MAN'S IMPACT ON THE BIOLOGY OF BISCAYNE BAY

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ABSTRACT

Biological pollution in Biscayne Bay is a problem requiring rational decision-making. Drainage patterns to the Bay have been altered leading to increased point-source drainage. Shoreline vegetation and vegetation at the mouths of canals has thus been altered. Canals themselves create new niches for marine organisms and microbial populations. Dredge and fill has had direct and indirect effects on the biota of Biscayne Bay. The primary example being the changes in flora and fauna of North Biscayne Bay. Sewage pollution has caused changes at outfalls. Problems of human pathogens (bacteria, viruses and fungi) associated with sewage outfall are still being studied and patterns of distribution are not clear. Heated effluents have been studied and provide a model of cooperation between industry, government and scientists in defining the problem, gathering data adequate for rational decision-making and finding compromise solutions to pollution of the bay. Pesticides, heavy metals and petroleum products have not been studied intensively in Biscayne Bay and their effect is not fully understood.

Our recommendations are for continued studies on the distribution of natural resources and basic research on energy flow and nutrient cycling in the food-web and the effect of pollutants to inhibit or alter the metabolism of the ecosystems of Biscayne Bay. In the interim we recommend that problems which require decisions should be reviewed by a board of scientists familiar with Biscayne Bay and whose specialties are in the area under discussion. These scientists should be paid for their services and responsible to the community for their input into the decision-making process.

INTRODUCTION

Pollution becomes a problem because living organisms are integrating the environment they live in. If the chemistry of the water is changed, the organisms respond to it. Response patterns also occur to changes in physical or geological parameters. Whereas a change in the biological organisms does not necessarily change the physical or chemical systems, changes to changing environment is a prime characteristic of the evolution of organisms over geological history; so that it is not only man's activities which cause drastic change, but rather change is an integral part of any living system.

The key is how much man can change the system and not alter it to become a less desirable ecosystem lies in the tolerance limits of the species present. The individual species are probably of less value than the role played by the species, but this is a decision-making value judgment for which we need a good deal of functional information on a scientific level. Each organism has a range of tolerance for a specific parameter and a certain point at which it cannot tolerate this parameter. As long as the changes are small and within the tolerance range, the organism will live. A similar pattern is seen for an ecosystem. The key to rational management is to understand these limits and to stay within them in the changes made to benefit man's use of the ecosystem.

In reviewing the history of Biscayne Bay, little thought has been given to staying within the tolerance limits of the ecosystem. We have numerous examples of man's uses of the bay which exceed the limits of the ecosystem. We will review the major ways in which man has changed Biscayne Bay and then present our suggestions for future use.

Much of the previous material presented in this volume outlines the major biological processes which occur in Biscayne Bay. Clearly each of the major constituents of the ecosystem have been effected by man's use and activities of the shoreline and the bay. We will divide the Bay up into shoreline, south, middle and north bay for purposes of description. The major changes in the biota of Biscayne Bay and its shorelines have resulted from drainage, from dredge and fill, from sewage pollution, from pesticide pollution and from heat pollution.

RESULTS

1. Drainage

Prior to major drainage activities in the greater Miami area, during 1900-1925, large quantities of rainwater collected in the interior flatlands called rocky glades and old drainage swales leading to Biscayne Bay. This flowed east until it reached the rock ridge which acted as a partial dam that formed impoundments in the swales. This older fresh-water storage head, which may occasionally have stood 4 to 6 feet higher than at present, poured over and through the ridge of limestone, now known as Miami Oolite, creating springs, seeps and surface runs all along the ridge and pushed the salt front far seaward of its present location (Parker, et al., 1955). Under those conditions fresh-water marl soils formed in the eastern "glades" and swales and over most of the coastal flat land between the ridge and Biscayne Bay.

Tequesta Indians occupied the site, perhaps as early as 2,000 years ago and left signs of their cultural evolution which still remain. At that time their view to the east would have encompassed broad, seasonally flooded, grasslands dotted with cabbage palm hammocks through which passed Arch Creek, Miami River, Snapper Creek and other streams. Large mangroves outlined the course of streams along the seaward end; pond apples and leather ferns probably formed a dense but narrow band in black soil at the seep zone along the eastern toe of the ridge. Cypress and other semi-aquatics grew around the lakes inland from the partially effective rocky barrier of the ridge itself. At very high stages of flooding, cataracts and large boiling springs flowed over barriers at low spots.

