

## ECOLOGY AND MANAGEMENT OF AN ESTUARY AT THE EDGE OF THE AMERICAN CARIBBEAN: BISCAYNE BAY

by

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### ABSTRACT

Biscayne Bay is a shallow subtropical estuary, 225 square miles of water, at the edge of the tropics, located within Dade County, one of the fastest growing counties in the U.S.A. The fragility of this seagrass and mangrove dominated estuary has been demonstrated by repeated destruction of these ecosystems by man's activities, such as dredging, filling, drainage, sewerage, thermal pollution, and others. At the southern end, the U.S. Department of the Interior has recently established the Biscayne Monument, a preserve area where fairly rigid restrictions for man's use of the biota are enforced. At the northern end, intense land development since 1910 along with establishment for artificial islands and causeways, bulkheading, sewerage outfall and other pollutants has altered the ecology greatly. Approximately 1.5 million people inhabit this area. Multiple authorities for regulating use in the bay and its shoreline exist ranging from county to Federal. Many problems of overlapping jurisdiction and enforcement occur.

Two symposia to bring together the knowledge of processes occurring in the bay and to delineate a policy for managing the bay were held in March 1976 resulting in the Volume, Biscayne Bay: Past, Present, and Future. Aspects of the ecology of this bay and of the management problems and goals will be discussed.

Biscayne Bay is a shallow subtropical estuary on the edge of the Caribbean. Physically, the bay is 45 miles long and approximately 10 miles wide. It is fringed to the west by the mainland (Miami and suburbs), to the southwest by the Everglades and to the east by barrier islands of the Florida Keys and Miami Beach (Fig. 1). The physical regime is dominated by tidal flushing of the bay's waters which in most areas is rather sluggish. Winter storms (June to October) activate a great portion of turn-over of the water, (LFE & ROUTH 1972, 1976). Temperatures average 21°C in the winter and 30°C in the summer.

Geologically the bay filled with water about 6,000 years ago as sea level water rose between Pleistocene limestone ridges 2—6 m in depth. The sediment in the bay consists primarily of lime mud and quartz-carbonate sand. Six major recent sediment regimes include the following: 1). longshore drift from the north of quartz and carbonate sediment; 2). quartz sand deposits; 3). tidal bars and belts of calcareous sand and mud; 4). mangrove

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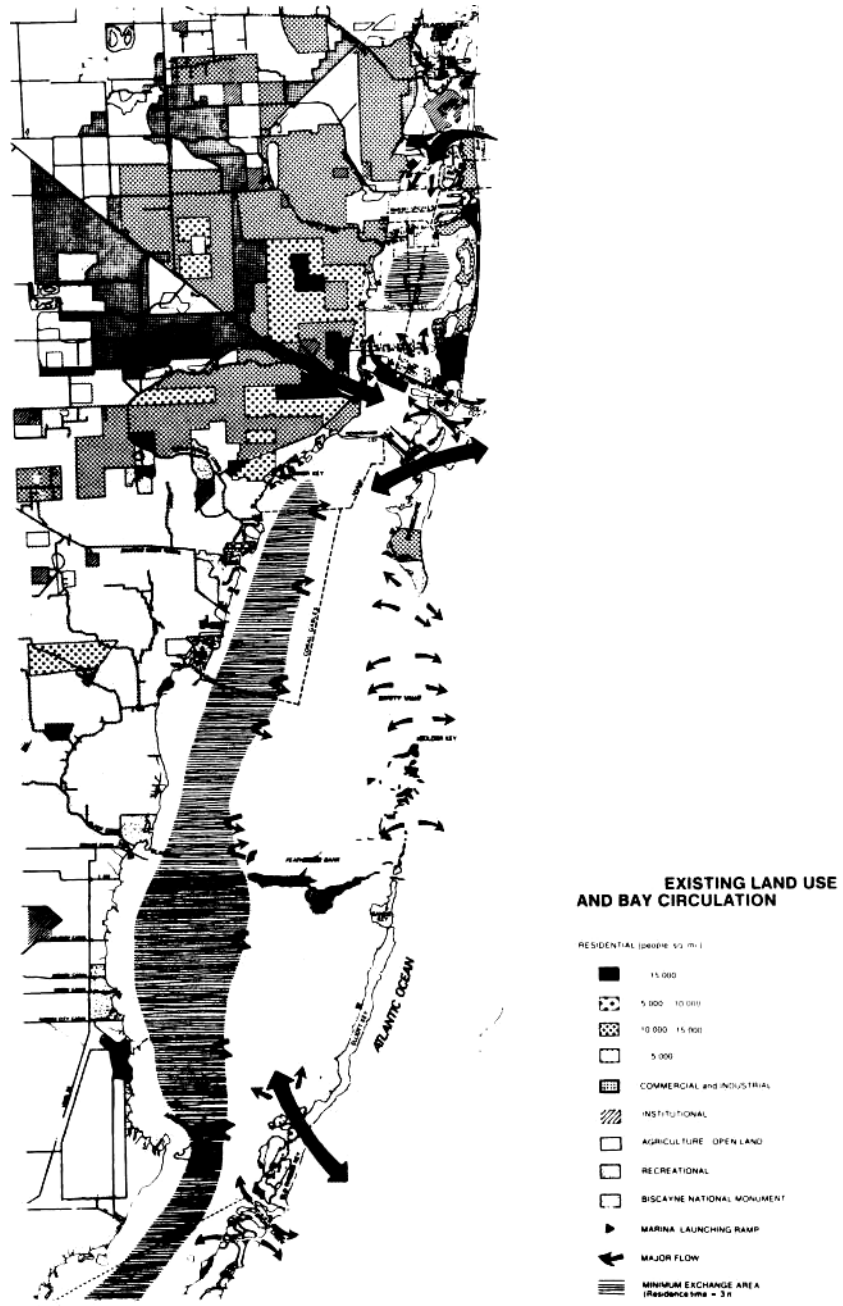


