglades is not known, but this possibility should be explored.

Most of the preliminary investigations so far made, have been carried out on the green periphyton, the most common type in the Shark River Valley. Samples of blue-green periphyton have been obtained from time to time from the Highway Station in Taylor Slough.² Water samples for laboratory analysis, and plankton samples have been collected occasionally as well. These data plus physico-chemical information obtained by the field team were presented by Hunt (1961) as indicative of conditions in Taylor Slough and by Reark (1960, 1961) in the latter's discussion of the major diurnal variations observed in the Shark River Valley.³ There are marked differences between these two regions at the secondary productivity level in terms of animal populations. Many factors are

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1. For periphyton classification, see: Reark, J.B. 1960. "Ecological Investigations in the Everglades." First Annual Report. (Mimeo.)
 2. For description and location of this station, see: Hunt, B.P. 1961. "A Preliminary Survey of the Physico-Chemical Characteristics of Taylor Slough With Estimates of Primary Productivity." (Mimeo.)
 3. Reark, J.B. 1960, 1961. First and Second Annual Reports. Hunt, B.P. 1961.

involved, but observations and sampling in the field indicate that the type of periphyton may play an important role in this difference (Hunt, 1961; Reark, 1960, 1961). There is little information thus far to explain why green periphyton predominates in the Shark River Valley while Taylor Slough contains more of the blue-green type.

These investigations also suggested that the effect of Hurricane Donna, September 9-10, 1960, was felt as much by the periphyton as by the larger organisms. A reconnaissance flight over Shark River Valley and Taylor Slough a few weeks after the storm revealed great masses of floating, drying periphyton just above the headwaters of the Shark River. There were similar, smaller masses of blue-green periphyton floating in Taylor Slough. Apparently the floating periphyton had been torn from the stems of the various plants.

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<u>PROBLEM:</u> The encrusting and periphyton-forming algal flora of fresh-water areas of the Park is little known but (as indicated earlier) appears likely to be of considerable importance in the overall ecology of Everglades wetlands communities. Unfortunately, the preliminary studies of 1960 and 1961 (cited previously) were not carried to completion. A more comprehensive understanding of periphyton and its relationship to the hydrology and biology of the Park is required for water management and interpretation purposes. This is a high priority subject.		
<u>RESEARCH NEEDED:</u> Considerably more information is needed concerning the role of periphyton in the basic biological productivity of Park waters, the interrelations of its components, the part it plays in the cycling and recycling of basic nutrients and minerals, its relationship to periods of drought, its response to varying degrees of salinity, its position in the food chains of consumer organisms, the conditions which result in a predominance of one type rather than another in a particular area, etc.		
Phytoplankton and periphyton are being extensively studied by Dr. Ferguson Wood and associates at the Institute of Marine Science, Miami, where		

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species lists, seasonality, etc., are being correlated with Ph, Eh and oxygen of sediments and water, and with the macrophytes. Quantitative studies of the relations between macro- and microflora and between microflora and carbonate precipitation, as well as detailed studies of desmid and diatom species, also are in progress. This work is to continue over 2 years and most of the results will be published only after the completion of the study. Additional research of this nature is needed in all wetland areas of the Park. PROBLEM: Even less is known about other phytoplankton, including certain of the so-called Protista (bacteria, photosynthetic and various nonphotosynthetic flagellates and dinoflagellates), and their contribution to the total biology of the Park. It is essential that we develop a thorough knowledge of these organisms in their varying habitats throughout the Park because (1) they play a primary role as converters of the sun's radiant energy to that which can be utilized by animal forms; (2) they comprise a food source for zooplankton, very low in the food chain of higher animals; (3) they contribute to the oxygenation (in certain instances, the reduction of dissolved oxygen) of Park waters; and, (4) they are potentially useful as early indicators of pollution. The role of phytoplankton and periphyton becomes especially important in consideration of suggestions that treated sewage effluent be utilized as a source of water supply for the Park. RESEARCH NEEDED: A checklist of the more common algal flora of marine and brackish waters around Flamingo is available (Tabb and Manning, 1961) and general publications on the hepatics (nonplankton; see Schuster, 1959-60 and references cited therein) include scattered material on identification, distribution, and ecology of various forms found in the Park. The latter publication is based principally		

upon Dr. Schuster's collections during several visits in the 1950's. However, exhaustive works on the identity, distribution and seasonal abundance of algal forms in the Park have not been produced and are badly needed.

In addition, we need definitive studies concerning the total phytoplankton and periphyton dynamics of all fresh and estuarine waters of the Park, the periodicity of blooms and regulating factors thereof, the role of the phytoplankton and periphyton in the cycling of minerals and nutrients, the population levels of individual species in relation to those of other algal species, their role as pollution indicators and in aeration or stagnation of Park waters (particularly at Royal Palm Hammock), their role in the food chain as it ultimately involves fish production, the presence and potential importance of toxic species, etc. A massive program of research on these and other facets of the phytoplankton-periphyton problem is imperative, hence of very high priority.

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Exotics

A number of introduced or escaped plants, mainly of tropical origin, have spread progressively in southern Florida at the expense of native vegetation. Examples are the water hyacinth, Australian pine, Brazilian pepper and punkywood.

PROBLEM: Some of the exotics appear to constitute a threat within the Park, but the overall extent of the problem is insufficiently known to permit proper management planning for control of these plants.

RESEARCH NEEDED: The Park should be surveyed carefully to establish the incidence and distribution of exotic plant species and to identify priority needs for their control in terms of the ecological threat they pose. Elimination of known stands of exotics may proceed appropriately without additional study after acceptable control techniques have been approved. The survey is a high priority item.

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Rare and Vanishing Species

Certain animal and plant species, once well represented, have now vanished or are decreasing in numbers at a rate which casts grave doubt as to the likelihood of their continued survival in Everglades National Park. Although some of these are not rare or vanishing on an international scale, their dwindling status in the contiguous United States is cause for concern.

PROBLEM: Historical accounts, dead trees, and relict stumps from former stands indicate that hammock hardwood forests of the south coast east of Flamingo once were dominated by West Indian mahogany in areas where few or no living trees of this species can now be found. The widespread disappearance of this formerly

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important member of the flora is a matter for concern. Reasons for the failure of regeneration are presently obscure. <u>RESEARCH NEEDED:</u> The former distribution of mahogany stands and reasons for their disappearance (wildfires, lack of adequate seed trees, habitat change as a result of hurricanes) need careful study. If the studies reveal that the earlier decline in population was not due to natural successional events, seedling mahoganies from southern Florida stock should be established in a selected study area, attempts made to correct or prevent the deleterious influences identified in the studies, and the trees' growth and progress watched closely. If, as the result of these efforts, reestablishment appears feasible, restoration projects should be implemented. <u>PROBLEM:</u> A number of species of ferns and epiphytic orchids have become exceedingly rare in the Park as a result of hurricanes, wildfire, and, above all, unprincipled collecting. Reestablishment of these forms in their native habitat from Florida stock is greatly to be desired. <u>RESEARCH NEEDED:</u> As in the mahogany project above, the forms in need of such assistance need to be identified, their former and present distribution in the Park established, stock suitable for reintroduction located, and (by experimental plantings) a determination made of whether reintroductions are likely to succeed. Upon completion of this investigation, a management plan should be developed to accomplish the actual reestablishment. Species believed to be in need of special attention include hand fern, holly fern, tropical maidenhair fern, spider orchid, Trinidad macradenia and mule-ear orchid. This is a high priority requirement.		

Growth Studies

Because of the year-round growing season and the presence of trees of both temperate and tropical types at the limits of their range, southern Florida offers unusually favorable opportunities for study of the relations between climatic factors and tree growth. The flora includes trees that are regularly deciduous, trees that are facultatively deciduous depending upon the severity of the dry season, and trees that are evergreen with no clear-cut dormant period.

PROBLEM: An understanding of growth processes and rates in Park trees is required to serve as a basis for (1) analyzing the significance of scars, ring checks, etc., which reflect the influences of historical natural events; (2) for determining the health and vigorous growth of trees under various conditions; and, (3) for establishing the response of trees to fire, drought, flooding, etc.

RESEARCH NEEDED: Microscopical study of wood to detect the nature of annual growth increments in trees of different seasonal characteristics, and other morphological and physiological research on the mechanisms and regulatory processes of tree growth in relation to environmental influences, are needed to provide data which has important theoretical interest as well as practical value for dating natural events in the history of the trees.

Preliminary work by Dr. P. B. Tomlinson of Fairchild Tropical Gardens and Dr. Frank C. Craighead of Homestead, Florida, has disclosed the following points:

1. Annual increments suggest that some species form annual growth rings; some form growth rings that are not necessarily annual, but may be induced by nonseasonal events such as hurricanes, frost, fire, or drought; and some form no growth rings.

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2. Correlation between growth rings and deciduousness is not complete. Species that form annual rings may not be deciduous; some species without obvious growth rings are deciduous. 3. Observations made by Dr. Craighead, in 1955, of growth around artificial scars on a number of trees, suggest that local pines add one distinct growth ring each year. Extension and expansion of this study to additional localities and more tree species is greatly desired. Other investigations to reveal growth processes and mechanisms and response to environmental events, should be instituted as soon as possible.		

Succession Dynamics

The plant ecology of southern Florida, including the Park, is fairly well known in the sense of static description of the kinds of plant cover that exist--their general composition, distribution, and the broad characteristics of sites occupied by various types. However, cover-type criteria and the environmental characteristics of sites still need considerable investigation. A reasonably accurate, small-scale vegetation map of the Park mainland is available (J. H. Davis, 1943) and the cover-types have been organized into several hypothetical successional series converging to the familiar regional monoclinal.

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<u>PROBLEM:</u> In contrast to the descriptive ecology, the dynamics of plant communities in the Park area--what significant and definitive changes, if any, are occurring and for what reasons--are less adequately understood and of great concern at this point. Considerable relatively recent broad-scale changes of plant cover are known or suspected to have occurred in many sections of the Park. Trends of vegetation change, mainly the extension of broad-leaved woody plants including mangroves, into the glades and		NW-4 NW-12 N-3

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pinelands, seem evident in many places, and in some cases are very marked. Some of these have been attributed to changes in the frequency and intensity of drought and fire; in other cases, the causes remain unknown. The loss of water lily slough and sawgrass marsh areas and the changes which have occurred to dry, marl, and rockland prairies may prove to be especially critical. A relationship between such changes and the decrease in fresh-water supply is likely. The Park's longstanding "water problem" may come to focus, in considerable part, on the attempt to recognize and arrest such adverse and unnatural changes in plant cover. In some instances, the changes are of interest and significance because they represent the recovery of vegetation from specific natural disturbances, such as hurricanes, that may be expected to recur. An accurate, up-to-date, and detailed large-scale vegetation map of Park areas is much desired to provide a means of determining the changes which have occurred and to establish a baseline against which future vegetation changes may be measured. Close study of the existing aerial photography of the region (series of 1940, 1951, and 1964-65) appears to offer the one likely possibility of obtaining certain quantitative data on the nature, rate, and extent of these changes. Although a large-scale map is desirable, the time and cost of developing such a map preclude its being completed within a relatively short time. Hence, efforts to obtain an aerial photo-based map should be pursued at once. The aerial photos in color obtained during the 1964-65 coverage would seem to provide suitable basic data for the preparation of such a map. RESEARCH NEEDED: The Park Biologist and personnel of the U.S. Geological Survey, Miami, are scheduled to begin such efforts to analyze vegetation changes		

through comparison of aerial photographs of the Park. A photogrammetry laboratory has been established at the USGS office and a technician skilled in this work has been added to the staff. Initially, the intent is to examine areas such as the mangrove-everglades interface where major change is suspected and, for comparison, samples of other areas (probably one square mile chosen at random within each township) throughout the Park.

Effective progress of the work has been held up by delay in the receipt and installation of advanced photo-plotting apparatus at USGS. At a later stage in the study it will be necessary to make on-site studies of the changes indicated by study of the photos. Preparation of a vegetation map from the color coverage should be scheduled as soon as possible. Mapping work will require a number of preliminary decisions about vegetation type criteria, and the most useful and feasible scale and style of the map. Studies of succession dynamics have a high priority.

Hurricanes

PROBLEM: Two severe hurricanes within 5 years--Donna, September 9-10, 1960, and Betsy, September 7-8, 1965--resulted in extensive alteration of landscape, vegetation, land levels, and soil characteristics throughout the coastal area of the Park. These storms have made it quite evident that occasional intense hurricanes are an environmental factor of profound significance in low-lying coastal sections. Studies of the effects of such storms upon plant cover, and of the patterns and rate of recovery of vegetation from hurricane damage, are of foremost importance to management and interpretation of Park resources.

Dr. Frank C. Craighead has developed pertinent information concerning the role of mangroves and other plants in the formation of extensive land deposition (Craighead, 1964). He found that natural levees, from 6 inches to 2 feet high and from a few

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feet to over 100 yards wide, have been formed throughout the Park area; some of the best defined are those along the coast and along the banks of the many lakes and bays. Practically all of the islands of White-water Bay and those in the major streams have raised banks. In addition, numerous cross-levees have developed in the scrub mangrove or fresh-water section of the mangrove forests.

Such levees are particularly well developed on the north banks of the string of lakes and bays that divide the mangrove areas of the Park into outer and inner zones. Although frequently interrupted by smaller creeks, these levees dam and hold extensive bodies of fresh water for several months after the Slough of the Shark River is dry. Levees of this kind are formed by the deposition of marl (a calcitic mud deposited by marine and fresh-water organisms) which has been carried by seasonal high tides and storm tides, water currents or winds, into the vegetation on the perimeters of these bodies of water--much as snow is deposited among deep weeds, or sand on beach vegetation. Over the years, as these marl deposits built up, humus has been added, forming a mixture of marl and peat, which is termed muck. These muck banks are quite impervious to water.

Accumulation of marl in the scrub mangrove and sawgrass areas of this region appears to have completely interfered with the loss of water through underlying rock, Miami Oolite, in Dade County. Thus, a large body of fresh water collects each year from precipitation and is stored in the mangrove area to the north of the string of lakes and bays.

During years of normal rainfall, parts of such reservoirs retain water throughout the year but in years of inadequate rainfall they may become completely dry. As this happens, the fish in the area are gradually concentrated in the deeper pools. The wading birds, otters and alligators glut themselves until the excess of fish finally die in a mass several inches thick. Finally, this foetid material is devoured by the buzzards.

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<u>RESEARCH NEEDED:</u> Dr. Craighead and members of the Park staff began to assess storm effects upon the vegetation immediately after Hurricane Donna, early work of necessity being mainly qualitative and descriptive. From 1962 to date (1966), very modest but gradually increasing funds have enabled Dr. Craighead to establish and study some 60 plots representing different plant communities and various degrees of storm damage. As the investigations continued, the plots exhibited the effects of Hurricane Betsy superimposed on those of the earlier storm. Publications from the work include Craighead and Gilbert (1962) and Craighead (1964). In addition, Dr. Craighead expects to prepare a manuscript detailing the ecological role of hurricanes in shaping coastal plant successions. It is imperative that further support be given to this project on a scale adequate to permit periodic recheck of the study plots. More research effort and support should be focused on analyses of the formation and ecological role of natural levee-like structures in the mangrove area. Examination should be made, as well, of the feasibility of artificially improving their water-retaining characteristics as a temporary and emergency measure to benefit certain critical areas currently threatened by man-caused water deprivation.		