Seaward of the coastal marl prairie dominated by grasses there was a barrier forest of red and black mangroves of very advanced age and large size. Since those earlier times most of that early forest has been eroded away by storms and, perhaps, by a rising sea, so that by early 1926 only a small remnant remained. The great storm of September 18, 1926 seems to have destroyed the remaining old forest. The peats from that old forest still can be found under Biscayne Bay at least 600 feet east of the present shore (Wanless, 1969) and in pockets farther offshore (Zieman, 1972), (also Teas, this volume).

Pristine West Indian hardwood hammocks were to be found along the ridge wherever flowing water had carved sinks, channels and caverns. Most hammocks contained ferns, air plants and orchids, as well as other moisture-loving plants. Where the stone was more resistant, hence drier, pines, palmettos and live oaks grew.

In the mid-1800's white settlers came and built homes and gardens for much the same reasons that had attracted the earlier Indians. There was water in abundance, relatively dry, fertile hammock soil, and access by boat to the Bay via creeks. Earliest plantings of mangos, sapodillos and door-yard plants, which still persist were their legacy.

In 1912-13 the Snapper Creek Canal, Coral Gables Waterway, Cutler Canal, etc., were excavated. These canals quickly lowered the water table to near sea level. The lakes dried out and much of the marl soil was farmed. Later springs failed and salt intrusion became a problem. This culminated, in the 1940's by inland advance of the salt front by more than 800 feet per year, abandonment of coastal well fields and a cessation of farming in the coastal marl prairies. Installation of "salt-control" dams near the seaward ends of the canals halted and then reversed the saline intrusion inland, but could not halt the salting of formerly fresh-water marshes seaward of the ridge (see Kohout, 1960, 1967: Kohout et al., 1964).

The post-1940 salt front adjusted to a position near the "toe" of the rock ridge, helped no doubt by numerous farm drainage canals and canals cut during the decades between 1910 and 1940.

There has also been an apparent rise in sea level which, when combined with effects of drainage and loss of an effective coastal barrier berm, now permits tidal intrusion onto most of the Perrine marl prairie. It is not entirely clear to us which major event, rising sea level, diminished fresh water supply, ditching, or a combination of these, has actually dominated, but we believe that drainage was the major factor. The results has been a widespread invasion of the entire coastal tract by tide-disseminated mangroves and associated salt-tolerant animals (Teas and Wanless, this volume).

Prior to drainage the Perrine marl prairie fresh water phase (Figure 1) had sawgrass (Caladium jamaicenses), Gulf spike rush (Eleochris cellulosa),cabbage palm (Sabal palmetto),leather fern (Acrostichum), pond apple (Annona glabra), black rush (Juncus roemerianus), cattail (Typha spp),and primrose willow (Jussiaea peruviana). In the brackish phase of the marl prairie the above plants intermixed with bunch cordgrass (Spartina bakeri), saltmarsh cordgrass (Spartina alterniflora),buttonwood (Conocarpus erectus), white mangrove (Laguncularia racemosa), black mangrove (Avicennia germinans),saltwort (Batis maritima),glasswort (Salicornia begelovii and S. virginica), saltgrass (Distichlis spicata),saltmarsh fimbristylis (Fimbristylis spadicea) and sea-oxeye daisy (Borrichia frutescens).

Relics and living remnants of these plant communities still persist in undeveloped areas along the coast but farming, development and salt intrusion has generally destroyed most of the fresh water communities. Drainage of the swales westward of the ridge has reduced subsurface flow and the remaining hammocks are severely stressed. Ferns, bromeliads and orchids no longer obtain sufficient moisture to thrive, and even the trees show stress and replacement with drier species.

The water budget of Matheson hammock might be restored if a small canal were built from Snapper Creek Canal to the hammock edge and water thus diverted from Snapper Creek Canal allowed to flow through the limestone, via old solution channels, to the Bay. If this attempt at restoration were successful, other hammocks might also be restored in a similar manner. There are three reasons for the suggestion of diverting fresh water from existing canal systems to subterranean flow through hammocks. First, the hammocks would benefit from the increased humidity; second, the underground flow through forests and grassland would tend to "scrub" nutrients, pollutants, bacteria and virus from the water entering Biscayne Bay; and third, the point sources (canal mouths) of fresh water would be partially dissipated to the original spring and "sheet flow" conditions which were found in earlier times (see Kohout and Kolopinski, 1967).