Figure 1. Map of Biscayne Bay from BILHORN (1976)

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swamps bordering protected shorelines having no point source freshwater input; 5). open bay areas have a thin veneer of quartzose calcareous sand over Pleistocene limestone rock in central portion and where bedrock is deep; and seagrass meadows are abundant along the shoreline as lime mud; 6). non-tidal mud banks (WANLESS 1976 A).

The chemistry of the Bay has not yet been integrated from a series of goal-oriented studies at specific sites. The nutrient content of the bay is generally low in the water as are the trace elements; higher concentrations are found in the sediments. A good deal of cycling of material occurs through the turtle grass growth and decay (GILIO & SEGAR 1976). Tidal flow transports material into and out of the Bay from the ocean, especially near tidal passes on the eastern border.

Ecologically the Bay was dominated landward by mangrove swamps which fringed the Bay although most of this has been removed in the north. Seaward turtle grass or *Thalassia testudinum* is the dominant plant species within the bay itself (Fig. 2). The primary productivity of the bay is very high (about 2,000 g dry weight m<sup>-2</sup> yr<sup>-2</sup>) with definite seasonal cycles. The food web in natural areas is a complex invertebrate-fish interaction. There are three major ecological zones in the Bay, (THORHAUG & ROESSLER 1976): those near the western shoreline, which are estuarine due to fresh water run-off; a mid-bay section, which has fewer plants and animals probably due to thin sediment layer and less light penetration; and a near-oceanic zone, bordering the fringing Florida keys, which sustains less salinity and other fluctuations. In terms of fish, there are 512 recognized species, 90 of which are commercial and 89 of which are sports species (DE SYLVA 1976). Tropical fishes are prevalent in the summer and partially replaced temperate forms in winter. The western shoreline shows influences of freshwater run-off on species diversity. Little quantitatively is known about how man's activities affect populations although effects can apparently decimate populations. A list of species and their habitats has been compiled for the south Biscayne Bay Monument region and the adjacent Florida Keys (Voss *et al* 1969). Approximately 450 invertebrates having been found in a very complex food web. The dominant numbers and diversity of both invertebrates and fish are associated with the seagrass community.

Species diversity, abundance and seasonal dynamics have been reported (THORHAUG & ROESSLER 1976) as have the description of species in the Biscayne Monument area (Voss *et al* 1969). Man's activities which have reduced invertebrate populations including shoreline changes, reduced flushing and seagrass bed destruction. Voss (1976) and THORHAUG, *et al*.