Fire Studies

Vegetation over the greater part of the Park has been held at subclimax levels by recurring natural disturbances, one of the most important of which was fire. The data indicate that this situation has prevailed through the recorded history of the area. Impairment of the effectiveness of these checks to plant succession--in particular by policies of fire exclusion--have established adverse trends of vegetation change, notably a widespread invasion of hardwood species into pineland and drying marsh habitats.

The invasion of hardwoods into the pine forest understory was considered sufficiently understood (Robertson, 1953a) and destructive to original natural habitats to permit the inauguration, in 1958, of a program of prescribed burning for control of hardwoods--the first venture by the National Park Service into vegetation management by this method. Although presented as an experimental operation, the project was on an area management scale of about 6500 acres, rather than of more limited scope. Because adequate support was not available, quantitative study of the pineland burning was limited to observation of the effects of burning upon height and density of hardwoods, and growth and survival of pines on about 70 one-tenth acre plots adjoining fire roads.

As a result of the extremely large and destructive Shark Valley Fire of May 1962, the question of using prescribed burning as a means of fire hazard reduction and hardwood control in marsh grassland areas has been raised.

PROBLEM: Extension of the studies of fire as a management tool in the Park is much needed. Aside from use in the control of unnatural invasions by undesirable vegetation species, burning may produce secondary benefits to Park deer populations. Restricted areas south from Long Pine Key to the Madeira Hammock along the Crocodile Point Road evidently harbored excellent deer populations prior to the establishment of the Park. Similarly, as late as 1952, deer were relatively common in the Alligator Creek area although such is not the case today. We need to know the role controlled burning in such areas would have in the

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restoration of more substantial deer populations to these and other areas south of the old Ingraham Highway and east of the new Flamingo Road.		
RESEARCH NEEDED: A summary of prescribed burning operations to date, including analysis of data recorded on study plots, is being prepared by Field Research Biologist Robertson. This report will complete the first phase of prescribed burning studies.		
Further research should include a more comprehensive investigation of the effects of prescribed burning and the general role of fire in the dynamics of pine and grassland communities. Specific topics that need study are: quantitative effects of burning on bird and mammal populations; effects of variation of season, moisture conditions, frequency and severity of fire in pine and grassland areas (this investigation will require a series of replicated plots on which certain of these factors can be varied experimentally); comparative evapotranspiration rates from burned and unburned grassland and pine understory; effects of burning on the chemistry of the substrate, especially on the recycling of nutrients; other changes that may be involved in the conspicuous efflorescence of grasses and small forbs on new pine-land burns; and, rate of buildup of combustible material following fire. High priority.		

Ecological Role of Frost

Frost occurs somewhere in the Park almost every year and, at irregular intervals, freezes of more than ordinary intensity do extensive damage to vegetation. Historical accounts mention freezes in 1898 and 1917 that were sufficiently severe to kill extensive areas of mangrove and mahogany forest around Flamingo. The most severe freeze in the history of the Park occurred in January 1958, and affected a large variety of plants on northern Key Largo in the supposedly frost-free Florida Keys.

PROBLEM: While the plants and areas most susceptible to frost damage are generally known, no systematic studies have been undertaken to establish the impact of frost in limiting the distribution of certain vegetation types, or to reveal patterns and rates of restoration of frost-damaged species.

RESEARCH NEEDED: Temperature recorders should be established in areas representing the vegetation types and topographic situations where frost is most likely to be an important factor. On the occasion of future freezes, every effort must be made to obtain careful records of the species affected, and the distribution and nature of damage. The location of plants found to be especially sensitive should be examined to find the extent to which distribution patterns may be determined by frost.

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Paleoecological Studies

The soils of the Park consist of a number of calcitic muds, peat, muck, and humus deposits, in depths of up to 15 feet, that lie on top of mid-Pleistocene marine limestone formations. Virtually all of the soils are recent (to about 4000 years ago), and almost all result from biological activity. The peat soils, particularly the mangrove peats, have attracted considerable attention from geologists and plant ecologists. J. H. Davis (1940, 1943a, 1946) summarized the earlier work.

More recently, Ginsburg (1953, 1954, 1956, 1958) pointed out that the deposits of carbonate mud in Florida Bay represent the unlithified equivalent of marine limestones of the sort that occur commonly in the geologic column of some major oil-producing areas. This work led to the use of Florida Bay by several oil companies as a field laboratory for training geologists.

Within the past several years, sediments in coastal areas of the Park have been studied by other geologists and botanists. Using carbon-dating techniques in studies of the sedimentation in the Whitewater Bay-10,000 Islands area, Scholl (1963, 1964a, 1964b) concluded that a sea level rise of approximately 10 feet has occurred over the past 4500 years. His evidence indicated that the rate of rise was rapid in the period 4500 to 3500 years ago, and that total rise over the past 3000 years was of the order of 3-4 feet. Craighead (1964) collected many of the lime mud and peat cores analyzed by Scholl, and, on the basis of his (Craighead's) study of the distribution of marl ridges and peat in the southern Everglades, had independently suggested a similar rise of sea level.

Spackman and his associates at Pennsylvania State University have conducted studies over a number of years in the Shark River area on peat sediments and the areas in which these deposits occurred as environments of coal formation (Spackman, et al., 1964). The group found that extensive beds of mangrove peat occur up to more than a mile offshore in the Gulf of Mexico along the southwest coast of the Park. The oldest dated samples recovered thus far in the area are fresh-water peats lying immediately on top the Miami Oolite in Whitewater Bay (Spackman's sample T 6, 4400 years ago) and at Big Sable Creek (4300 years ago).

Taft and Harbaugh (1964) concluded from study of Florida Bay lime mud that most of the unconsolidated material has been secreted by organisms, Florida Bay lime mud being largely aragonite, while inland fresh-water marls are chiefly calcite. Shier (1965) found that much of the mangrove peat of the 10,000 Islands was developed over vermetid reefs. Additional studies of Florida Bay sediments by Fleece (1962), Gorsline (1963), Lloyd (1964), and Pilkey (1964) were concerned principally with Florida Bay oceanography and the geochemistry of the sediments.

A considerable body of information thus is available to establish the conclusion that paleoecological data of great significance are recoverable from the recent sedimentary strata of the Park area. The studies cited also illustrate the necessity of a better coordinated research program for the Park. Many of the investigations were carried on without knowledge that similar studies were in progress concurrently elsewhere in the Park. Inevitably, this has led to some duplication of effort and to failure to realize full possibilities from work done and cores collected. A coordinated interdisciplinary attack on this complex and fascinating problem by geologists and biologists is greatly needed.

PROBLEM: Investigations completed thus far clearly show that the organic and lime-mud sediments lying on top of the Miami Oolite contain preserved materials which, when carefully studied, may provide clues to the changes which have occurred in the location of shorelines and reveal the sequence of vegetation changes through much of post-Wisconsin time. As noted, the subject has been approached from several directions by a number of geologists and by several biologists.

In the main, these investigators have worked independently on relatively limited aspects of the overall problem. Hence, the broad conclusions reached thus far must be considered tentative. Further work is necessary to produce much needed information for interpretive activities in the Park. Additional data should permit conclusive judgment on the trends of land-sea relationships in the area, a subject that has figured to some extent in discussions of the Park's water problem.

RSP	Rel. RSPs

RESEARCH NEEDED: The problem requires concerted, interdisciplinary attack by geologists and biologists employing the full battery of specialized techniques and equipment now available for this sort of research. Complete sediment cores should be collected along a number of carefully chosen transects across coastal and offshore areas of the Park and its environs. These cores should be correlated precisely, subjected to thorough physical and chemical analysis, and examined for fossil inclusions--pollen, mollusk shells, and other plant or animal material. Peat and any inclusions in the cores susceptible to such analysis should be dated by Carbon-14 or other techniques. While a comprehensive investigation of this kind will require financing on a scale probably well beyond National Park Service capabilities, the high likelihood that it will yield scientific data of great importance should support a strong claim for grant assistance.

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D. ANIMAL LIFE

Estuarine and Inshore Marine

During the past decade marine scientists have come to recognize that Everglades National Park offers a valuable natural laboratory for estuarine research. Although changes have occurred in the ecology of some of the Park's estuaries--indeed, some of the changes threaten to have disastrous results--other estuarine areas of the Park appear to be relatively unchanged and many are only moderately altered thus far.

With the mounting pressure on estuaries over the whole of the United States and with the dark likelihood of damage to these sites of beauty and productiveness nearly everywhere, there is dire need for natural laboratories where ecologists can gather the facts necessary for protection and management of estuaries. We may find that Everglades National Park is as important to the American public for this purpose as for its more commonly recognized values.

A variety of estuarine studies already have been centered in the Park. Several have been designed to establish baseline data for natural subtropical estuaries. With such baseline information we can measure the nature and degree of changes which result from draining, filling, polluting or otherwise altering estuaries of this type. Some of the most conclusive research findings available on estuaries have resulted from Everglades studies. Effective popularization of the findings has contributed to the dramatically increased appreciation of estuarine resources and the growing official and public resistance to the dredge-and-fill blight that has destroyed too much estuarine habitat in Florida and elsewhere in the United States.

Estuarine research in Everglades National Park serves as an important stimulus to the development of insights and principles needed for the recognition of the values of estuaries throughout the world. However, the most immediate urgency of such investigations stems from the requirement for information so necessary in the effective management of the Park's resources to assure their perpetuation in an undisturbed condition.

	RSP	Rel. RSPs
<u>PROBLEM:</u> Investigations by Durbin Tabb and associates at the Institute of Marine Science, University of Miami--begun in 1957 and still continuing--constitute landmark research in subtropical estuaries. The original work in Coot Bay, Whitewater Bay, and western Florida Bay during the period 1957 through 1960 was supported by the Florida State Board of Conservation. Tables of hydrographic data (Tabb, Dubrow and Manning, 1959; Tabb and Dubrow, 1962), and an annotated checklist of the organisms encountered have been published (Tabb and Manning, 1961). Another paper (Tabb, Dubrow and Manning, 1962) included a description of the ecological communities of brackish and inshore marine waters of the area in relation to water depth, bottom type, and periodic fluctuations of salinity, temperature, dissolved oxygen, pH, and turbidity. During the past two and a half years, greatly expanded investigations have been conducted of the quantitative ecology of coastal waters of the Park in the region extending from the Florida Keys to the Chatham River in the 10,000 Islands. This work, supported by the U.S. Public Health Service, Division of Water Supply and Pollution Control, is designed to determine the role of fresh-water runoff in altering salinity and, thereby, the plant and animal composition. Particular emphasis has been placed on the problems of Everglades National Park, and results of the study should assist us in our efforts to determine the quantity and pattern of flow of fresh water required to maintain desirable ecological conditions in the estuaries of the Park. A new investigation, designed to determine the kinds of fish that inhabit the complex marsh environment of the Park, was initiated recently by the Institute of Marine Science. This study is supported by the U.S. Bureau of Sport Fisheries and Wildlife.		

	RSP	Rel. RSPs
Thus, eventually, almost the whole extent of the Everglades estuary system will have had a reasonably intensive ecological survey. These investigations doubtless will disclose further avenues of productive research in estuarine ecology and should provide some of the information needed for understanding the problems associated with Park waters. Such understanding clearly is necessary for the development of suitable management of the Park water budget, and for maintenance of the fish populations resident in the estuarine and adjacent marine waters. RESEARCH NEEDED: The types of estuarine research described above must be intensified and expanded to cover as many facets of the marine-estuarine-fresh-water interrelationships as possible and, thus, provide for clearer interpretation and effective management of these complex communities. Very high priority. PROBLEM: A major value of estuaries is their role as a refuge from oceanic predators as well as providing favorable growing conditions for younger life history stages of many animals which, as adults, are chiefly marine. Some of the species concerned support or are primary constituents of fisheries of major economic importance. It is imperative that the identity, distribution, food and habitat requirements, and other ecological features of all larval, juvenile and adult animals utilizing the Park estuaries be investigated exhaustively in order to provide for full understanding of the biological role played by these bodies of water. RESEARCH NEEDED: Research conducted in the Park by the Institute of Marine Science, University of Miami, and by Costello and others of the U.S. Bureau of Commercial Fisheries provided an elegant demonstration of this dependence when numbers of pink shrimp marked in the Everglades estuary as juveniles were recovered from commercial catches on the grounds off Dry Tortugas.		

	RSP	Rel. RSPs
Additional investigations of the movement of juvenile and larval pink shrimp are being pursued by the Institute of Marine Science, University of Miami, and by the U.S. Bureau of Commercial Fisheries. The Institute of Marine Science is analyzing the overall movement of aquatic organisms to and from interior estuarine waters of the Park via Buttonwood Canal. A study by the Florida State Board of Conservation of the occurrence and movement of larval and post-larval stages of the spiny lobster recently was extended to the Flamingo area. Tabb (1963: 90-92) presents a project outline for more intensive study of the biology of the juvenile pink shrimp in estuarine sections of the Park. Research of this kind on this species and others should be assigned a high priority, because demonstration of the critical dependence of commercial fisheries upon undisturbed estuarine conditions may be the most telling economic argument for maintenance of an unrestricted flow of fresh water across the Park. Any knowledge that will help to extend, refine, or quantify the relationship of juvenile marine organisms to diluted waters in the Everglades estuary has particular importance, especially during the next few years when ultimate control measures and schedules of allotment of fresh water in the southern Everglades are likely to be determined. <u>PROBLEM:</u> Northeastern and central portions of Florida Bay are well isolated from the influence of periodic tides and receive fresh-water inflow from a limited drainage area that may be directly threatened by salt water intrusion from the Aerojet Canal (C-111) unless suitable control structures are installed. Hypersalinity, ranging up to twice that of standard sea water and nearing the tolerance limits of many marine animals, has been recorded frequently during drought periods. This part of Florida Bay supports all Park crocodiles, all nesting reddish egrets and roseate spoonbills, important sport and commercial fisheries, and it is		

on the ingress-egress route of juvenile pink shrimp using the Everglades estuary. Thus, the extreme importance of preventing toxic hypersalinities in these waters seems quite obvious.

RESEARCH NEEDED: Wind patterns and intensities as well as evaporation rates play unusually important roles with fresh-water supply in controlling degree of circulation and levels of salinity in Florida Bay. Therefore, synoptic data gathering should be undertaken at all major inlets to the Bay system. The data collected should include wind direction and velocity, evaporation, tidal exchange, variations in water height, and mass transport studies of various major tidal inlets to the Bay on the east, south and west.

At the same time, detailed rainfall records need to be maintained for the entire watershed as well as for the Bay itself. The necessity for continuous data monitoring cannot be overemphasized because rapid, short-term changes in water movement and depth, superimposed on the seasonal rise and fall of sea level, can be expected to produce significant developments. Very high priority.

PROBLEM: Everglades National Park was established to preserve part of the subtropical flora and fauna of the Florida Everglades and to provide recreation for the American public. One of the most popular attractions of the Park is the variety and excellence of its sport fishing. Sport fishing in the Park from the Florida Keys, Flamingo, and Gulf Coast entry points near the Park (Chokoloskee, Everglades, Marco, Naples) has increased rapidly.