Canals with saltwater intrusion have not received a great deal of scientific attention until recently and these investigations are still in press (see Sallman et al., this volume; and Seigel et al., this volume). The sediments and water as well as fish and certain other organisms are being studied with respect to their microbiology. Fish diseases such as "whirling fish" and fish kills have been reported with increasing frequency in the canals. Human bacteria and viruses (human viruses usually die in salt water) have been found in suprising numbers at times in these canals. The problem of these artificial drainage structures as a new biological habitat which opens to and mixes with the Bay for organisms presents a series of problems which are not yet clearly defined, nor resolved. (1) Drainage previously was sheet run off through shallow vegetation and rock, both of which altered the drainage water. Now drainage comes directly through much deeper canals and is point source run off. These deeper canals contain a different biological compostion. (2) Human and domestic animal microbes survive in the warm water of these subtropical canals. What is the fate of these microbes, and do they enter other animals, especially commercially fished species? (3) The flushing appears to be sluggish in these canals which are predominantly on the western shoreline, especially in northern Biscayne Bay where circulation has been altered significantly. However, larger animals such as fish can freely migrate back and forth from anal to Bay. (4) Much of the natural vegetation such as bottom grasses, fringing mangroves etc., was altered when the canals were constructed and often bulkheaded with fill behind the bulkhead. Often the area has not revegetated so that denuded areas frequently are found.

Hopefully, the studies underway can define the processes occurring in the canals and lead to better guidelines for managing these man-made additions to the Bay.

The interaction of the canals with the Bay ecosystem is complex and not fully understood.

A station in south Biscayne Bay located off Mowry Canal, at which trawling was conducted monthly from July 1968-December 1968, shows the dramatic effect of point source fresh water discharge. In August 1968 the dominant vegetation was the red algae (Digenia simplex)and the number and diversity of animals collected was high. In October 1968 salinity dropped to 5 ppt and the algae were killed. Table 1 shows the before and after discharge catches of algae and animals. The number of animal species decreased by about 50% and the number of individuals decreased by a factor of five.

A second station in south Biscayne Bay located off the mouth of North Canal shows the more subtle effects of point source drainage. Table 2 shows catches from a control station, the station off North Canal, a station located in the thermal effluent of the Turkey Point Plant and a mid-Bay shallow water station adjacent to West Arsenicker Key. Vegetation at the control was dominated by Thalassia testudinum and a complex of red algae; the station off North Canal was dominated by Halodule wrightii; the station in the thermal plume was dominated by microalgae, especially blue-greens in summer and the algae Acetabularia crenulata and Bataphora oerstedii and some Halodule in winter; and the mid-Bay station had Thalassia and Laurencia poitei (see Thorhaug, 1974a).

The catches show that the impacts of point sources of fresh water do not dramatically affect species richness but the numbers of mollusks and crustaceans were lower at the canal station. The heated station, likewise, showed little difference in species richness, although there were fewer kinds of mollusks and more kinds of polychaetes,echinoderms and flatworms. Numbers were markedly lower even though the catch per unit of effort reflects winter sampling and sampling after the effluent was diverted to Card Sound. The mid-Bay station shows greater species richness and most of the gain is in the relatively more stenohaline forms.

2. Dredge and Fill:

The most direct effect of dredge and fill, which includes channel and canal building, causeway and artificial island construction as well as bulkheading and backfilling, is to remove the bottom community in that area. Secondary effects include turbidity and decreased light penetration, causing bottom vegetation to receive less light for photosynthesis. In addition, silting effects on surrounding areas is often severe unless strict precautions are taken. There is an unfortunate cycle to these processes. The seagrasses, discussed by Thorhaug (this volume) as the dominant Biscayne Bay submerged vegetation, act to maintain water clarity and cut down turbidity by their baffling effect. However, seagrasses are often the major plant removed by the dredge and fill process and subsequent increased turbidity and siltation. Therefore, the baffle disappears and turbidity increases, often making it impossible for seagrasses to revegetate because of lack of light.

There are short-term and long-term dredge and fill effects. One additional station in South Biscayne Bay compared to those discussed above under drainage was located adjacent to Homestead Bayfront Park Marina Channel. It illustrates the effect of short-term dredge and fill programs. When the channel was deepened, silt from the operation reduced light penetration at the station. Grasses and algae showed temporary stress but recovery was rapid. Animal catches showed no detectable trends. Thus, this short-term dredge project did not create marked changes in the biota except in the immediate area dredged and filled.