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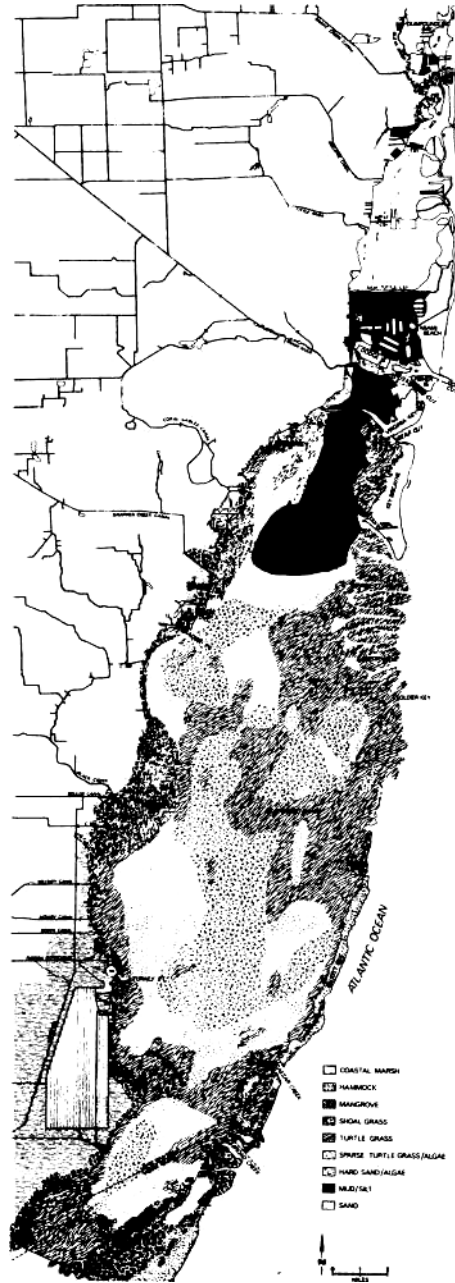
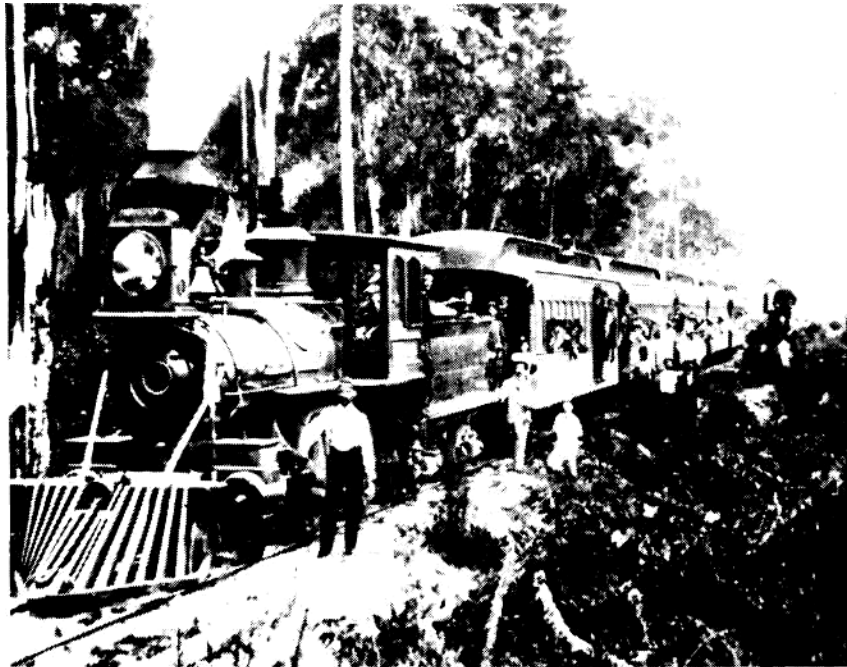


Figure 2. Vegetation map (from ROESSLER & BEARDSLEY ).

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(1976) have discussed pollution effects. Birds are an important segment of the higher predators; and inventory of taxa with ecological note has been outlined by OWRE (1976) with an outline of foraging habits. Plankton (both zoo- and phyto-) appear not to be as important as in northern estuaries in the food web except seasonally in terms of year classes (REEVE & COSPAR 1972).

Historically the development of the Bay in terms of social systems has been very rapid. Originally there were Indians from about 100 B.C. until 1763, who were non-agricultural people making a marginal living from the bay, when the Spanish came and began changing the shorelines of the bay immediately. In 1896 when the city of Miami was founded, an expanding national economy led to an intense growth rate especially in North Biscayne Bay (CHARDON 1976). Also in 1896, the railroad, vital link to the north was begun (Fig. 3). Intensive development occurred around the northern portion



**Figure 3.** The first railroad train to Miami in 1896.

of the Bay between 1910 and 1950, mostly by a process of filling in the northern Bay (almost no re-development). In 1950 there were about one half million people living in Dade County whereas today there are about a million

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and a half inhabitants (excluding tourists who come in great numbers during both the summer and winter since this is one of Miami's major industries). The percentage of the population within walking access of the bay has actually declined since 1950 as the population has moved from a center around the bay towards the southwestern part of the county in suburban developments. This trend appears to be changing to an intense redevelopment of business and housing around the water. Causative factors are the energy crisis (cost of transportation to work plus housing cost are a constant), the friction of urban space, and the constraints introduced by land regulations are changing the conditions (PRESTAMP 1976). The Bay offers urban services required for high density uses; conditions must be balanced by environmental constraints.

There were environmental problems associated with this growth. In 1910 the opening of the Bay to traffic began connecting Miami Beach (even then a tourist center) to the mainland with the first causeway built across the bay bottom (Fig. 4). The real estate boom in the 1920's increased the