Agreements reached at the time the Park was established commit NPS to permit commercial fishing "on a sustained-yield basis." A commercial fishery for various fin fish (mainly enterprises of long standing) persists in Florida Bay and along the Gulf

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	RSP	Rel. RSPs
Coast. In recent years, a rapidly growing stone crab fishery has been established in Park waters. Because sport fishermen exploit many of the same species that are important in the commercial catch, the existence of this substantial resource is threatened by our rapidly rising human population. In the near future the Park will contain one of the few undisturbed inshore-fish habitats in the country and the resource will have to sustain an exceedingly heavy and increasing fishing pressure. Consideration of this and other mushrooming problems led the National Park Service to contract with the Institute of Marine Science in 1958 for a continuing study of the status of game fish stocks as reflected by catch per unit of effort records. The funds provided were inadequate to support anything more than a study of the sport fishing effort that originated from Flamingo. While a recent change to more advanced methods of data processing has helped to a degree, even the size of the sample of Flamingo sport fishermen contacted has been near the minimum necessary for reasonable statistical reliability. Detailed studies of several species of marine game fish have been carried out in association with the project, mainly as advanced degree research problems by graduate students at the Institute. These have provided information on the local populations of redfish, sea trout, and mangrove snapper. A detailed life history study of the tarpon, now in progress, has included considerable research in the Park. The data available from the fishing effort study demonstrate that the number of anglers at Flamingo has increased by 46% during the period of the investigation and the catch has more than doubled since 1958-59. The ability of the fishery stocks to maintain themselves in the face of such pressure is a question which the National Park Service must explore		

	RSP	Rel. RSPs
at once for such increase in harvest may result in serious depletion of the resource.		
Another and perhaps more immediate threat to the Park fish stocks is associated with the overall requirement for fresh water. Some 45 species of fish are caught by Park anglers. The area is sometimes said to be one of the richest fishing grounds in the State because of its estuarine character, which provides food, shelter, spawning and nursery areas for many species. Changes in the estuarine environment caused by reduced supplies of fresh water may be critical for the continued existence of these fish populations.		
To accomplish the difficult task of balancing "reasonable use" with safeguarding the resource, the Park Service must have up-to-date information on the status of the resource and on the response of the fish populations to harvesting pressure and habitat alteration. Such items of information as reproductive potential, spawning requirements and behavior, age distribution, growth rates, food habits and requirements, mortality rates, longevity, limits of tolerance to environmental influences, and other biological characteristics of the fish populations serve as bases for monitoring the welfare of the stocks. When combined with catch per unit of effort statistics, these data provide measures of the relative abundance or availability and the reaction of the stocks to fishing pressure. The optimum situation exists when the catch consists of healthy, rapidly growing fish of acceptable size whose rate of capture does not exceed recruitment to the population over the same period of time.		
<u>RESEARCH NEEDED:</u> Present investigations should be expanded to include more adequate coverage of estuarine and marine sport fishing catch statistics in the Park from points other than Flamingo. Data on commercial fishing for shellfish should be secured as well. In addition, provision needs to be made for the collection of basic biological data from the fish		

	RSP	Rel. RSPs
populations concerned (e.g., food, age, size at maturity, spawning period), and for analysis of the roles played by local as well as extra-Park production in maintaining the levels of the Park populations. The biology of the stone crab, for which the Park now has a major fishery, was virtually unknown until rather recently when an Institute of Marine Science study began to yield results. Research on the Park's sport and commercial fisheries has high priority and should be intensified. <u>PROBLEM:</u> Dense beds of several important marine flowering plants, especially turtlegrass, occur in the shallow, inshore, marine waters of Florida Bay and in some interior estuarine habitats. The sea grass beds are grazed by manatees and some sea turtles, they are important in stabilizing bottom sediments, and they shelter a variety of small animal life. Indeed, these <u>Thalassia</u> beds in themselves constitute ecosystems which require substantial study and understanding. <u>RESEARCH NEEDED:</u> Considerable fundamental information about sea grass and its animal inhabitants in the Flamingo area is available from the work of Tabb and his associates, but the probable importance of this specialized habitat amply justifies even more detailed study. A U.S. Public Health Service investigation now in progress should contribute further information. Dr. Donald Moore of the Institute of Marine Science is presently engaged in intensive studies of the sea grass ecosystem in Biscayne Bay. Extension of this research to the Park is highly desirable. Among additional investigations which should be undertaken on sea plants in Park waters is that concerned with the rate of recolonization of sea grasses in areas where the bottom has been scoured by outboard motor traffic. High priority.		

	RSP	Rel. RSPs
PROBLEM: The Cape Sable area of Everglades National Park is an "island" of higher ground cut off from the main body of the Park by the Shark River and the Whitewater Bay-Coot Bay estuarine complex. Aquatic habitats of the Cape Sable hinterlands include a number of lakes, seasonal ponds, and shallow, flooded mudflats where large numbers and numerous species of water birds feed. Three canals dug in about 1922 to connect the complex of shallow brackish ponds and marshes on the south edge of the Cape with the Gulf of Mexico, apparently opened new areas not previously occupied by certain of the estuarine animals. Commercial fishermen reported good catches of shrimp and certain commercial fish in or near these canals. The canals were closed with earth dams shortly after the establishment of Everglades National Park but the closures are only partially effective because periodic high tides and storm tides force sea water into the canals behind the dams. Such periodic inundations probably transport the young of many estuarine species into the small ponds and account for the presence of animals, such as blue crabs, tarpon, ladyfish, red drum and black drum, which cannot spawn in this kind of habitat. Because there is at least periodic flooding with sea water and no discernible steady flow of fresh water into these ponds, they will likely remain brackish. One of them, Bear Lake, was said to be too salty for human consumption before the canals were constructed. Recent measurements revealed about 20⁰/oo of salinity in the canals on the inland side of the earthen plugs and nearly oceanic levels of salinity on the seaward side. Existing salinities are too great for strictly fresh-water organisms and the dams somewhat restrict marine and estuarine animals from utilizing the area as a nursery and feeding ground. Consequently, the ponds are largely unused and relatively unproductive for both marine and fresh-water organisms.		

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It might be argued that if the young of the estuarine animals had easier access to the ponds, much larger populations of important marine game fish and commercial animals such as shrimp and crabs might be supported. However, any alteration to make this possible could constitute a further deviation from original natural conditions. Alteration of an area simply to increase its game fish production hardly appears compatible with the Service's management objectives for a National Park. Present dams might be rendered more effective if backed up by additional inshore plugs. The problem appears to warrant further consideration. <u>RESEARCH NEEDED:</u> Even if we could demonstrate that Cape Sable is hydrologically separated from the main drainage of the Park (not yet proven), a much better understanding of the likely biological consequences would be required before any further man-caused changes toward greater salinity can be justified. Two of the most urgently needed basic studies are: 1. A topographic-hydrographic survey of the Cape Sable area to determine what connections, if any, exist between the waters of Whitewater Bay, Coot Bay, western Shark River and the shallow ponds behind Cape Sable. In addition, this survey should attempt to determine where, when and how much sea water enters these ponds despite the earthen plugs in the canals and whether or not there is actually a loss of fresh water from the Park via these routes. If so, how much. 2. A qualitative study of the area to determine the benthic and limnetic fauna present and to develop more suitable techniques for quantitative sampling of these environments. Quantitative sampling should start as soon as the methods are developed and be continued at periodic intervals for at least several years to permit an understanding of population changes in relation to "normal" conditions of the environment and, more important, to natural		

	RSP	Rel. RSPs
extremes of such conditions. Observations of environmental conditions should include those of water and air temperature, salinity, substrate type, vegetative cover, water depth, turbidity, dissolved O ₂ , etc. Analyses of these data should permit understanding of the role of the dammed canals in the biology of the Cape Sable ponds. High priority.		

Fresh Water

Given impetus by the rapid escalation of the Park's "water problem" in recent years, several studies of the ecology of Everglades marshes are underway and detailed proposals have been presented for additional investigations. The primary orientation of the work in progress and proposed is toward an understanding of: (1) the biological productivity of marshes in relation to given quantities of fresh water; (2) the reaction of the aquatic fauna and flora of Everglades marshes to drought stress and the time required for substantial recovery of populations when water again becomes available following extended drought; (3) the ecological effects likely to obtain if water from supplemental sources is used as partial replacement for the reduced overland flow of fresh water from the northern Everglades.

The importance of these studies can scarcely be overstated for they contribute to definition of the ecological conditions necessary for survival of the Park biota. It should be recognized that quantitative ecological research has come very late to the Everglades. Investigators face the task of determining critical limits of fluctuation in environmental factors and of the response by aquatic animal and plant populations in a complex ecosystem, already much modified, where wide ranges of seasonal and year-to-year fluctuation are normal. In the present authentic water crisis, the temptation to seize upon early findings for administrative use is strong. The temptation need not be resisted as long as administrators recognize the difference between preliminary indications and definite conclusions.

A greater danger, perhaps, is that the currently obvious necessity for ecological research may be forgotten once an administratively satisfactory solution to the immediate problem of fresh-water supply is negotiated. It is unrealistic to expect ecological research to generate reliable results overnight in this situation.

A great deal of research needs to be completed. The program should be regarded as continuing indefinitely because, irrespective of what agreements are reached, water is the critical factor in the well-being of this Park and the problem is here to stay.

Biological Productivity

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PROBLEM: As suggested above, the water-animal and plant relationship reaches to the heart of the biotic survival problem in Everglades National Park. Until it is known how the living components of the Park respond to various conditions of fresh-water supply, the Park management is not in a position to make sound decisions relative to the measures required to promote the welfare of these organisms. RESEARCH NEEDED: Biological productivity in relation to hydrologic conditions is the central study in the program of ecological research being conducted for the National Park Service by the U.S. Geological Survey. Aquatic environments selected for intensive study of changes in biological populations are the fresh-water glades, alligator holes, and the brackish, transitional zone between fresh and marine waters. Field work began in 1965. The objective of the research in progress is to describe and define the basic biological communities in the fresh and brackish waters in relation to hydroperiod, water depth, salinity and other chemical and physical characteristics of the water. Special traps have been designed to collect quantitative samples of the biota. Data from research of this quantitative nature will have particular importance when ultimate control measure and schedules of fresh-water releases into the Park are being determined. This kind of research must be intensified far beyond that now in progress. Very high priority.	NW-3	

Drought Reactions	RSP	Rel. RSPs
PROBLEM: Many aquatic and semiaquatic animals and plants have developed adaptations which facilitate survival during periods when their normal habitat is in various stages of desiccation. It is imperative that we know what effect droughts of unusual duration or frequency will have on the residual individuals that ordinarily repopulate the glades when water again reaches the levels normal for the wet season. Work which relates to some of these questions is in progress as part of the USGS ecological research program. RESEARCH NEEDED: This study of survival mechanisms and rate of population recovery should be expanded. A comprehensive study of adaptation to drought and resulting desiccation involves aspects of physiology, animal behavior, and hydrology with emphasis on water quality. A more extensive study aimed at determining the various types of drought refugia and their distribution over the glades at large is desirable. The drought resistance of a few grasses was studied as early as 1827 by de Saussure, but the literature on the desiccation resistance of plants in general is scanty. The botanical aspect of this problem is closely related to research needed on the dynamics of plant cover in the Park area, as previously discussed under Succession Dynamics in this chapter. Particular attention should be directed to the species survival role of burrowing animals in soils, limestone solution cavities, and burn-out ponds in peat. The microenvironments of these different types of refugia need to be analyzed in relation to tolerances of the animals concerned. Very high priority.	NW-9	

Supplemental Water	RSP	Rel. RSPs
PROBLEM: The use of mineralized artesian water from the Floridian aquifer as a localized, supplementary water source in the Park has been suggested frequently. Particular attention to the water need is focused on the pools and ponds at the Royal Palm visitor area, where considerable numbers of fish have died in recent years. The potential use of this water will be dependent upon the effect of its high mineral content on the biota and upon drilling costs in relation to the quantity of water produced. RESEARCH NEEDED: A test well has been drilled to the Floridian aquifer at a depth of 1,300 feet near the Anhinga Trail as part of the ecological research program of the U.S. Geological Survey. Laboratory and field studies are in progress to determine whether the indigenous fresh-water plants and animals can adjust to the salt content of this water (2,900 parts per million chlorinity), to the potentially toxic effects of a few heavy metals that are present, and to the relatively low dissolved oxygen content of the artesian water. The findings of the investigation will be helpful in determining the feasibility of using artesian water to supplement the normal fresh-water supply. High priority. PROBLEM: Several years ago the National Park Service rejected a suggestion that treated effluent from a sewage treatment plant, proposed for location in the southwestern part of Dade County, be discharged into the Shark River Slough as a supplement to the fresh-water supply. Although the rejection was based on competent technical advice, the issue is still alive. It is almost certain that the southeast coast urban area eventually will find it necessary to discharge treated effluent to the interior for ground water recharge, rather than to the sea as at present. Indeed, Gilson (1963) predicts that the amount of effluent available by 1980 will be 430,000 acre feet, which is only a little less than the average	NW-1	

measured flow of fresh water through the eastern 43 miles of the Tamiami Trail during the period 1941-57.

Although such quantities of fresh water might approximate the Park's needs and serve two important functions, treated effluent will markedly increase the nutrient levels over very wide areas of the Park, including the estuaries, and may cause significant and most undesirable changes in floral and faunal characteristics.

RESEARCH NEEDED: It is clearly in the general interest of the Park to support all water-conserving measures consistent with the basic philosophy which governs protection of the resource. However, the actual suitability of "used" water supplies, in terms of their effects on the Park environment, can only be determined by research.

In anticipation of the urgent need to discover the ecological effects of such use of sewage effluent, the Institute of Marine Science has submitted a proposal to the U.S. Public Health Service requesting funds to develop basic data on the problems involved. This work has very high priority.

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Terrestrial

Invertebrates

Information on nonaquatic invertebrates has accumulated slowly as specialists in various groups have assembled and identified specimen collections from the Park. Except for the larger land mollusca, the more conspicuous insects, and a few economically important or health related groups, such as mosquitoes, there is still much to be done before the faunistic inventory of the Park can be considered adequate.

At one time, entomologists of the Florida State Plant Board indicated an interest in carrying out a survey of the insects and other terrestrial arthropods in the Park similar to work they did at Fort Jefferson National Monument. The present status of this proposal is not known. It would seem desirable for the Park to contact the entomologists involved and encourage them to conduct the survey if they are still interested. In this same connection, the Park should establish and/or maintain working relationships with Dr. Maurice Provost and other scientists at the excellent Entomological Research Center of the Florida State Board of Health, Vero Beach. Dr. Provost heads a very fine staff of scientists skilled in various aspects of entomology and in related disciplines. Their participation in Park-based research should be encouraged.

PROBLEM: Because their habitat outside the Park has been largely obliterated, any further research on the natural history of the unique Liguus tree snails and on the problems of shell color pattern inheritance posed by the more than 50 named forms, will of necessity have to be done in the Park.