A major long-term result of dredge and fill is continued turbidity and decreased light transmission, such as found in North Biscayne Bay (see deSylva, 1970), which will kill seagrasses and has a marked effect on the fauna. The works of McNulty (1961 and 1970) show the fauna in North Biscayne Bay to be dominated by polychaetes, brittlestars and mollusks. From Smith (1896), the photos of La Gorce (193 and Chardon (this volume) we may assume that North Biscayne Bay was similar to South Bay prior to 1900. Thus a comparison of the flora and fauna from north and mid Bay described by McNulty (1961 and 1970), McNulty, Work & Moore (1962a, 1962b), Moore et al., (1968), O'Gower and Wacasey (1967), Low (1973), and Rosenberg (1975) and that of south Bay by Voss and Voss (1955), Voss et al., (1969), Bader (1969), Bader and Tabb (1970), Bader and Roessler (1971, 1972), Smith (1973), Thorhaug (1974), Thorhaug et al., (1974), Roessler et al., (1974, 1975), Brook (1975), Sprogis (1975), Thorhaug and Roessler (1976) and Hixon (1976) can be used to demonstrate presumed changes which have occurred in North Bay. Also see papers in this volume by Teas, Humm, Thorhaug, Fenhale and Sprogis, Voss, deSylva, and Snedekar and Brook.

However, we cannot specifically identify the source of the changes in North Biscayne Bay because of the multiple stresses which include massive dredge and fill (see McNulty, 1970; and Compton, 1970), causeway and island construction and resulting changes in bottom communities and circulation, sewage pollution adding turbidity as dissolved and suspended solids, excess nutrients resulting in phytoplankton blooms and reduced light penetration for benthic plants, storm discharge from urban and suburban areas, industrial pollutants and increased erosion of shoreline areas from boat wakes.

The work of Rosenberg (1975) compares mid-Bay stations studied by McNulty, Work and Moore (1962) and McNulty and Lopez (1969) in the 1950's and the same area in 1975. The principle changes were an increase in the total numbers of animals m^2 in 1974 but a decrease in the biomass from the 1950's. Thus, more small individuals are present in the area. Animal diversity has increased and polychaetes have increased in abundance while mollusks have decreased. A shift toward smaller more generalized forms has occurred in the animals.

The bottom vegetation has not shown the same pattern. Originally, North Biscayne Bay had a relatively similar bottom vegetation type to South Biscayne Bay. By 1961, when McNulty published his extensive work the floral community had decreased in species and standing crop compared to South Biscayne Bay. Between this study and the present time, certain areas have become denuded of bottom vegetation (Roessler et al., and Thorhaug, unpublished). Unfortunately no quantitative study of the vegetation of North Biscayne Bay has been attempted, so that the above patterns are qualitative rather than quantitative.

In general, the North Bay area has a community of filter feeders such as barnacles, "coon" oysters, tunicates and sponges on piling and seawalls and of small-particle detritus feeders such as polychaetes and brittlestars. Few of the mollusks, crustacea and larger echinoids, that utilize the larger particles of seagrass and mangrove detritus found in abundance in the southern Bay now occur in northern Biscayne Bay. In addition, the clear water, stable salinity forms found near the Biscayne National Monument are absent further north. The middle reach of the Bay is intermediate in nature (turbidity being somewhat higher than in South Bay) and the trend here is toward the North Bay community. Anything more than a generalized qualitative comparison is hampered because a synoptic survey of the Bay with identical gear and methods has not been done except for studies of plankton by deSylva (1970) and the cursory survey of vegetation shown in Roessler and Beardsley (1975).

3. Sewage:

The major study of sewage pollution on the biota of Biscayne Bay by McNulty (1970) compared flora and fauna from November 1953 to July 1961. This was before and after a domestic sewage disposal plant began operation in the fall of 1956. Changes took place after the plant began operating. In an area 100 to 740 m seaward from the outfall benthic macroinvertebrate populations declined from abnormally large numbers of species and individuals to what McNulty calls "normal" numbers on the hard bottom. Soft bottom populations changed qualitatively, but not quantitatively. Zooplankton volumes decreased to about one-half the pre-abatement values. The amphipod tubes declined markedly, but other fouling organisms remained about the same. McNulty concluded that there was no evidence that improved commercial and sport fishing followed abatement, which he interpreted as a long-term detrimental effect from sewage pollution and dredging.

In microbiological studies, human pathogenic enteric viruses have been recovered in and around the bay. There are larger numbers in the sewage effluent area than of Virginia Key in North Biscayne Bay or Miami Beach (see Seigel et al., this volume). This is significant since viruses tend to die in seawater and still they are found in numbers.