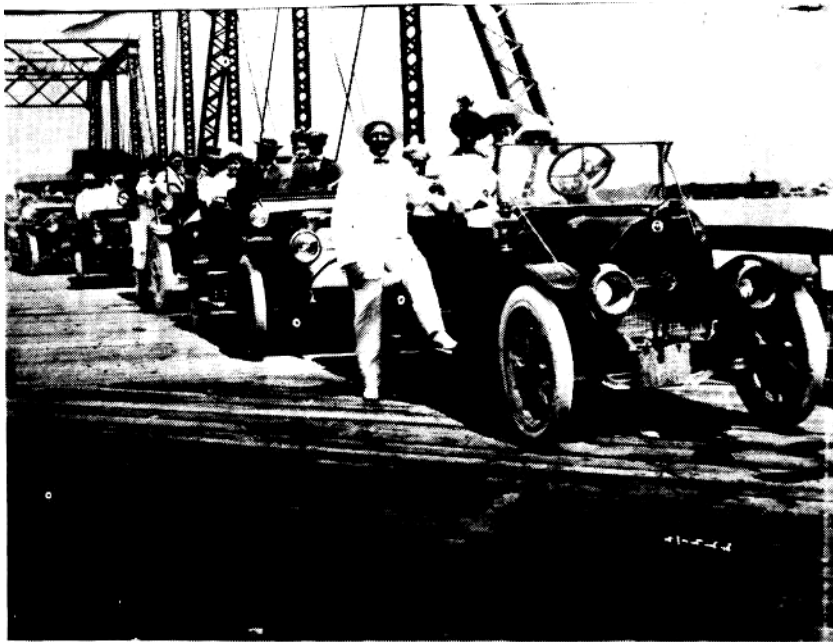


Figure 4. The first traffic across the bay on the Venetian Causeway, 1913.

population of Miami; developments, especially of choice property near the bay (Fig. 5 & 6), made great changes to the northern Bay by dredging 30

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**Figure5. The construction of Lincoln Road on Miami Beach, 1915, now in the heart of Miami Beach.**

major artificial islands, an intracoastal water way with many minor islands, causeway construction, and stabilizing structures (bulkheading and filling to the shoreline formerly populated- by the more fluid mangrove and seagrass ecology). One of the major problems of the sociology of urban development of the bay is that most of the land is in private hands and in small parcels; there is very little public access to the Bay. Single family dwellings are the major mode in South Biscayne Bay whereas multiple family units or office buildings have a major hold in North Biscayne Bay.

Economically, the county is quite dependant on the Bay. Our most important factor of the economy is tourism dependent on climate and aesthetics. It is fortunate that we have the wide ocean front beaches on Miami Beach and Key Biscayne and the nearby recreational facilities of the Florida Keys and Bahamas as well as the Gulf Stream (fishing & boating), which allow a large portion of the resident and tourist population to have contact with the ocean waters which takes pressure from use of the Bay by this influx of millions. The second major industry is the airlines a good portion bringing people to partake in the tourism; the third is the marine industry including shipping, cruise lines, boat construction and sales, marinas

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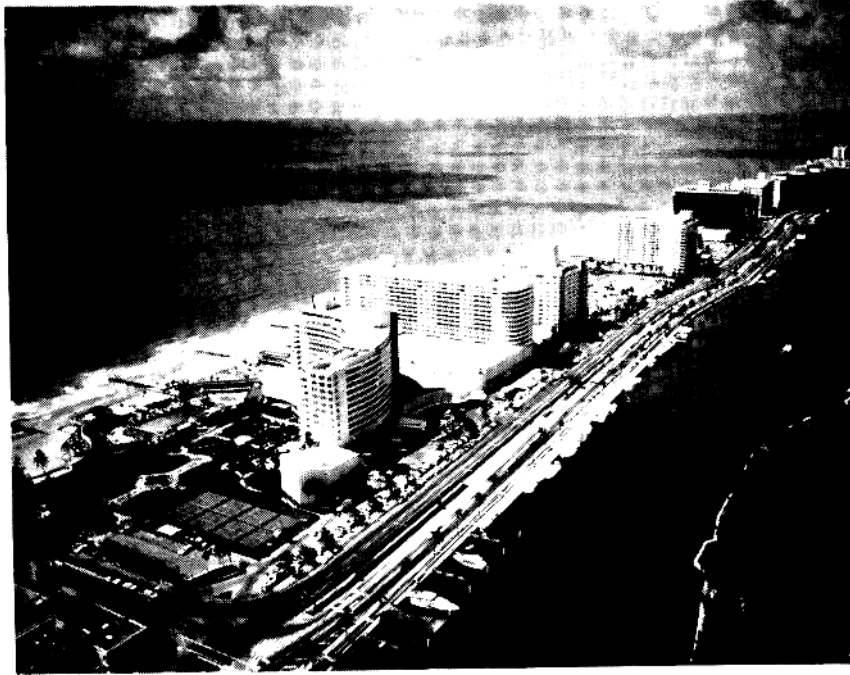


Figure 6. Fabulous Miami Beach in the 1970's, the fabulous "Gold Coast" near where Figure 5. was taken.

and many other related industries. Fisheries also are fairly important both commercial fishing within the Bay (most important are shrimp, silver mullet) and also an extensive sport fishery from bridges, shorelines, and large boats as well as small boats (lobsters, fish, shrimp and other seafood). Real estate and land development have always been an important part of the economy of Dade County. At present the 70 mile of bay shoreline is used in the following manner: 40 miles (66%) private; 3 miles (4%) public parks (state and county) with view access only; 1 mile (1.5%), sides of Rickenbacker Causeway (never intended for this purpose) public beach; 5 miles (7.5%) commercial marine - Port, Coast Guard base, etc; 14 miles (21%) unusable, (right of ways of Causeways, etc.) and not yet developed (large privately held tracts, chiefly in south bay) (BILHORN 1975). It should be noted that much of the eastern shoreline (the upper Florida Keys down to Key Largo) is included in "not yet developed". Above Key Largo, this area is only accessible by boat. Some of these economic uses of the bay have been in conflict with maintaining a high environmental quality; and in the case of North Biscayne Bay, environmental quality was directly sacrificed to economic gain.