For the past several years, Park Ranger Erwin C. Winte, National Park Service Collaborator Archie Jones, and others have worked on a program which involves the reestablishment of populations of rare or nearly extinct color forms of Liguus at safe locations within the Park. Dr. Frank Young, Indiana University, an authority on these animals, has been a consultant on the work. Most of the reestablishment

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of rare color forms has now been completed successfully. Several major collections of shells have been donated to the Park.

RESEARCH NEEDED: These donations of living and preserved material provide the Park with the opportunity and, in a sense, the obligation to undertake studies that will improve the protection and interpretation of Liguus. So far, the work has been accomplished mainly through the donated personal services of the investigators and with substantial outlay of their personal funds. The National Park Service contribution has consisted largely of some assistance with transportation within the Park. The intent of the investigators is to undertake more concerted field studies of the genetical inheritance of the various color characters of Liguus, and of the life history of these snails. This phase of the work will be greatly enhanced if the Service can provide modest funds to permit closer cooperation by Dr. Young. Study projects involving rare or vanishing species such as these have very high priority.

Amphibians and Reptiles

PROBLEM: A good summary of what is known about the distribution, morphological variation, and ecology of the amphibians and reptiles of southern Florida, including the Park, is contained in a recent publication by Duellman and Schwartz (1958).

The Park's herpetofauna probably is reasonably well known except for the possible occurrence of a few secretive or rare species. However, we have little detailed information about the ecology or abundance of the local populations. Studies by Ligas (In Fla. Game and Fresh Water Fish Comm., 1960; Ligas, 1963) of commercially exploited southern bullfrogs in Conservation Areas 2 and 3 seem to be the only thorough life history investigations of an amphibian or reptile population in an Everglades setting.

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RESEARCH NEEDED: Similar research is greatly needed on the ecology of populations of other species, especially some of the smaller forms (green tree frog, Anole, box turtle) that are sufficiently abundant to have an important role in food chains.		
PROBLEM: The American crocodile occurs in the U.S. only in southern Florida. During the present century its numbers have diminished steadily under the pressures of land development and its range is limited now to the extreme southeastern mainland of Florida, eastern Florida Bay and some of the Florida Keys. The larger part of the present known range lies within Everglades National Park. Moore (1953a) summarized the little that is known about the species in Florida. There is an impression that the crocodile population in the Park may have declined in recent years despite protection. The impression may be groundless because crocodiles are not easily observed and reports of Park field personnel contain relatively few data of significance. Nonetheless, the possibility of losing the American crocodile is too great to permit the luxury of guessing what its status might be. Only concerted field studies can determine accurately the present status of this rare and threatened species, and provide the biological information upon which assured preservation measures can be based. RESEARCH NEEDED: Intensive efforts must be initiated to learn in as much detail as possible: the present population size and trend, geographical and ecological range, life history, reproductive rate, limits of tolerance to temperature and salinity change, food requirements, response to increased disturbance by human visitors, and significant aspects of behavior of the American crocodile in southern Florida, especially in Everglades National Park. Systematic field studies should include the capture, marking and recapture of individuals for	N-1	

	RSP	Rel. RSPs
study of movement, mortality, and population turn-over--provided suitable immobilization and marking techniques can be devised. Such investigations need to be supplemented, if possible, by observations of social behavior, food preferences, food requirements, temperature requirements and reproductive behavior of mature male and female crocodiles held in captivity. It is also desirable to study in detail the food requirements and growth of young crocodiles in captivity. Among other aspects, this phase of study should undertake to determine the age and size at which young crocodiles are most suitable for release to restock depleted range. There is little reason to doubt that much of the available crocodile habitat is understocked at present. Thus, restocking appears desirable provided healthy stock of Florida origin can be obtained. Such animals, before release, could be utilized for the previously suggested studies of captive young crocodiles. All crocodiles released should be marked for future recognition, and their fortunes in the wild followed as closely as possible. Mr. William Piper, Everglades Wonder Gardens, Bonita Springs, Florida, is keenly interested in the conservation of this species. He has a number of Florida crocodiles, some of which have nested in captivity. Enlistment of Mr. Piper's interest and support will be of great help to crocodile research and management. Crocodile investigations have a high priority. <u>PROBLEM:</u> The general biology and life cycle of alligators in the Everglades is known in broad outline, but reliable population data are few. In 1965, the Florida Game and Fresh Water Fish Commission began a population study of alligators in the Conservation Areas which will include observations in the vicinity of the Shark Valley Road in the Park. This investigation should yield information applicable to the Park alligators of the Shark River Slough; it may		

	RSP	Rel. RSPs
also develop techniques of immobilization and marking that will be useful in other Park studies of alligators and crocodiles. RESEARCH NEEDED: Investigations of alligator populations in other environmental situations within the Park are needed to supplement the State studies. The work should concentrate on populations in habitats differing from the central Everglades sloughs, such as: the eroded rockland north of Long Pine Key; Taylor Slough (because of the particular interest attached to the alligator population of the Anhinga Trail-Royal Palm area); coastal sections, including both those where alligator and crocodile populations are in contact (Madeira Bay-Joe Bay hinterlands), and those where crocodiles are said to be exceedingly scarce or absent (Cape Sable, Whitewater Bay, Gulf Coast). Studies in areas which contain both alligators and crocodiles and in those marginal regions where crocodiles are present in much reduced numbers should seek to determine the nature and extent of competition between these two species of reptiles, particularly the possible role of alligators in limiting the range and abundance of crocodiles. Among the lines of study which should be pursued on alligators are: (1) an intensive program of marking and recapture (or reobservation) to establish seasonal movement, population structure, and mortality; (2) bioenergetics of growth in captive individuals; (3) physiological and behavioral adaptations to drought; (4) food requirements; (5) reproductive capacity; (6) rate of recovery of populations and reoccupation of restored habitats; and (7) territorialism. PROBLEM: Loggerhead turtles nest in some numbers on beaches of Everglades National Park. Records from Service field personnel provide rather good but general indications of the seasonal distribution of nesting activity. The records also suggest that successful nesting is rare in most areas because of heavy predation on the eggs by raccoons.		
	N-7 (N-14)	

	RSP	Rel. RSPs
A number of methods of reducing losses from predation, in addition to direct control of raccoons, have been suggested. Some reduction of the raccoon population was accomplished in the 1966 turtle nesting season with promising results. However, this technique and most of the other methods proposed require further testing.		
The outstanding possibilities for interpretation that the sea turtle story affords are largely unexploited at present.		
It is most necessary that we obtain additional information upon which more effective National Park Service trusteeship of this important and fascinating wildlife resource can be based.		
RESEARCH NEEDED: Research efforts should be initiated to determine: (1) which species of sea turtles nest in the Park and in what numbers; (2) the seasonal pattern of nesting; (3) the rate of nesting success in various localities and the main causes of nesting failure; and, (4) the feasibility of management and protection measures designed to improve the rate of nesting success.		
A tagging project of 3-6 years' duration is needed to analyze: (a) reproductive periodicities; (b) recruitment, migratory routes and schedules; and (c) population size, identities and distribution.		
Park Ranger Max Holden devoted considerable time to study of loggerheads nesting on the Cape Sable Beach during the nesting seasons of 1964 and 1965, conducted the previously mentioned followup studies of 1966, and made an excellent beginning on some of the points mentioned above.		
Any sea turtle study at Cape Sable should include close watch for nesting green turtles. About 6,600 hatchling green turtles were restocked in this area during 1963-65, but it remains to be seen whether or not animals so released will return to the vicinity		

	RSP	Rel. RSPs
of the release point to breed. The sea turtle studies have high priority.		
PROBLEM: The disjunct population of <u>Gopherus polyphemus</u> on Cape Sable was mentioned in Chapter II under Coastal Prairie. The scarcity of this species in the Park, and points of considerable scientific interest associated with the isolation of the population, make it an attractive and important subject for research.		
RESEARCH NEEDED: Studies of the general scope outlined for other reptile and amphibian populations should be undertaken emphasizing population size, reproductive success, movement, and mortality, particularly that associated with hurricanes.		
The fact that gopher turtles are localized in definite burrows offers possibilities for detailed investigation of movement and home range. In conjunction with the population studies, an effort should be made to clarify the history of this population as to whether it is indigenous or introduced.		
Aside from attempts to verify various reports of introduction, two approaches to the problem suggest themselves: (1) Establish the distribution of gopher turtles in relation to the available habitat (if, for example, the turtles are not found north of the Middle Cape Canal, the likelihood that the population results from a relatively recent introduction may be much increased); (2) Compare the burrow fauna of Cape Sable gophers with that found in more central areas of the range (Young and Goff, 1939). Presence of most of the gopher turtles' (central areas) array of commensal arthropods in burrows on Cape Sable would argue strongly that the Cape Sable gophers are a remnant of the natural population.		

Mammals

Southern Florida has only 30 or 35 species of native mammals. Some of these, such as the cottontail rabbit, gray squirrel, and wood rat, do not occur in the Park; others, including the striped skunk and black bear, are represented in the Park by very sparse populations.

Nearly all of the land mammals are familiar species widely distributed in the Southeast, or even more extensively in North America. Although the general biology of most of the species is well known, few have been studied in detail locally, or in habitats resembling those they occupy in southern Florida. Exceptions are the fox squirrel (Moore, 1956, 1957), the white-tailed deer (Loveless, 1959b; Loveless and Ligas, 1959), and the round-tailed muskrat (Birkenholz, 1963).

Three Park mammals--the mangrove fox squirrel, manatee, and Florida panther--are properly considered rare and endangered species (subspecies, in the case of the squirrel). The fox squirrel has been studied in some detail; the manatee and panther have been proposed for study but their rarity and elusive habits make them difficult research subjects. Park field personnel should give special attention to recording carefully all observations of these three species.

The roof rat is the only nonnative mammal that is known to be well established in the Park but it does not appear to pose a special problem. A population of nine-banded armadillos, established when the animals escaped from captivity, now has an extensive range in central and south Florida and several have been found in the Park.

Populations of feral pigs exist in Conservation Area 3 and elsewhere north and west of the Park. These are hunted but the population is supplemented through restocking by the State as well as by hunters' organizations. Individuals occasionally range into the Park. Both armadillos and pigs are likely to be destructive to native biota and should not be permitted to become established in the Park.

Population studies of several of the more common carnivores, the marsh rabbit, and the small mammal fauna (shrews and rodents) have also been proposed.

	RSP	Rel. RSPs
PROBLEM: Although stable, if rather small, populations of manatees can still be found at several places in Florida outside the Park, the future of these populations is at best uncertain. Throughout its wide range along the coast of tropical America, the manatee is hunted so intensively for its meat that it has become a rare species almost everywhere. The Park seems ideally suited for long-range and definitive life history research on this interesting mammal. Indeed, such research is required to serve as a basis for optimum management, as well as interpretation, of the relatively small population of manatees found in the Park. RESEARCH NEEDED: Because of the difficulty of observing manatees in the wild and the current necessity to devise effective study techniques by trial-and-error, it has been suggested that the best approach to this problem might be a long-term investigation with a relatively low annual input of funds and effort and, perhaps, carried out by a biologist in residence. However, in view of the uncertainty surrounding the future of these animals, it might be better to establish a more comprehensive and accelerated research program. Published studies of southern Florida manatees by Moore (1951a, 1951b, 1953b, 1958) should be helpful in developing a program of manatee studies. The studies should seek to find out as much as possible about the number and distribution of manatees in the Park, the trend of manatee populations, the limits of tolerance to environmental factors, and the life history of the species. Studies of captives in an impoundment may be the only approach to some aspects of the investigations. The potential value of manatees as a natural control of water hyacinth and other troublesome aquatic plants provides a utilitarian purpose for the study. High priority.		

	RSP	Rel. RSPs
PROBLEM: The Florida panther population presents difficulties similar to those of the manatee in that individuals of the species are rare and difficult to observe. In addition, they range widely, further complicating the study. Again, although it has been suggested that a long-term study should be undertaken by a staff biologist who is on the ground and able to take advantage of special research opportunities as they occur, a more accelerated program to determine the panther's environmental requirements might be more desirable because of the animals' scarcity. The last stand of this wilderness species in the Eastern United States is in Florida, and, within Florida, the panther has few, if any, assured refuges except the Park. Study of its numbers and needs thus is very much a National Park Service responsibility. RESEARCH NEEDED: Particularly needed are studies designed to determine the number of panthers in the Park, the life history in as much detail as possible, the relations between the panther and populations of major prey species, and the extent and significance of their disturbance by man. Data on movement and home range are of critical importance. It is vital to establish to what extent panthers from the resident population range outside the Park. The most productive approach to study of movement doubtless is by radio-tracking of instrumented animals. However, suitable means of capturing and immobilizing panthers must be devised before such techniques can be utilized. High priority. PROBLEM: As indicated earlier, raccoons are serious predators on the eggs of sea turtles that nest at Cape Sable and, probably, other mainland beaches. At times, the raccoons have done considerable predatory damage to wading bird rookeries as well. Finally, inasmuch as these abundant animals frequent areas of heavy public use wherever food is easily found, such as in the vicinity of garbage cans and picnic tables,		

there is considerable concern that visitors may be bitten by rabid raccoons.

More information is needed on all aspects of the population biology of raccoons in the Park.

RESEARCH NEEDED: Investigations are required to establish the range of raccoons over the Park, particularly as related to the distribution of nesting wading birds and sea turtles. Raccoon distribution on the Florida Bay keys and on islands off the Gulf Coast is of equal concern.

Utilizing large-scale trapping and marking exercises (perhaps including use of radiotelemetry techniques), concerted efforts should be made to determine the abundance, mortality, behavior, age-sex structure, and individual and seasonal movements, for raccoon populations in various parts of the Park. Specimens should be collected, as well, for study of food habits and parasites, and to determine whether and to what extent a reservoir of rabies infection exists in the Park population. Those parts of the study concerned with raccoon damage to nests of sea turtles and the incidence of rabid raccoons have very high priority.

PROBLEM: The otter is one of the Park's most interesting mammals and the local population seems to undergo large fluctuations in more or less direct relation to general water levels in the interior Everglades. The population evidently reached a low during the 1961-62 drought and has shown little sign of recovery since then. Some of the fresh-water fish species on which it preys have shown a similar population depression.

RESEARCH NEEDED: Aims and methods of the study should be somewhat similar to those of the proposed raccoon investigations, except that collection of specimens for study of food habits is not advisable at the present low population level. Predation upon otters

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RSPs

	RSP	Rel. RSPs
by alligators in times of extreme drought should be investigated as a potentially significant mortality factor. High priority. <u>PROBLEM:</u> Both bobcats and marsh rabbits are common enough throughout the Park to be of considerable importance in food chains, but almost nothing is known in any detail about the populations of either species. <u>RESEARCH NEEDED:</u> The approach to an understanding of both the bobcat and the marsh rabbit populations is likely to be similar to that proposed for the raccoon study--determination of range, abundance, mortality, population structure, movement, and life history, including study of food habits and parasites of the animals in various sections of the Park. A major part of each operation would be that of trapping, marking, and recapturing (or reobserving) the animals. In the marsh rabbit study, special attention should be directed to investigations of geographic distribution, rate of occurrence, and mode of inheritance of a phenotype (or types?) with melanistic pelage which occurs in parts of the Park. Finally, the studies should include analyses of the interactions of the bobcat and marsh rabbit populations. How does population size, trend and distribution of one species influence, or become influenced by, population characteristics of the other? <u>PROBLEM:</u> Surprisingly, a single unpublished master's thesis (Opsahl, 1951) seems to contain the only quantitative data that are available on the abundance of small mammals in southern Florida. The importance of rodent populations in food chains and as a sylvatic reservoir for certain viruses makes it highly desirable to learn more about these populations in the Park.		

	RSP	Rel. RSPs
RESEARCH NEEDED: Population density of rodents and shrews needs to be investigated systematically in major habitats of the Park. Standard techniques have been developed for quantitative studies of small mammals but field-testing of the techniques undoubtedly will be needed to determine the methods best suited to local conditions. Comparative study of techniques in itself provides opportunities for interesting theoretical contributions. An investigation of small mammal populations in Park pinelands, as related to removal of the understory by fire, has been proposed under the expanded controlled burning study. The U.S. Public Health Service has made a limited study of the small mammal populations of Park hammocks in connection with its investigations of endemic foci of the Venezuelan encephalitis virus (VEE). The presently recommended research should be closely coordinated with all such studies in progress.		

Birds

The conspicuous, rare, and interesting birdlife of the area is one of the features of greatest interest to visitors and perhaps the most important single reason for preservation of the Park. Included in the Park avifauna are a number of threatened species that have disappeared elsewhere. Many features of the birdlife seem to have a particularly close dependence upon the general ecological state of the area.

Rookery success or failure is one of the main yardsticks by which the success or failure of our approach to water management problems may be measured. These factors, plus continuing needs for bird interpretation of all sorts justify special research attention to this field. Although some work has been accomplished in certain phases of ornithological study, other much needed investigations have tended to lag or have been neglected altogether.

The lack of exhaustive analyses of the ecology of wading bird rookeries appears to constitute one of the major existing gaps in

the Park's program of ecological research focused on the problem of fresh-water supply and its relation to the welfare of the biota. Several of the other bird investigations identified in this chapter are in progress but are treated more briefly, with discussion being confined to mentioning their present status and any projected additional fieldwork.

PROBLEM: Despite the general interest they have attracted, and the amount published about them over the past 75 years, surprisingly little critical information is available on the ecological requirements of southern Florida's large wading birds. With a few notable exceptions, such as Allen's study of roseate spoonbills in Florida Bay in the late 1930's and Kahl's recent papers on Corkscrew Swamp wood ibis, the literature is mainly descriptive and anecdotal, sparsely peppered with details of qualitative natural history.

Considering the obvious importance of these populations to many phases of Park activities, and the fact that we have long known, in a general way, that breeding success of some species is closely related to the amount of fresh water available in the southern Everglades, it is rather remarkable that our store of information about these animals has improved so very little during National Park Service custodianship of the Park. Indeed, even the research effort currently being emphasized in the Park does not include a comprehensive study of wading birds. However, this deficiency has been the result of inadequate funding rather than the want for research proposals. Approximately half a dozen detailed outlines for research on wading birds have been prepared by Park personnel in recent years with little or no success in securing supporting funds.

RESEARCH NEEDED: Research on wading birds should define for all important species: (1) their abundance and population trends; (2) the principal nesting and roosting aggregations, and the feeding grounds of each such aggregation; (3) qualitative and quantitative feeding habits and requirements

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	RSP	Rel. RSPs
throughout the annual cycle, including the relation of breeding success to food quality and availability; (4) the local and seasonal movement of populations that are resident in or enter the Park; and (5) the age-structure and reproductive capacity of the different populations. Because wading birds are the major end consumers of Everglades marsh and estuarine food chains, close liaison should be established between investigators involved in the present study and those active in the Aquatic Biology studies. It is highly desirable that some study sites for the Aquatic Biology projects be located in areas where wading birds from rookeries feed. To a certain extent, the most needed data are those revealing the annual production which reaches levels usable by wading birds and available to them in proper season and in sufficiently close proximity to support successful nesting on the traditional breeding sites. The year-to-year variation in this effective biological production in relation to water supply and other environmental variables is of equal importance. It is clear that only well-supported and vigorous research efforts continued over a period of years can provide the information needed for intelligent protection of this immensely valuable wildlife resource. In the southern Florida of a generation hence, the "leave 'em alone and hope for the best" scheme of population management-protection pursued until now will have been revealed as tragically inadequate. Research postponed until the resource is seriously deteriorated may be much too late for effective application. Even now there may not be enough time to acquire, for wading bird populations and other elements of the Park's complex ecosystems, the knowledge that will permit us to define their needs precisely and take the remedial steps necessary to assure their continued survival amidst the wreckage of man's treatment of his environment.		

	RSP	Rel. RSPs
Of all the wading birds, the wood ibis population appears to be in the most precarious condition at this time. Substantial effort has been devoted to a study of recent population trends of this species. Work by Field Research Biologist Robertson was continued in the winter of 1965-66 in an attempt to locate feeding areas used by wood ibises of different rookeries, and to record the feeding efficiency of this and other wading birds in connection with modest efforts to manage the distribution of water within a restricted area of the Park. However, the magnitude of research effort possible from resources now available is very limited and should be greatly expanded. Very high priority. PROBLEM: Investigations of bald eagles by Field Research Biologist Robertson have continued since the nesting season of 1958-59 with the following principal findings: 1. The Park and its immediate environs support a breeding population of approximately 55 pairs of bald eagles, fewer than one-third of which were known when the study began. 2. The population is reproducing normally. Production over 7 seasons has not departed significantly from 50 percent of active sites being successful and 1.5 young fledged per successful site. Productivity data are available for virtually the entire population for the past 5 years. 3. Since the study period included both a severe hurricane (Donna, 1960) and years of extreme drought, it appears that, within wide limits, such environmental stress has only minor effects upon the productivity of this population. 4. An inverse relationship between productivity and population density has characterized the bald eagles of Florida Bay over the period of the study. Eagles in eastern Florida Bay, with 5 to 7 occupied	N-9	

	RSP	Rel. RSPs
sites in a land-water area of 162 square miles, produced an average of 1.17 fledged young per occupied site per year. In the area of most concentrated nesting in central and western Florida Bay, with 14 to 17 occupied sites in a land-water area of 117 square miles, production averaged 0.62 fledged young per occupied site per year. The population in each of the areas included both routinely successful and chronically unsuccessful pairs. 5. Contrary to established opinion prior to the study, most breeding adult bald eagles and many younger birds remain in southern Florida through the summer. 6. An inland roost regularly occupied by up to 50 subadult bald eagles was located in the Park. The roost was unknown prior to the study. The phenomenon of age-segregated roosts has not been reported for any other large raptorial bird. RESEARCH NEEDED: Two phases of this study need to be pursued as forcefully as possible: (1) Publication of the data thus far acquired. Because of acute concern about the recent decrease of the bald eagle over most of its breeding range elsewhere in the Nation, and the suspected involvement of pesticides in the breeding failures reported from many areas, a great amount of study of bald eagle biology is going on currently. Studies of the Park population have critical importance to much of the work in other areas, because the Park findings provide a measure of the normal productivity of a relatively undisturbed bald eagle population--data that now can be had from few other regions. Moreover, it should be recognized for this study and all other research in the Park, that expenditure of time and money on research may be somewhat wasted unless the results are made available to other workers in acceptable format within a reasonable time.		

	RSP	Rel. RSPs
(2) Additional studies identified as the result of bald eagle research accomplished to date, must be explored with substantial vigor. This is a second major responsibility normally accepted by anyone who undertakes research. In the case of the present work, the Service must initiate detailed field studies focused on eagle food habits, on the behavioral and ecological aspects of the previously mentioned roost of subadult bald eagles, and on the characteristics of territories and the behavior of particular pairs that have a long history of either success or failure in reproduction. Studies of individually marked eagles should be undertaken as soon as effective marking methods can be devised. This work will yield information on the extent of the breeding area from which the roosting population of subadults is drawn, and on the movement and feedback of subadults into an essentially stable breeding population. Owing to the bald eagles' status elsewhere on the East Coast as a rare and vanishing species, this project has very high priority. <u>PROBLEM:</u> The reddish egret survives in the Eastern United States only in southern Florida, chiefly in the Florida Bay section of Everglades National Park. It was abundant in Florida prior to the plume hunting of the late 1800's, and then decreased almost to the point of extinction. Although the remnant has been protected effectively since 1935, only limited response is evident and the present population numbers fewer than 300 individuals. Little detailed information on the species' environmental tolerances or requirements exists. Thus, the factors responsible for failure of the population to respond more vigorously to protection are unknown. <u>RESEARCH NEEDED:</u> Among the research required on this species is that designed to: (1) determine, for the population of reddish egrets now inhabiting Everglades National Park, the numbers, nesting dates and localities, breeding behavior, nesting success,		
	N-5	

	RSP	Rel. RSPs
seasonal movements, feeding ecology, and interactions with other species; (2) review and analyze all data pertinent to the past history of the species in Florida; and (3) gather additional data on the often-noted late summer influx of reddish egrets containing numerous white phase individuals of unknown, but probably extra-Floridian, origin. High priority. PROBLEM: Allen's 1942 study provides an excellent understanding of the basic life history and ecology of the roseate spoonbill in Florida Bay. Protection and management, based upon Allen's research, has brought about a more than tenfold increase in the breeding population to a present peak of 350 to 500 pairs of adults. Recently, some longstanding rookeries have been abandoned and a number of new nesting areas established. Reasons for these moves are not well understood, but it appears that encroachment of real estate developments upon feeding areas outside the Park may have been an important factor. A clearer understanding of present numbers and of the major feeding areas used by the different colonies is urgently needed. Another important gap in our current knowledge concerns the complex movements of roseate spoonbills in southern Florida. Adults nesting in Florida Bay are thought to come from and return to Cuba. Young birds raised in Florida Bay appear to disperse northward, but their later movements are not clearly understood. The origin of the adult and subadult spoonbills, 300-500 of which are regularly present along the southwest coast of Florida, and their relations, if any, to Florida Bay birds are not known. Effective conservation of the species in Florida requires a much better understanding of these population segments.	N-6	

	RSP	Rel. RSPs
<u>RESEARCH NEEDED:</u> This study should concentrate upon: (1) the ecology of spoonbills at their nesting keys in eastern Florida Bay, with particular emphasis on the availability and use of nesting and feeding areas; and (2) the movements and relationships of population segments of roseate spoonbills in southern Florida. High priority.		
<u>PROBLEM:</u> The great white heron is a relatively uncommon bird whose known breeding range is limited to the Florida Bay section of the Park and the Florida Keys. It hybridizes with local great blue herons, but the rate of occurrence of mixed pairs appears to be strongly nonrandom and the taxonomic status of the populations has not been conclusively determined.	N-12 N-13	
<u>RESEARCH NEEDED:</u> In cooperation with the U.S. Bureau of Sport Fisheries and Wildlife, Field Research Biologist Robertson has, for a number of years, made periodic aerial counts of great white herons throughout the known breeding range of the species. These data need to be assembled, analyzed, and the results published. Research effort should then be directed to more intensive field studies that bear directly upon the matter of white heron-blue heron interrelationships and the biological relationship between these and other aquatic birds of the Park. The great white heron is an endangered species and, thus, deserves very high priority research attention.		
<u>PROBLEM:</u> The Cape Sable sparrow, a resident of fresh and brackish water marshes in southwestern Florida is very rare and in danger of becoming extinct because its restricted habitat is subjected to severe disturbance from hurricanes, fire, drought, etc. Estimated numbers range from less than 500 to less than 1,000. Nearly the entire population is believed to be located within the confines of Everglades National Park or in areas immediately adjacent to the Park yet we know very little about the life history and requirements of these birds. Very high priority.		

	RSP	Rel. RSPs
The Park contains a number of other species of birds which require study in order to determine their role in the ecosystems of the Park. Many, such as the swallow-tailed kite, the short-tailed hawk, and the white-crowned pigeon, are poorly understood although the individuals inhabiting the Park are a substantial part of the U.S. population in each case. High priority. Additional strong candidates for thorough study are the brown pelican and osprey whose populations have declined precipitously in parts of their range in recent years. The Park populations of both species are sizeable and the decline in numbers elsewhere enhances the importance of the Everglades individuals in the overall efforts to preserve the species. Medium priority. <u>RESEARCH NEEDED:</u> Each of the species listed above needs to be subjected to exhaustive studies of its biology and population characteristics including: reproductive capacity and nesting behavior, mortality, distribution and territorialism, food habits and requirements, age-structure, limits of tolerance to temperature change, movement and migration, population trend, factors influencing rate of population fluctuation, cyclic phenomena, impact of disease and predation as population control factors, adaptation to drought, rate of population recovery in devastated areas, etc. Particular care must be taken to avoid damaging or destroying these scarce animals in marking-recovering activities and in only the species with populations of more adequate numbers should birds be sacrificed for food habit studies. Many of the investigations might better be undertaken in the laboratory rather than in the field. Indeed, in the case of the Cape Sable sparrow, the Service would be wise to establish and maintain colonies in captivity to provide a reservoir from which the wild populations can be reestablished in the event of natural catastrophe.		

	RSP	Rel. RSPs
PROBLEM: The existing references that summarize bird distribution in southern Florida are inadequate because a large amount of pertinent information--particularly that based upon collections and publications since 1930--has been overlooked or omitted. Consequently, the interpretation of many important aspects of the region's birdlife--for example, the apparent extension of ranges by some West Indian land birds in southern Florida, and withdrawal northward of some land birds that formerly nested in the area--has been hampered. RESEARCH NEEDED: The most suitable solution to this problem appears to be immediate completion of the recording, tabulation, and reexamination of the ornithological information that exists for the south Florida area and preparation of more adequate species accounts based upon a background of complete data. Much energy has been devoted by Field Research Biologist Robertson to assembling the data, but the research has lagged pending arrangements to follow through with necessary additional work in northern museums. This project is highly important to the Park interpretive program as well as to the field of ornithology.	N-8	

E. MANAGEMENT STUDIES

Park Staff Participation

The Park staff normally includes individuals with special training, talents, and interests in one or more of the natural science disciplines. While their primary functions may be those of Park Naturalist, Park Ranger, Engineer, Maintenance Man or comparable management category, they frequently desire an opportunity to utilize these special aptitudes and interests.

These people can contribute a great deal to the natural science studies program, and their participation should be encouraged. Documented observations, photographs, collection of other routine data, and specific short-term studies are among the types of responsibilities which they should be urged to undertake as part of their regular assignments. Indeed, these individuals should be given every incentive and assistance to undertake research of their own choosing during off-duty hours, as well. In addition to benefiting the natural sciences program, such activities would (1) enable the participants to maintain or enhance their proficiency in the area of their scientific speciality; (2) afford an outlet for special talents and interests; (3) develop a better understanding of resource management problems and the related capabilities of the natural science studies programs; and (4) improve working relationships between the researcher and the manager.

Maximum benefit will accrue to the Service and to the management participants through joint preparation of a research program by the participants and the coordinator of research for the Park. It is desirable but not mandatory that the investigations be coordinated with and designed to fill a need in the overall research program for the Park. A realistic appraisal should be made--before its inception--of the amount of duty time the participant can reasonably expect to devote to the Service-desired study to ensure that it can be successfully concluded. This will minimize undue pressures on the participant, as well as disappointment to all parties concerned.