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One area of Bay related economy has recently been studied (AUSTIN 1976). Recreational boating, highly dependant on the Bays resources, is an obvious conflict between the use of the bay for boating and the quality of the water and biota. There are 36,000 registered boats and only wet berth for 5,600 places; so the public boat ramps or lifts available are intensely used. Recreational use of the bay shows several categories of conflicts between users and uses of the bay's resources: 1). conflicts through geographical exclusivity where two or more activities cannot co-exist at the same place, 2). user conflicts through exploiting the same resource, such as sports versus commercial catch of lobster, 3). user conflicts through interdependent areas of natural resources, chiefly environmental quality versus marine recreational use.

Management of the Bay is complex, including overlapping jurisdiction between federal, state, regional, county and municipality authorities. Almost all of Biscayne Bay is within Dade County; in addition there are 11 municipalities bordering the bay. The land use itself is regulated by the municipality of Dade County, and in those places where regional impact has some influence South Florida Regional Planning Council also has jurisdiction. Central and South Florida Flood Control District have already made extensive changes in the land especially in the natural sheet flow of water in order to keep the water table stable so salt water intrusion does not occur further, to prevent flooding of lands which have been drained and to provide water for inhabitants (Fig. 7) (BUCHANAN & KLEIN - 1976). Some of this has had a detrimental environmental effect (THORHAUG *et al.* 1976). Water use itself is in many cases has overlapping jurisdictions between the various levels of authorities. Navigation of course, is mostly regulated by Federal agencies: Corps of Engineers, and the Coast Guard. Dredge and fill which has been a primary use of the Bay is complex including Federal (the Corps of Engineers, the Department of the Interior) the state, who own the land through the Florida Department of Natural Resources, (sometimes the Department of Environmental Regulations, the Florida Pollution Control Board) and then the county. A permit for any dredging or filling must include permits from all of these agencies, and are becoming increasingly difficult to obtain.

Water use in the section of the southern part of the Bay designated as the Biscayne Monument, (Fig. 1) (established in 1968 includes 96,000 acres) is managed in good part by the National Park Service of the U.S. Department of Inferior, through a strict legislative code of use with a fairly large staff to enforce it; propriatory jurisdictions prevail Much of the rest of the bay has been designated an aquatic park by the county (1974) and a State Aquatic

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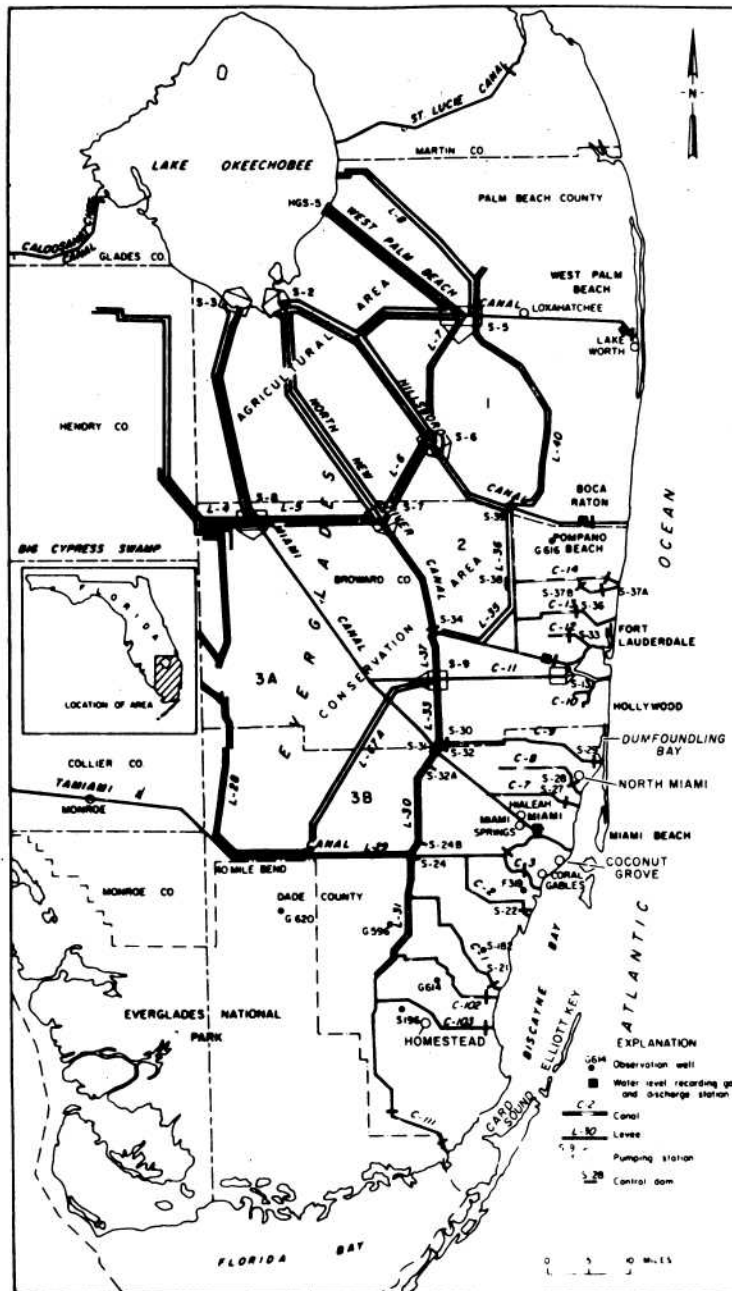


Figure 7. Central and Southern Florida Food Control project structures and hydrologic features in southeastern Florida (from BUCHANAN 1976).

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Preserve (established 1974), the management of which falls to both county and state.

Problems of management of the Bay have been discussed by BILHORN (1976): 1). There is an apparent insufficient capability at all levels of government to even monitor those actions which require permits, 2). The complexity of the permit process is because there are too many agencies involved; the many reviews require a great amount of time and effort; and there is a strong uncertainty of what is and is not acceptable, causing wasted effort; 3). Sound statistical information is lacking about many facts pertinent to management, 4). In addition, long term goals for management on all levels of government have not been formulated in sufficient detail with sufficient funding to implement them. 5). Lack of coordinations between governmental levels in policy has also been lacking. 6). Insufficient scientific input as to natural processes in the bay and how to avoid irretrievably altering them has hampered decisions.

In the early years of development of Biscayne Bay, user demands dominated. Several years ago, the pendulum swung, and conservation interests backed by new environmental protection legislation began to be articulate, persuasive and able at a legal level. In addition, funds became available for many studies of the Bay environments, (summarized in THORHAUG 1976). Both interests are now present at management levels, so that a new type of more informed and rational managerial capacity appears.

Legally we have a rather complex situation. There are plenty of laws to regulate usage; however the laws are not adequately enforced. There are overlapping jurisdictions between the various laws; there is a lack of coordination at the different levels of law enforcement; and many laws were not made with the view of a comprehensive policy oriented perspective. There has been little clarification of goals in terms of fashioning the laws, and also many of the laws were made before the present and future problems (which we now foresee) were fully understood. The complexity of the legal situation results in uncertainty as to extent of jurisdiction and as to the power of various governmental bodies. Often enforcement officers in agencies at local, state, or federal levels believe they are not entitled to exercise jurisdiction, when in fact they are. Coordination between enforcement levels needs improvement. Spotty and/or weak enforcement is another problem. However the existing laws do not provide all the answers, even if well enforced. Before laws and regulations can be fashioned clear cut goals for use of the Bay and management policies must be formulated (O'CONNOR 1976).

Previous lack of environmentally concern guidelines at the various levels

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of management, as well as weak enforcement of existing legislation to protect the environment has led to a series of actions which have totally disrupted the ecology of North Biscayne Bay and threaten that South Biscayne Bay may undergo the same fate. Artificial inlets, causeways and island construction have completely altered the physical regime in North Biscayne Bay (MICHEL 1976). Fresh water flow to Biscayne Bay through natural drainageways, overland flow and coastal underseepage has been significantly reduced in quantity and time due to extensive water management practices instituted since the 1947 floods. Ground water level recession rates are twice as rapid as before 1947, (BUCHANAN & KLEIN 1976). Although we do not yet have the full details or analysis of the chemistry of Biscayne Bay, there are considerable contaminants entering the Bay from urban runoff: sewage, oil and grease, heavy metals, and others (WAITE 1976). During the past 75 years, man has dramatically modified the morphology sedimentary environments and sedimentary dynamics of Biscayne Bay, particularly in the North. Creation of artificial cuts across Miami Beach, obstruction and modification to the natural sediment movement on the ocean beaches, dredge and fill projects for waterways and land fill, construction of drainage canals across marginal freshwater marshes, and increased turbidity are the major geological impacts (WANLESS 1976B). The biology of the bay has been severely altered by dredge and fill, change of drainage patterns, canal construction, sewage effluents, other industrial effluents such as heat and heavy metals, and potentially (although not yet studied) by petroleum and pesticide runoff, (THORHAUG *et al.* 1976). North Biscayne Bay is highly altered, while parts of far south Biscayne Bay remain fairly intact.