Some investigations particularly suited to participation by qualified management personnel include:

Pesticide Residues

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PROBLEM: Plans for water control development in projects adjacent to the east boundary of the Park envision drainage discharge westward by pumps, particularly into the upper portion of Taylor Slough. Because much of the drainage concerned originates in areas of intensive agriculture where large quantities of various pesticides and herbicides are used, it is imperative to determine the degree of pollution of this water by the persistent chemical residues and its effects upon the Park biota.

RESEARCH NEEDED: We need to collect water samples from agricultural drainage in the South Dade and Southwest Dade areas on a basis that gives adequate areal and seasonal coverage; analyze the samples fully for residues of pesticidal chemicals such as DDT, dieldrin, heptachlor, etc., that are known to persist in natural systems and be concentrated upwards in food chains; and, at the same time, undertake a thorough sampling of habitats throughout the Park to establish the existing baseline of pollution by pesticide residues. The baseline data can then be used as a checkpoint against which increased pollution can be measured. This project has very high priority and is urgent.

Deer

PROBLEM: The white-tailed deer is the only large mammal that is relatively common in the Park and the only one often seen by visitors. Deer are subject to heavy hunting pressure on private lands within the Park and around its periphery. The experience of other National Park Service areas demonstrates that white-tailed deer, when largely relieved of natural predation, as is the case here, may quickly increase beyond the capacity of the range available to support them.

N-11

A prevailing opinion is that peripheral hunting pressure, plus the environmental stress imposed by

flooding, make overpopulation unlikely in Everglades National Park. However, this remains to be demonstrated because accurate and detailed information on the population dynamics of the Park deer herd is extremely limited. Conditions should be established for the acquisition of more reliable and comprehensive deer population and range data by National Park Service personnel in the area.

RESEARCH NEEDED: The research required includes:

(1) summary and analysis of existing records in Park wildlife observation files relative to the annual reproductive cycle and distribution of deer in the area; (2) establishment of a series of quarterly or more frequent air patrols for deer surveys, based on the technique successfully used by Loveless (1959b) in Conservation Area 3 adjacent to the Park; (3) development of a list of deer food plants from the data included in Park records, literature and field observations; and (4) on-site examination of areas of deer concentration to determine the general condition of forage and to check for signs of overbrowsing and disappearance of preferred food plants.

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Rel.
RSPs

THE BIBLIOGRAPHY

The following is a bibliography of over 500 titles covering natural sciences subjects for Everglades National Park and vicinity, and other pertinent areas or topics. The list is thought to be reasonably complete to April 1966.

As new bibliographic material becomes available, it should become a part of this listing. For this reason the bibliography should be updated periodically--perhaps each five years.

The six columns at the right of the list denote subject field, as follows:

- A - Geology and Soils
- B - Hydrology and Climate
- C - Vegetation
- D - Animal Life, Terrestrial
- E - Aquatic Biology
- F - General

Checkmarks in the appropriate columns denote the field or fields covered in the item.

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Abbott, R. T. 1954. AMERICAN SEASHELLS. D. Van Nostrand and Co., New York. 541 pp.					x	
Ahlgren, I. F. and C. E. Ahlgren. 1960. ECOLOGICAL EFFECTS OF FOREST FIRES. Bot. Review 26: 483-533.			x			
Alexander, T. R. 1953a. THE LARGEST MAHOGANY TREE. Ever. Nat. Hist. 1: 6-10.			x			
_____. 1953b. PLANT SUCCESSION ON KEY LARGO, FLORIDA, INVOLVING <u>PINUS CARIBAEA</u> AND <u>QUERCUS VIRGINIANA</u> . Quart. Jour. Fla. Acad. Sci. 16: 133-138.			x			
_____. 1955. OBSERVATIONS ON THE ECOLOGY OF THE LOW HAMMOCKS OF SOUTHERN FLORIDA. Quart. Jour. Fla. Acad. Sci. 18: 21-27.			x			
Allen, R. P. 1942. THE ROSEATE SPOONBILL. Natl. Aud. Soc. Research Report 2: 142 pp.				x		
_____. 1954. STATUS OF THE FLAMINGO IN FLORIDA. Ever. Nat. Hist. 2: 115-118.				x		
_____. 1954-1955. THE REDDISH EGRET: BIRD OF COLORS AND CONTRASTS. Aud. Mag. 56: 252-255; 57: 24-27.				x		
Allen, E. R. and W. Neill. 1949. INCREASING ABUNDANCE OF THE ALLIGATOR IN THE EASTERN PORTION OF ITS RANGE. Herpetologica 5: 109-112.				x		
_____ and _____. 1950. THE LIFE HISTORY OF THE EVERGLADES RAT SNAKE, <u>ELAPHE OBSOLETA ROSSALLENI</u> . Herpetologica 6: 109-112.				x		

	A Geol & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terr.	E Aquatic	F General
_____ and _____. 1953. THE TREE FROG, <u>HYLA SEPTENTRIONALIS</u> , IN FLORIDA. Copeia 1953: 127-128.				x		
_____ and D. Swindell. 1948. COTTONMOUTH MOCCASIN OF FLORIDA. Herpetologica 4: 1-16.				x		
Babbitt, L. H. and C. H. Babbitt. 1951. A HERPETOLOGICAL STUDY OF BURNED-OVER AREAS IN DADE COUNTY, FLORIDA. Copeia No. 1: 79.				x		
Bailey, H. H. 1924. THE ARMADILLO IN FLORIDA AND HOW IT REACHED THERE. Jour. Mammal. 5: 264-265.				x		
Bailey, R. M., et al. 1960. A LIST OF THE COMMON AND SCIENTIFIC NAMES OF FISHES FROM THE UNITED STATES AND CANADA. 2nd Edit. Amer. Fish Soc. Spec. Pub. No. 2 (Ann Arbor)				x	x	
Baker, J. H. 1943. TIME IS RUNNING OUT ON THE EVER- GLADES. Aud. Mag. 45(3): pp. 176-179.						x
Baker, M. F. 1955. FLORIDA WILD FLOWERS. (2nd printing, Rev. Ed.) Macmillan, N. Y. 245 pp.			x			
Baldwin, M. and H. W. Hawker. 1919. SOIL SURVEY OF THE FORT LAUDERDALE AREA, FLORIDA. U.S. Bureau Soils, Dept. Agric., Field Operations, during 1915: 751-798, pl. A and B (folded maps), 26-29, and large soil map.	x					
Barbour, T. 1923. THE CROCODILE IN FLORIDA. Occ. Papers Mus. Zool., Univ. of Mich. 131; 6 pp.				x		
_____. 1944. THE VANISHING EDEN, A NATURALIST'S FLORIDA. Little Brown and Co., Boston. 250 pp.						x

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Bayer, F. M. 1948. CHARLES T. SIMPSON'S TYPES IN THE MOLLUSCAN GENUS <u>LIGUUS</u> . Smith Misc. Coll. 107 (16); 8 pp.				x		
Beard, D. B. 1938. WILDLIFE RECONNAISSANCE OF THE EVERGLADES NATIONAL PARK PROJECT. National Park Service, 106 pp.				x		
_____. 1954. LET 'ER BURN. Ever. Nat. Hist., 2(1): 1-8.			x			
Beard, J. S. 1944. CLIMAX VEGETATION IN TROPICAL AMERICA. Ecology 25: 127-158.			x			
Berner, L. 1950. THE MAYFLIES OF FLORIDA. Univ. of Fla. Biol. Sci. Series 4(4); 267 pp.				x	x	
Bessey, E. A. 1911. THE HAMMOCKS AND EVERGLADES OF SOUTHERN FLORIDA. Plant World 14: 268-276.			x			
Bird, R. T. 1955. NO BUTTERFLY LIKE A HELICONIAN. Everglades Nat. Hist. 3: 18-23, 89-95.				x		
Birkenholz, Dale E. 1963. A STUDY OF THE LIFE HISTORY AND ECOLOGY OF THE ROUND-TAILED MUSKRAT (<u>NEOFIBER ALLENI</u> TRUE) IN NORTH-CENTRAL FLORIDA. Ecological Monographs 33(3): 255-280.				x		
Bishop, S. C. 1947. HANDBOOK OF SALAMANDERS. Comstock Publ. Co., Ithaca, N. Y. 555 pp.				x		
Bowman, H. H. M. 1917. THE ECOLOGY AND PHYSIOLOGY OF THE RED MANGROVE. Proc. Amer. Philos. Soc. 56: 589-672.			x		x	
Brookfield, C. M. and O. Griswold. 1949. THEY ALL CALLED IT TROPICAL. Data Press, Miami. 77 pp.						x

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Brown, R. H. and G. G. Parker. 1945. SALT WATER ENCROACHMENT IN LIMESTONE AT SILVER BLUFF, MIAMI, FLORIDA. Economic Geology 40: 235-262.	x					
Buchanan, G. D. 1958. THE CURRENT RANGE OF THE ARMADILLO, <u>DASYPUS NOVEMCINCTUS MEXICANUS</u> , IN THE UNITED STATES. Texas Jour. Sci. 10: 349-351.				x		
Burt, W. H. and R. P. Grossenheider. 1952. A FIELD GUIDE TO THE MAMMALS. Houghton Mifflin Co., Boston.				x		
Buswell, W. M. 1942. GOLDENRODS OF SOUTH FLORIDA. Bull. Univ. Miami 16; 14 pp.			x			
_____. 1945a. NATIVE ORCHIDS OF SOUTH FLORIDA. Bull. Univ. Miami, 19(3); 29 pp.			x			
_____. 1945b. NATIVE TREES AND PALMS OF SOUTH FLORIDA. Bull. Univ. Miami 19(6); 54 pp.			x			
_____. 1946. NATIVE SHRUBS OF SOUTH FLORIDA. Bull. Univ. Miami 20(3); 48 pp.			x			
Byers, C. F. 1930. A CONTRIBUTION TO THE KNOWLEDGE OF FLORIDA ODONATA. Univ. Fla. Publ., Biol. Sci. Series 1(1); 327 pp.				x	x	
Carr, A. F., Jr. 1939. NOTES ON THE BREEDING HABITS OF THE WARMOUTH BASS. Proc. Fla. Acad. Sci. 4: 108-112.					x	
_____. 1940a. DATE OF FROG CHORUSES IN FLORIDA. Copeia 1940: 55.			x			

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terr.	E Aquatic	F General
_____. 1940b. A CONTRIBUTION TO THE HERPETOLOGY OF FLORIDA. Univ. of Fla. Publ., Biol. Sci. Ser., 3(1): 1-118.				x		
_____. 1952. HANDBOOK OF TURTLES, etc. Comstock Publ. Co., Ithaca, New York, 542 pp.				x		
_____ and C. J. Goin. 1955. GUIDE TO REPTILES, AMPHIBIANS, AND FRESH WATER FISHES OF FLORIDA. Univ. Fla. Press, Gainesville, 341 pp.				x		
Carr, M. H. 1942. THE BREEDING HABITS, EMBRYOLOGY AND LARVAL DEVELOPMENT OF THE LARGE-MOUTHED BLACK BASS OF FLORIDA. Proc. New England Zool. Club 20: 43-77.					x	
_____. 1946. NOTES ON THE BREEDING HABITS OF THE EASTERN STUMPKNCKER, <u>LEPOMIS PUNCTATUS</u> <u>PUNCTATUS</u> (CUVIER). Proc. Fla. Acad. Sci. 9: 101-106.					x	
Carroll, M. N., Jr., L. E. Fox, and W. T. Ariail. 1957. INVESTIGATIONS OF THE TOXIC PRINCIPLES OF <u>HIPPOMANE MANCINELLA</u> L. III. Jour. Amer. Pharmaceutical Assoc., Scient. Edit. 46: 93-97.			x			
Carson, R. B. 1951. THE FLORIDA TROPICS. Economic Geography 27: 321-329.		x				
Chapman, V. J. 1960. SALT MARSHES AND SALT DESERTS OF THE WORLD. Plant Science Monographs. Leon- ard Hill (Books), Ltd., London, 392 pp., 45 plates, 101 figs.			x		x	
Chipman, R. K. 1959. STUDIES OF TOLERANCE OF CER- TAIN FRESH-WATER FISHES TO BRINE WATER FROM OIL WELLS. Ecology 40(2): 299-302.					x	

	A	B	C	D	E	F
	Geol & Soils	Hydro & Clim.	Vegetation	Animal-Terr.	Aquatic	General
Clapp, G. H. 1921. LAND SHELLS OF CHOKOLOSKEE KEY AND CAPE SABLE, FLORIDA. Nautilus 34: 108.				x		
Clayton, B. S. 1936. SUBSIDENCE OF PEAT SOILS IN FLORIDA. Bur. Agric. Eng., Dept. of Agric. Report 1070. Mimeo.	x					
_____. 1943. NATURE AND EXTENT OF SURFACE SUBSIDENCE OF THE ORGANIC SOILS OF THE EVERGLADES. PART I: SHRINKAGE AND SUBSIDENCE DUE TO DRAINAGE AND CULTIVATION. Proc. Soil Sci. Soc. of Fla., V-A: 118-120.	x					
_____, J. R. Neller, and R. V. Allison. 1942. WATER CONTROL IN THE PEAT AND MUCK SOILS OF THE FLORIDA EVERGLADES. Univ. Fla. Agric. Exp. Sta. Bull. 378: 1-74.	x					
Clench, W. J. 1923. THE MARINE SHELLS OF SANIBEL, FLORIDA. Nautilus 37: 52-56; 38: 93-95.				x	x	
_____. 1931. "LIGGING" IN THE EVERGLADES OF FLORIDA. Nautilus 45: 10-15.				x		
_____. 1946. A CATALOG OF THE GENUS <u>LIGUUS</u> WITH A DESCRIPTION OF A NEW SUBGENUS. Occ. Papers on Mollusks, M.C.Z. 1(10): 117-128.				x		
_____ and G. B. Fairchild. 1939. THE CLASSIFICATION OF FLORIDA <u>LIGUUS</u> . Proc. New England Zool. Club, 17: 77-86.				x		
Coe, E. F. 1951. STORY OF THE EVERGLADES NATIONAL PARK PROJECT FROM THE CONCEPTION OF THE IDEA, INCLUDING ITS ESTABLISHMENT AND DEDICATION. Coconut Grove, Fla. Mimeo. 208 pp.						x