In the atmosphere of the above problems and capabilities for solutions, a series of steps are being undertaken at all levels of government to solve these problems. Federal, state, and county agencies are actively concerned and better funded to undertake and coordinate long-term planning and policy making activities. A better informed public has demanded its voice in decisions by a series of means reflected in environmental problems becoming front page headlines in local papers. Developers can now sit down with conservationists and discuss problems. A series of rather strong legal opinions are now being handed down from the courts to enforce new environmental legislation (MERTONS 1976). Yet, having focused on the conflicts and problems of management of Biscayne Bay no one is comfortable with the present state of management. Interests of all types feel that things will get much worse if left to follow past patterns.

Because of the conflicts the University of Miami Research Council

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supported by National Oceanographic and Atmospheric Administration (Sea Grant Program) and the U.S. Energy Development Research Administration held two Symposia on Biscayne Bay: first to summarize the present state of knowledge of natural and social sciences in Biscayne Bay, which was published as a book available to participants at the time of the conference (THORHAUG 1976A); second, to bring together various concerned segments of the community, who might otherwise not have a chance to communicate, in an attempt to come to rational alternatives on a whole range of pressing problems (including long-term goals and policies). The second objective was met via a two day decision making symposium which included participants from the federal, state, county levels, scientists, conservationists, lawyers, people from agriculture and industry and concerned members of the public meeting to discuss the questions of policy and priorities on many of the pressing problems. Small groups of 20 were formed to go over a prearranged list of topics in an American-assembly type meeting; concensus had to occur within the seminar itself. A policy statement on Biscayne Bay resulting from this group of 120 people, representing all interested sectors was published by Sea Grant (MCKENRY 1976).

The following represents highlights of this policy statement. A clean bay is an economic asset to the whole community. Increased access to the bay, when the use of the access has been approved with respect to its environmental impact, was urged (many access points for roads, viewing parks, bicycle trails, etc. have little impact on the Bay): It was urged that only water related activities be allowed on public water front property. Private developers will be encouraged to leave the shoreline in a natural state by buffer areas. Redevelopment plans for North Bay must include this and enforce height, density and spacing standards regardless of increasing waterfront costs. Tax relief or zoning "trad-offs" for developers to leave a vegetative zone were urged. Compartmentalization of the bay for uses was considered, but only action on a master use plan was recommended. Public education must be improved as to water safety and ways to implement this were suggested.

The group was divided into two opinions as to future management although clearly a better plan was urgent. Plan one called for a unified Bay authority with responsibility and enforcement powers. The other group felt within the given governmental structure one of four alternatives would be viable to coordinate Bay activities with the county initiating action to create such. Unlimited growth of Bay use is not compatible with a social and environmental policy of reducing destruction to the Bay. Water availability might be a limiting factor.

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There was a strong feeling that restoration, especially of North Biscayne Bay where intensive commercial and residential use had done a great deal to impoverish the water quality and the ecology of the bay, should be undertaken and this burden should be borne by the private, federal, state and county in equal parts. Restoration would include the mangrove fringe, the seagrass at the bay bottom and rip-rap which would include natural rock so the intertidal organisms would return.

The two symposia were an attempt to look at what we have gained in terms of knowledge of the bay and to ask where do we go from here in a bay bordering the tropics which as had extensive modifications including development, and population growth and yet retains a large part of the bay still relatively intact.

I would offer these symposia as a model of the type of effort in which developing nations might invest to begin properly to access the economic and social value, the future needs, and possible management schemes for their estuaries. The first Symposium, which was a summary of the state of knowledge in the form of oral presentations and a book (ready at the time of the conference) about the bay at present, served as a multidisciplinary tool to inform researchers, governmental officials and other interests about what we know to date and what important things we need to know to make rational decisions. A balanced research program to solve management needs can be composed from this. The book is a wealth of source material for multiple uses. The decision-making Symposia participants (from 4 small groups representing a cross-section of all concerned interests) had long arguments on many specific points, but finally came to a consensus of opinion about goals and implementation of action for better management of the bay. This use of the American-assembly type forum is urged for other communities and nations. The key to success is the selection of a group comprising all viewpoints of influential people involved in decision-making who will help to implement decisions reached. Trained moderators who can guide the group through the conflicts to conclusions is also vital. Careful prior formulation of only the key questions to be discussed is critical, as is the final written formulation of the concensus so that future action may be taken from it.

Our group now has a body of key people from various concerned segments of the community who are meeting on a regular basis to implement the conclusions, each responsible to report back at intervals on progress of their task. This continuation of effort is obviously a key point in the process of management.

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Up to this time we have spoken little of the "tropical" nature of our problem. The volume "Biscayne Bay" (THORHAUG 1976) is replete with examples and thoughts about tropical and subtropical characteristics. The tropics tend to be more fragile and easily disrupted and are not the "happy, mature ecosystems" as they were previously conceived (MOORE 1972, THORHAUG 1976C). In fact, they are often on the "brink of disaster" (MOORE 1972) where a small perturbation can cause ecosystem disaster. Attention has only recently been focussed on nearshore tropical areas, so that efforts, such as the International Symposium on the Ecology and Management of Some Tropical Shallow Water Communities (Jakarta, June, 1976) sponsored by the **INDONESIAN INSTITUTE OF SCIENCES** and the Western Naturalist Society, can serve to delineate and integrate knowledge of how tropical ecosystems work. The IOC Conference on Pollution in the Caribbean (Trinidad 1976) is another step toward this end, as was the First International Congress of Ecology in the Hague in 1974. (VAN DOBBEN & LOWE - MCCONNELL 1975)

The tropics, one of the most rapidly growing areas of the world, and especially their estuarine shorelines, where particularly intense growth is occurring, have their own sets of problems not always amenable to solutions used in the technology-rich temperate areas. We have presented this, in hopes that some of our problems and methods of solution will serve to help others with tropical estuarine management problems of ecological import.

In summary, the northern part of our Bay (North Biscayne Bay) is a "monument" to use. It has been ecologically decimated while the human population has grown tremendously; a great deal of it has been utilized to the point perhaps, of irretreivable damage; however, restoration attempts are now underway. In the southern part, a hard battle has been waged in an attempt to preserve and conserve the resources which are so important to the people as well as to the major industry of tourism, boating and which makes the shoreline real estate land values higher because of the clarity of the water and the naturalness which is preserved in the South Biscayne Bay for people of Dade County. The Southern part of the Bay is now an aquatic preserve and about one half is Biscayne Bay National Monument (U.S. Department of Interior, Park Service), where there are very strict regulations in terms of Biscayne Bay. Which pattern shall we follow?

Hopefully our conflicts resulting in the above-described model are of general enough value to be utilized by management groups in many other parts of the subtropics and tropics.

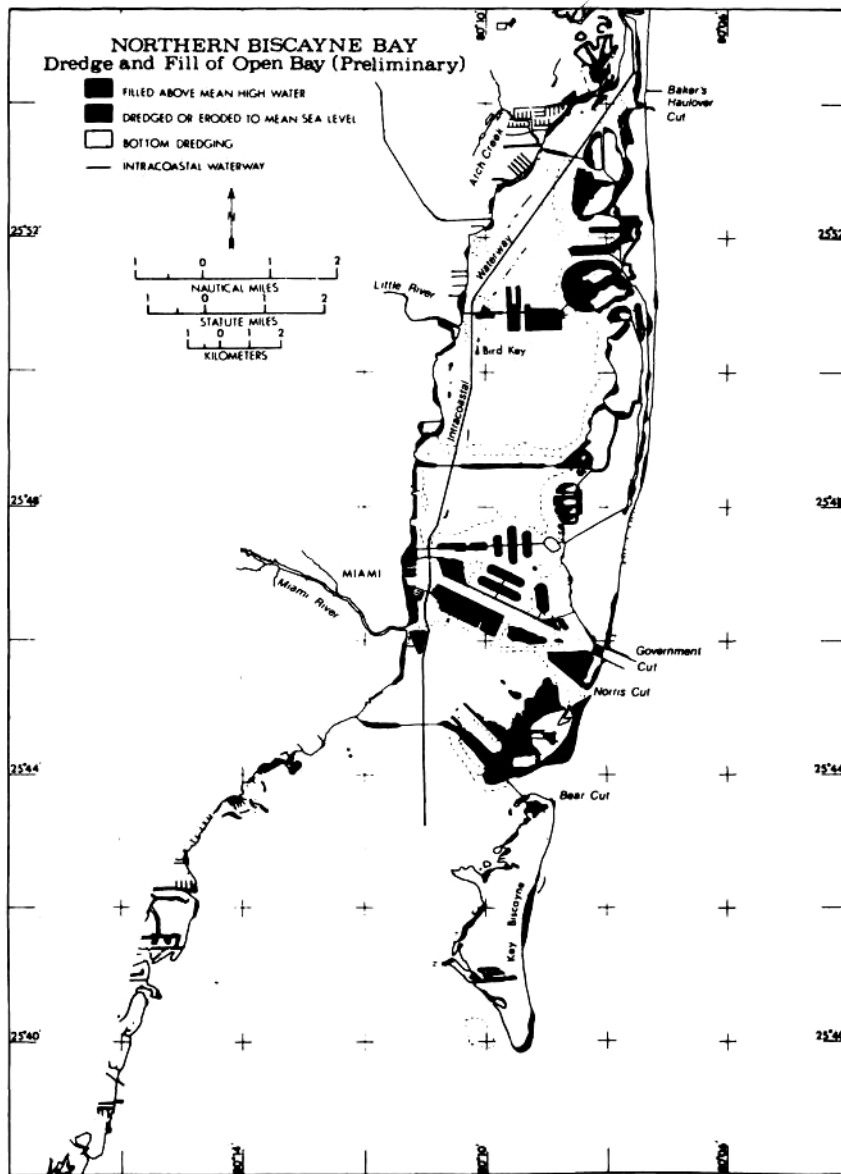


Figure 8. Northern Biscayne Bay filled areas (in black) (from CHARDON 1976).

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