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Cole, W. S. 1941. STRATIGRAPHIC AND PALEONTOLOGIC STUDIES OF WELLS IN FLORIDA. Bull. Fla. Geol. Surv., No. 19.	x					
_____. 1942. STRATIGRAPHIC AND PALEONTOLOGIC STUDIES OF WELLS IN FLORIDA, #2. Bull. Fla. Geol. Surv., No. 20.	x					
_____. 1944. STRATIGRAPHIC AND PALEONTOLOGIC STUDIES OF WELLS IN FLORIDA, #3. Bull. Fla. Geol. Surv., No. 26, pp. 25-26.	x					
Cook, O. F. 1910. HISTORY OF THE COCONUT PALM IN AMERICA. Contr. U.S. Nat. Herb. 14(2): 271-342.			x			
Cooke, C. W. 1931. SEVEN COASTAL TERRACES IN THE SOUTHEASTERN STATES. Jour. Wash. Acad. Sci., 21(21): 503-513.	x					
_____. 1935. TENTATIVE AGES OF PLEISTOCENE SHORE LINES. Jour. Wash. Acad. Sci., 25:331-333.	x					
_____. 1939. SCENERY OF FLORIDA INTERPRETED BY A GEOLOGIST. Fla. Geol. Surv. Bull. 17:1-118.	x					
_____. 1945. GEOLOGY OF FLORIDA. Fla. Geol. Surv. Bull. 29: 1-339.	x	x				
Cooper, H. H., Jr. 1959. A HYPOTHESIS CONCERNING THE DYNAMIC BALANCE OF FRESH WATER AND SALT WATER IN A COASTAL AQUIFER. Jour. Geophys. Res. 64: 461-467.			x			
_____. 1962. THE MOVEMENTS OF SEA WATER IN COASTAL AQUIFERS. Proc. 1st Natl. Coastal and Shallow Water Res. Conf., pp. 277-280.	x					

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terre.	E Aquatic	F General
Cooper, H. H. and G. G. Parker. 1944. WATER LEVELS AND ARTESIAN PRESSURE IN FLORIDA, 1943. U.S. Geol. Surv. Water-Supply Pap., 987.		x				
Correll, D. S. 1938. A COUNTY CHECKLIST OF FLORIDA FERNS AND FERN ALLIES. Amer. Fern Jour. 28: 11-16, 46-54, 91-100.			x			
_____. 1950. NATIVE ORCHIDS OF NORTH AMERICA NORTH OF MEXICO. Chronica Botanica Co., Waltham, Mass. 399 pp.			x			
Cottam, C. and W. S. Bourn. 1952. COASTAL MARSHES ADVERSELY AFFECTED BY DRAINAGE AND DROUGHT. Trans. N. Amer. Wildl. Conf. 17: 414-421.		x				x
Craighead, F. C. 1963. ORCHIDS AND OTHER AIR PLANTS OF EVERGLADES NATIONAL PARK. Univ. of Miami Press, Coral Gables, Fla. 127 pp.			x			
_____. 1964. LAND, MANGROVES, AND HURRICANES. Fairchild Tropical Gardens Bull. 19, No. 4.	x	x	x			
Craighead, F. C. and V. C. Gilbert. 1962. THE EFFECTS OF HURRICANE DONNA ON THE VEGETATION OF SOUTHERN FLORIDA. Quar. Jour. Fla. Acad. Sci. 25(1): 1-28.			x			
Crawford, D. R. and W. W. J. DeSmidt. 1922. THE SPINY LOBSTER, <u>PANULIRUS ARGUS</u> OF SOUTHERN FLORIDA: ITS NATURAL HISTORY AND UTILIZATION. Bull. U.S. Bur. of Fisheries 38: 281-310.						x
Creaser, E. P. 1931. SOME COHABITANTS OF BURROWING CRAYFISH. Ecology 12(1): 243-244.					x	

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terre.	E Aquatic	F General
Croker, R. A. 1962. GROWTH AND FOOD OF THE GREY SNAPPER, LUTJANUS GRISEUS, IN EVERGLADES NATIONAL PARK. Trans. Amer. Fish. Soc. 91(4): 379-383.					x	
Cross, W. P. 1942. WATER LEVELS AND ARTESIAN PRESSURE IN SOUTHEASTERN FLORIDA. U.S. Geol. Surv., Water-Supply Pap. 907: 26-34.		x				
_____. 1943. WATER LEVELS AND ARTESIAN PRESSURE IN FLORIDA, 1941. U.S. Geol. Surv., Water-Supply Pap. 886: 64-68.			x			
_____ and S. K. Love. 1942. GROUNDWATER IN SOUTHEASTERN FLORIDA. Jour. Amer. Water Works Assn. 34(4): 490-504.		x				
Crowson, D. H. 1950. THE ALGAE OF A MODIFIED BRACKISH POOL. Fla. State Univ. Studies 1: 1-32.			x		x	
Curtiss, A. H. 1888a. HOW THE MANGROVE FORMS ISLANDS. Garden and Forest, 1: 100.			x			
_____. 1888b. THE FLORA OF THE FLORIDA KEYS. Garden and Forest, 1: 279-280.			x			
_____. 1903. AMONG FLORIDA FERNS. Plant World 4: 66-72, 91-92.			x			
_____. 1904. THE FERN FLORA OF FLORIDA. Fern Bull. 12: 33-38.			x			
Cypert, E. 1961. THE EFFECTS OF FIRES IN THE OKEFENOKEE SWAMP IN 1954 AND 1955. Amer. Midland Nat. 66: 485-503.			x			

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terre.	E Aquatic	F General
Dachnowski-Stokes, A. P. 1926. FACTORS AND PROBLEMS IN THE SELECTION OF PEAT LANDS FOR DIFFERENT USES. Bull. U.S. Dept. of Agric., No. 1419.	x					
_____. 1930. PEAT PROFILES OF THE EVERGLADES IN FLORIDA: THE STRATIGRAPHIC FEATURES OF THE "UPPER" EVERGLADES AND CORRELATION WITH ENVIRONMENTAL CHANGES. Jour. Wash. Acad. Sci. 20: 89-106.	x					
_____. 1935. PEAT LAND AS A CONSERVER OF RAINFALL AND WATER SUPPLIES. Ecology 16(2): 173-177.	x					
_____. 1939. IMPROVEMENT OF UNPRODUCTIVE AND ABANDONED PEATLAND FOR WILDLIFE AND RELATED USES. Ecology 20(2): 187-197.			x	x		
_____ and R. V. Allison. 1928. A PRELIMINARY NOTE ON BLUE-GREEN ALGAL MARL IN SOUTHERN FLORIDA IN RELATION TO THE PROBLEM OF COASTAL SUBSIDENCE. Jour. Wash. Acad. Sci. 18: 476-480.	x				x	
Dade County Commissioners. 1928. HISTORY OF THE TAMiami TRAIL. 38 pp.						x
Dambaugh, L. N. 1962. LAND USE IN DADE COUNTY, FLORIDA. Quart. Jour. Fla. Acad. Sci. 25(1): 29-44.						x
Darlington, P. J. 1938. THE ORIGIN OF THE FAUNA OF THE GREATER ANTILLES WITH DISCUSSION OF THE DISPERSAL OF ANIMALS OVER WATER AND THROUGH THE AIR. Quart. Review Biol. 13: 274-300.				x		

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terre.	E Aquatic	F General
Davis, C. C. 1948. NOTES ON THE PLANKTON OF LONG LAKE, DADE COUNTY, FLORIDA, etc. Quart. Jour. Fla. Acad. Sci. 10: 79-88.					x	
_____ and R. H. Williams. 1950. BRACKISH WATER PLANKTON OF MANGROVE AREAS IN SOUTH FLORIDA. Ecology 31(4): 519-531.					x	
Davis, D. E., F. L. Woodward, H. A. Svenson, A. D. Stoesz, D. H. Wallace, and J. W. Kimball. 1951. SYMPOSIUM ON THE APPLICATION OF ECOLOGY TO WATER CONSERVATION. Sci. Monthly 73(6): 343-355.		x			x	
Davis, J. H. 1940. THE ECOLOGY AND GEOLOGIC ROLE OF MANGROVES IN FLORIDA. Carnegie Inst. Wash., Publ. 517, Pap. Tortugas Lab. 32(16): 303-412.	x		x			
_____. 1942. THE ECOLOGY OF THE VEGETATION AND TOPOGRAPHY OF THE SAND KEYS OF FLORIDA. Pap. Tortugas Lab. 524: 113-195.			x			
_____. 1943a. THE NATURAL FEATURES OF SOUTHERN FLORIDA, ESPECIALLY THE VEGETATION AND EVERGLADES. Fla. Geol. Surv., Geol. Bull. 25: 1-311.	x	x	x	x	x	x
_____. 1943b. VEGETATION OF THE EVERGLADES AND ITS CONSERVATION FROM THE POINT OF VIEW OF THE PLANT ECOLOGIST. Proc. Soil Sci. Soc. of Fla., V-A: 105-115.			x			
_____. 1946. THE PEAT DEPOSITS OF FLORIDA. Fla. Geol. Surv., Bull. 30: 1-247.	x		x			
Davis, Kenneth P. 1959. FOREST FIRE: CONTROL AND USE. McGraw Hill. (Good coverage on prescribed burning and fire effects)			x			x

	A Geol. & Soils	B Hydro & Clim.	C Vegetation	D Animal-Terre.	E Aquatic	F General
Dawson, C. E., Jr. and C. P. Idyll. 1951. INVESTIGATION ON THE FLORIDA SPINY LOBSTER, <u>PANULIRUS ARGUS</u> (LATREILLE). State of Fla. Bd. of Cons. Tech. Series 2. 39 pp.					x	
Day, R. L. 1953. WEATHER EXTREMES IN FLORIDA DURING 1950-1951. Qu. Jour. Fla. Acad. Sci. 16:102-110.		x				
DePourtales, L. F. 1877. HINTS ON THE ORIGIN OF THE FLORA AND FAUNA OF THE FLORIDA KEYS. Amer. Nat. 11: 137-144.			x	x		
DeWitt, James B. and James V. Derby. 1948. CHANGES IN NUTRITIVE VALUE OF BROWSE PLANTS FOLLOWING FOREST FIRES. U.S. Dept. of the Int., Fish and Wildlife Service. Progr. Rep., pp. 1-8, typed.						x
Dickerson, R. E. 1942. TRENDS OF PLEISTOCENE OCEAN CURRENTS ACROSS THE FLORIDA EVERGLADES. Geogr. Rev. 32: N 135-139.	x					
Dickson, J. D. 1955. AN ECOLOGICAL STUDY OF THE KEY DEER. Fla. Game and Fresh Water Fish Comm., Tallahassee, Fla. 104 pp.				x		
Dickson, J., R. Woodbury, and T. R. Alexander. 1953. CHECKLIST OF FLORA OF BIG PINE KEY, FLORIDA AND SURROUNDING KEYS. Quart. Jour. Fla. Acad. Sci. 16: 181-197.			x			
Dilley, W. E. 1951. PRELIMINARY CHECKLIST OF THE BIRDS OF EVERGLADES NATIONAL PARK. Everglades National Park. 17 pp., Mimeo.					x	
Dimock, J. 1915. FLORIDA ENCHANTMENTS. Outing Publ. Co., New York, 338 pp.						x

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Dodge, C. R. 1894. SUBTROPICAL FLORIDA. Scribners Mag. 15: 345-362.						x
Douglas, M. S. 1947. THE EVERGLADES: RIVER OF GRASS. Rinehart and Co., New York, 406 pp.						x
Dovell, J. E. 1942. BRIEF HISTORY OF THE FLORIDA EVERGLADES. Proc. Soil Sci. Fla., IV-A: 132-161.						x
Duellman, W. E. and L. N. Bell. 1955. THE FROGS AND TOADS OF EVERGLADES NATIONAL PARK. Ever. Nat. Hist. 3: 102-115.				x		
_____ and A. Schwartz. 1958. AMPHIBIANS AND REPTILES OF SOUTHERN FLORIDA. Bull. Fla. State Mus. 3(5): 182-324.				x		
Egler, F. E. 1948. THE DISPERSAL AND ESTABLISHMENT OF RED MANGROVES, <u>RHIZOPHORA</u> , IN FLORIDA. Caribbean Forester 9(4): 299-320.			x			
_____. 1950. SOUTHEAST SALINE EVERGLADES VEGETATION, FLORIDA, AND ITS MANAGEMENT. Vegetation; Acta Geobotanica. (W. Junk, Den Haag), 3(4-5): 213-265, 1950 (1952).			x			
Eldredge. 1938. FOREST RESOURCES OF CENTRAL AND SOUTH FLORIDA. Progr. Rep., So. Forest Exp. Sta., Forest Survey Release 38. 30 pp.			x			
Emerson, A. E. and E. M. Miller. 1943. A KEY TO THE TERMITES OF FLORIDA. Ent. News, 54: 184-187.				x		
Emery, K. O., R. E. Stevenson and J. W. Hedgpeth. 1957. ESTUARIES AND LAGOONS <u>IN</u> : TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY. The Geol. Soc. of Amer. Memoir 67, 1: 673-749.						x

	A	B	C	D	E	F
	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
Erwin, T. C. 1948. SOME WATER QUALITY RELATIONSHIPS OBSERVED UNDER EVERGLADES CONDITIONS IN THE COURSE OF STUDIES OF POSSIBLE AFTER EFFECTS FOLLOWING HYACINTH TREATMENT WITH 2, 4-D. Proc. Soil Sci. Soc. of Fla., IX: 111-113.		x	x		x	
Evans, C. B. and R. V. Allison. 1942. THE SOILS OF THE EVERGLADES IN RELATION TO RECLAMATION AND CONSERVATION OPERATIONS. Proc. Soil Sci. Soc. of Fla., IV-A.	x					
Eyles, D. E. and J. L. Robertson, Jr. 1944. A GUIDE AND KEY TO THE AQUATIC PLANTS OF THE SOUTHEASTERN UNITED STATES. Pub. Health Bull. 286. Govt. Printing Office, Washington, D. C.			x		x	
Fairbanks, G. R. 1896. THE GREATER AND LESSER FREEZES IN FLORIDA FOR A CENTURY <u>IN</u> : PRESENT CONDITION AND TREATMENT OF ORANGE GROVES. Fla. Agr. Exp. Sta., Bull. 33:230-236.		x				
Fairchild, David. 1929. THE PROPOSED NATIONAL PARK IN THE SOUTHERN EVERGLADES OF FLORIDA. Fla. Dept. Agric., Sup. Bull., New Ser., 17.						x
Farb, Peter. 1965. DISASTER THREATENS THE EVERGLADES. Sept.-Oct. Audubon Mag., pp. 302-309.						x
Fenneman, N. M. 1938. PHYSIOGRAPHY OF THE EASTERN UNITED STATES. 714 pp. McGraw-Hill, New York.	x					
Ferguson, G. E. 1944. IN: SYMPOSIUM: NATURAL FACTORS AFFECTING WATER CONSERVATION AND FLOOD CONTROL IN THE KISSIMEE VALLEY. THE SURFACE WATER RESOURCES OF THE KISSIMEE RIVER BASIN. Proc. Soil Sci. Soc. of Fla., VI: 16-19.	x					

	Geol. & Soils	A	B	C	D	E	F
	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General		
. 1945. SUMMARY OF THREE YEARS OF SURFACE WATER STUDIES IN THE EVERGLADES. Proc. Soil Sci. Soc. of Fla. V-A: 18-23, 1943 (1945).	x						
Fleece, J. B. 1962. THE CARBONATE GEOCHEMISTRY AND SEDIMENTOLOGY OF THE KEYS OF FLORIDA BAY, FLORIDA. Report to Office of Naval Research from Sedimen- tological Research Laboratory, Dept. of Geology, Fla. State Univ., Tallahassee, Fla. 112 pp.	x						
Flint, R. F. 1945. CHRONOLOGY OF THE PLEISTOCENE EPOCH. Quart. Jour. Fla. Acad. Sci. 8: 1-34.	x						
. 1947. GLACIAL GEOLOGY AND THE PLEISTO- CENE EPOCH. John Wiley and Sons, Inc., N.Y. 589 pp.	x						
Florida Game and Fresh Water Fish Commission. 1956. RECOMMENDED PROGRAM FOR CONSERVATION AREA 2. Tallahassee, Fla. 121 pp., Mimeo., figs. & maps.	x	x	x	x	x	x	
. 1960. RECOMMENDED PROGRAM FOR CONSERVATION AREA 3. Vero Beach, Fla. About 220 pp.; many figs.; Mimeo.	x	x	x	x	x	x	
Florida State Board of Conservation. 1948. OBSERVED RAINFALL IN FLORIDA. 427 pp.	x						
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	Geol. & Soils	Hydro & Clim.	Vegetation	Animal-Terre.	Aquatic	General
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COMMON - SCIENTIFIC* PLANT NAMES

Bay	<u>Magnolia virginiana</u>
Bladderwort, purple	<u>Utricularia purpuria</u>
Brazilian pepper	<u>Schinus terebinthifolius</u>
Buttonwood	<u>Conocarpus erecta</u>
Custard apple	<u>Asimina reticulata</u>
Cypress, bald	<u>Taxodium distichum</u> var. <u>distichum</u>
Cypress, dwarf (pond cypress)	<u>Taxodium distichum</u> var. <u>nutans</u>
Fern, hand	<u>Ophioglossum palmatum</u>
Fern, holly	<u>Stenochlaena kunzeana</u>
Fern, tropical maidenhair	<u>Adiantum melanoleucum</u>
Fig, strangler	<u>Ficus aurea</u>
Hackberry (sugarberry)	<u>Celtis laevigata</u>
Holly (Dahoon)	<u>Ilex cassine</u>
Hyacinth, water	<u>Eichornia crassipes</u>
Macradenia, Trinidad	<u>Macradenia lutescens</u>
Mahogany, West Indian	<u>Swietenia mahagoni</u>
Maidencane	<u>Panicum hemitomon</u>
Mangrove, black	<u>Avicennia nitida</u>
Mangrove, red (mangrove)	<u>Rhizophora mangle</u>
Mangrove, white	<u>Laguncularia racemosa</u>
Maple, red	<u>Acer rubrum</u>
Orchid, mule-ear	<u>Oncidium luridum</u>
Orchid, spider	<u>Brassia caudata</u>
Palm, cabbage	<u>Sabal palmetto</u>
Palm, royal	<u>Roystonea elata</u>
Pine, Australian	<u>Casuarina equisetifolia</u>
Pine (slash)	<u>Pinus elliottii</u> var. <u>densa</u>
Punkywood (punk-tree, cajeput-tree)	<u>Melaleuca leucadendron</u>
Rush, beak	<u>Rhynchospora</u> spp.

*Scientific names according to:
Lakela and Craighead, 1965
Little, 1953
Robertson, 1953a

Salt-wort
Sawgrass
Spike-rush
Switchgrass

Batis maritima
Mariscus jamaicensis
Eleocharis cellulosa
Spartina spartinae

Turtlegrass

Thalassia testudinum

Wax myrtle
Willow

Myrica cerifera
Salix

COMMON - SCIENTIFIC* ANIMAL NAMES

MAMMALS

Armadillo, nine-banded	<u>Dasypus novemcinctus</u>
Bear, black	<u>Ursus americanus</u>
Bobcat	<u>Lynx rufus</u>
Deer, white-tailed	<u>Odocoileus americanus osceola</u>
Dolphin, bottle-nosed	<u>Tursiops truncatus</u>
Fox, gray	<u>Urocyon cinereoargenteus</u>
Manatee	<u>Trichechus manatus</u>
Muskrat, round-tailed	<u>Neofiber alleni</u>
Opossum	<u>Didelphis virginiana</u>
Otter	<u>Lutra canadensis</u>
Panther	<u>Felis concolor</u>
Pig	<u>Sus scrofa</u>
Rabbit, cottontail	<u>Sylvilagus floridanus</u>
Rabbit, marsh	<u>Sylvilagus palustris</u>
Raccoon	<u>Procyon lotor</u>
Rat, cotton	<u>Sigmodon hispidus</u>
Rat, roof	<u>Rattus rattus alexandrinus</u>
Rat, wood	<u>Neotoma floridana</u>
Skunk, striped	<u>Mephitis mephitis</u>
Squirrel, fox (mangrove)	<u>Sciurus niger</u>
Squirrel, gray	<u>Sciurus carolinensis</u>

BIRDS

Anhinga	<u>Anhinga anhinga</u>
Bluebird	<u>Sialia sialis</u>
Bobwhite	<u>Colinus virginianus</u>
Buzzard (turkey vulture)	<u>Cathartes aura</u>
Cormorant, double-crested	<u>Phalacrocorax auritus</u>
Cuckoo, mangrove	<u>Coccyzus minor</u>
Eagle, bald	<u>Haliaeetus leucocephalus</u>
Egret, reddish	<u>Dichromanassa rufescens</u>
Hawk, short-tailed	<u>Buteo brachyurus</u>

*Scientific names according to:

Mammals: Burt and Grossenheider - 1952

Birds: Robertson - 1962

Fish: Tabb and Manning - 1961, Bailey, B. M. - 1960

Reptiles and Amphibians: Muller - 1962

Invertebrates: Tabb and Manning - 1961, Klots - 1951

Heron, great blue
Heron, great white
Ibis, white
Ibis, wood
Kite, swallow-tailed
Osprey
Pelican, brown
Pelican, white
Pigeon, white-crowned
Sparrow, Cape Sable
Spoonbill, roseate
Turkey, wild
Warbler, pine

Ardea herodias
Ardea occidentalis
Eudocimus albus
Mycteria americana
Elanoides forficatus
Pandion haliaetus
Pelecanus occidentalis
Pelecanus erythrorhynchos
Columba leucocephala
Ammospiza mirabilis
Ajaia ajaja
Meleagris gallopavo
Dendroica pinus

REPTILES AND AMPHIBIANS

Alligator
Anole lizard
Crocodile, American
Rattlesnakes
Snake, black (Racer)
Snake, indigo
Snake, mangrove water
Terrapin, diamondback
Turtle, Atlantic green
Turtle, Atlantic hawksbill
Turtle, Atlantic leatherback
Turtle, Atlantic loggerhead
Turtle, box
Turtle, gopher

Alligator mississippiensis
Anolis carolinensis
Crocodylus acutus
Sistrurus and Crotalus spp.
Coluber constrictor paludicola
Drymarchon covais couperi
Natrix sipedon compressicauda
Malaclemys terrapin
Chelonia mydas
Eretmochelys imbricata
Dermochelys coriacea
Caretta caretta
Terrapene carolina
Gopherus polyphemus

Bullfrog, Southern
Frog, Green tree

Rana gryllio
Hyla cinerea

FISH

Anchovey
Bass
Drum, black
Drum, red (redfish)
Gar, Florida
Killifish (diamond)
Ladyfish

Anchoa spp.
Micropterus spp.
Pogonias cromis
Sciaenops ocellata
Lepisosteus platyrhincus
Adinia zenica
Elops saurus

Mullet, black (striped)
Mullet, white (silver)
Snapper, mangrove (gray)
Snook
Sunfish (bream)
Tarpon
Trout, sea

Mugil cephalus
Mugil carema
Lutjanus griseus
Centropomus undecimalis
Lepomis and others
Megalops atlantica
Cynoscion nebulosus

INVERTEBRATES

Butterfly, Atala hairstreak
Butterfly, zebra

Eumaeus atala
Heliconius charithonius

Crab, blue
Crab, stone
Crayfish
Lobster, spiny
Shrimp, pink

Callinectes sapidus
Menippe mercenaria
Procambarus alleni
Panulirus argus
Penaeus duorarum

Snail, tree

Liguus spp.

GEOGRAPHIC FEATURES NOT SHOWN ON THE MAPS
WHICH ACCOMPANY THIS REPORT

Alligator Creek	About 1000 yards north of Ranklin Bight.
Big Cypress area	A large cypress swamp area adjoining the Park, bounded on the south by Highway 94.
Big Sable Creek	About halfway between Ponce de Leon Bay and Northwest Cape.
Coot Bay Canal	Same as Buttonwood Canal of Map.
Cattail Lake	About 1 mile west of Fox Lakes.
Crocodile Point	Major east-trending point to the west of Madeira Bay.
Highland Beach	Just south of Highland Point.
Little Sable Creek	First creek north of Northwest Cape.
Madeira Hammock	A general area of mahogany hammocks along the Crocodile Point Road.
Old Ingraham Highway	The old road to Flamingo. In context used here, the loop which lies south of and roughly parallels the present Flamingo Road in the area between Royal Palm and Mahogany Hammocks.

THE MIAMI LIMESTONE* OF FLORIDA
AND ITS RECENT BAHAMIAN COUNTERPART**

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Abstract: The Miami Oolite, named by Sanford (1909) for the oolitic limestone of Pleistocene age which covers a large part of the southern tip of Florida, has been found to consist of two separate units - an upper unit, herein designated the Oolitic facies, and a lower unit called here the Bryozoan facies. In this paper the two units are combined as the Miami Limestone, a name which now seems more appropriate than the Miami Oolite. The Bryozoan facies, the dominant constituents of which are massive compound colonies of the cheilostome bryozoan Schizoporella floridana Osburn surrounded by ooids and pellets, covers the greater part of Dade County and extends in places into adjoining counties - a total area of about 2000 square miles. It averages 10 feet in thickness in eastern Florida and thins to a foot or so westward to the Gulf of Mexico. It is the surface rock of the southern Everglades, and is one of the largest bryozoan limestones in the country. In southeastern Florida it is covered by an elongated mound of cross-bedded oolitic limestone, the upper unit or Oolitic facies. This is the rock of the Atlantic Coastal Ridge. It has a maximum thickness of 35 feet under the Ridge summit and thins westward toward the lowlying Everglades as it encroaches over the Bryozoan facies.

The origin of the two units has been a matter of considerable interest. It has been recognized recently that similar deposits are being actively produced in a nearby area. Immediately east of Miami on the western edge of the Great Bahama Bank, strung in a north-south line, are the islands of Bimini, Cat Cay, Sandy Cay, etc. This is the region described by Newell and others (1959). To the east of the Cays and parallel to them a large underwater mound of Unstable Oolite is forming. East of the mound in the

*The Miami Limestone refers to the formation which has been called the Miami Oolite by previous writers.

**Abstract submitted for publication to Bulletin of the Geological Society of America, 8/66.

Shallow Lagoon large numbers of massive, tubular bryozoans, Schizoporella floridana Osburn are growing. The oolite from the mound is slowly encroaching over the bryozoan beds. It is believed that the bathymetric and ecologic conditions now extant in this area are similar to those which existed during the Pleistocene to form the units of the Miami Limestone. Another way of expressing it is that the features of the southern part of Florida represent a mirror image of those now found on the adjacent Bahama bank.

The eastern slope of the Unstable Oolite mound of the Cat Cay, Sandy Cay area is cut by tidal channels which run normal to the direction of the mound itself. Narrow valleys, similar to these channels, can be found in the indurated rock of the Oolitic facies of the Atlantic Coastal Ridge. It is believed that the valleys had their origin as channels produced by tidal currents at the time the oolitic mound of the Ridge was in an unstable condition. It is also believed that the shape and orientation of the Lower Keys of Florida originated in a similar fashion.

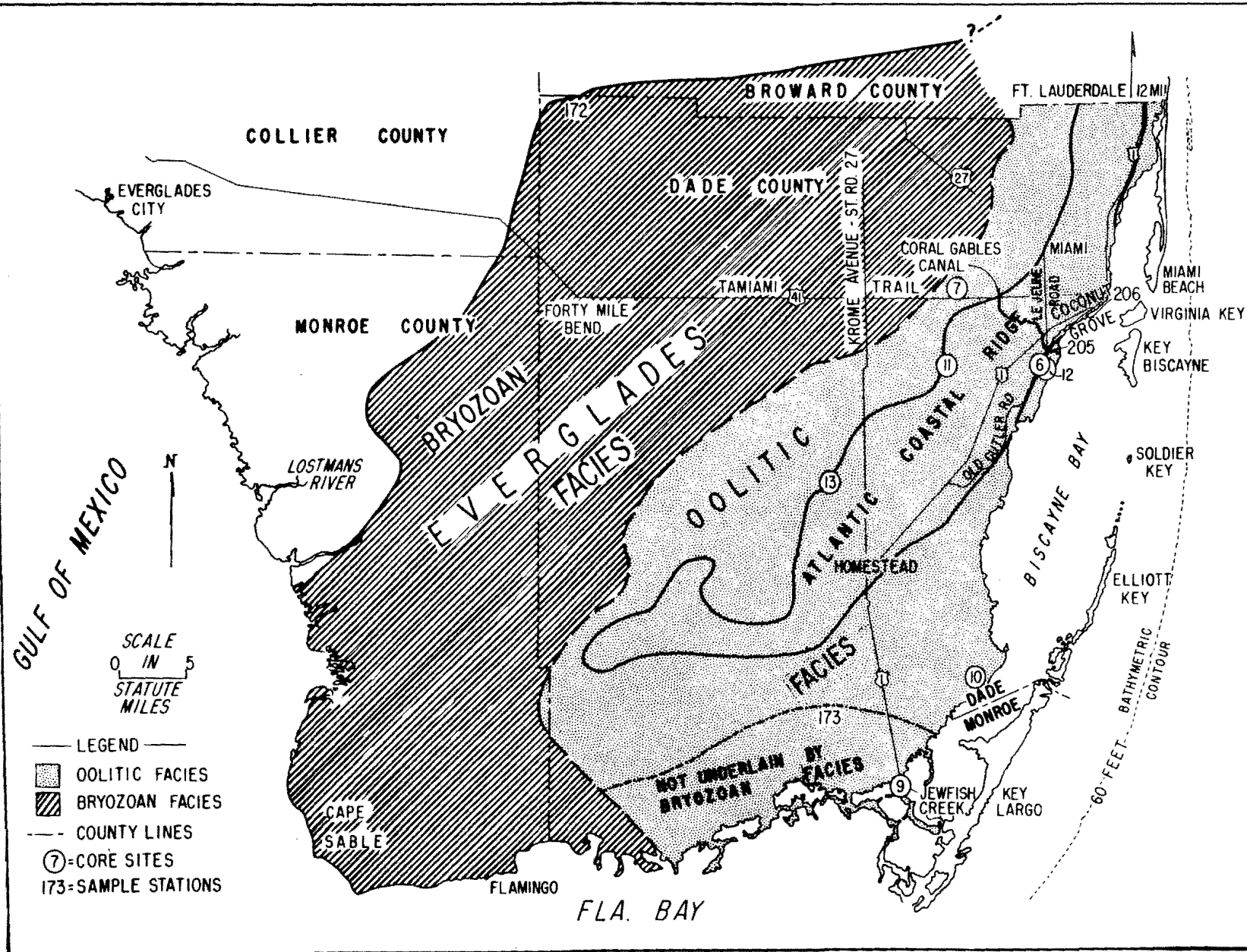


Fig. 1. Surface extent of Oolitic facies and Bryozoan facies, southern Florida.