Bacterial studies summarized by Saliman et al., (this volume) have shown survival of outfall organisms indicating the closer to the outfall, the higher the numbers. The warm waters allow longer survival and higher rates of multiplication of bacteria, presenting problems not encountered in northern waters.

D'amato has shown that even with the present Virginia Key outfall located 4,500 feet offshore that there is a significant movement of effluent into the Bay via Bear Cut, Norris Cut and Government Cut. Proposed pipeline extension evidently will not eliminate the problem. Proposed expansion of the plant further complicates this issue.

Other smaller treatment plants in Dade County contribute effluent to the Bay via canal systems. In addition, viruses have been found in canals in well-sewered areas, presumably from dogs and cats, further complicating the microbial problems in the Bay.

One of the major concerns lies in the safety of humans utilizing water for swimming, wading, etc., which has pathogenic microbial flora present. A second concern is the uptake of these microbes by fisheries organisms which may be eaten by man. The last major problem is the long-term effect of chemical enrichment by the outfalls in the sediment and water of the Bay and subsequent changes in the biota. Do lesser levels of outfall than that studied by McNulty have long-term detrimental effects on the biota? What are the tolerance limits of the Bay to moderate to low sewage pollution levels brought in by tides and wind conditions from ocean outfalls?

As the population of Miami expands, as does the tourist industry, further answers to these questions must be found.

4. Heat

Thermal effluents from industry have been emitted into Biscayne Bay since the Cutler Ridge Power Plant reached full capacity in 1956. This plant was only studied before the release of effluents by aerial photographs. The area which was denuded of vegetation in 1956 was 8.5 ha. By 1973 the area of bare sediment had reached 35 ha. Evidently, this plant acts as a sump for fine sediment. The relationship of this silt to destruction of bottom vegetation is not clear (Smith and Teas, 1976).

The most extensive study of the effects of heat has been done at the Turkey Point Power Plant complex. This is one of the only examples in Biscayne Bay, where the underlying tolerance limits of major organisms were studied along with the effects of the pollutant on the ecosystem. The data was utilized in rational decision making about the siting of the mouth of a second effluent canal.

It is to the great credit of the concerned governmental agencies as well as the industry itself that a final decision was made for disposing of effluents in such a way as to do minimal harm to the ecology of the Bay. In addition, the far-sightedness of the U.S. Energy Research and Development Commission (formerly AEC), Sea Grant, and Florida Power & Light Corporation allowed an opportunity to revegetate the 25 ha denuded by heated effluents. This is the only large-scale example of restoration of a seagrass community in the U.S. today, and provides a model for Biscayne Bay restoration efforts as well as throughout the U.S.

The Turkey Point plant did not have a quantitative investigation prior to the opening of the Grand Canal. However, the events after the initiation of heat were as follows: The Thalassia community disappeared in an area of about 9.3 ha off the mouth of the canal, 5°C above ambient. In an area of approximately 30 ha 3 to 4°C above ambient, the Thalassia community declined by about 50% and important macroalgae fell to about 30 of the former populations. As a result, selected entities of the animal population increased temporarily, due to feeding on dying plant material. After exploiting this food many mobile forms departed. This, coupled with strong current from the effluent removed considerable nutrients from the area, which then became covered with blue-green algae.

Increased temperature is not necessarily detrimental to a subtropical ecosystem: control and limitation in the essential factor. For example, in the areas were a +3°C isotherm was maintained the macroalgae and grass populations fell markedly in the summer as temperatures exceeded 31°C. However, during the winter months Thalassia rebounded. Comparatively speaking the +2°C isotherm was extremely productive, exceeding that of the control stations outside the obvious influence of the thermal plume. This may be due to a number of factors, the increased availability of nitrogen via decaying detritus, modification of circulation and elevated winter temperatures, etc. Regardless of the reason it does indicate that with sufficient understanding and adequate control, man's activities normally detrimental to the environment can be put to productive use.

The catch of animals correlated well with the data on benthic macroplants. Predictive models based on 350 species of animals caught with a 10-foot otter trawl over a period of two and a half years near the Turkey Point effluent indicate that maximum numbers of species and numbers of individuals of benthic macroinvertebrates and fishes will occur near 26°C. About half the species are excluded at 33°C, 75% above 37°C. Laboratory studies on the macrophytes show an optimum near 28°C. Laboratory investigation on lethal temperature limits corroborated filed data on both plants and animals.

Multiple regression analyses of dominant species of mollusks, echinoderms, and sponges indicated that the principle variables related to catch were vegetation and salinity. Those species most closely related to vegetation were near-shore forms, while those related most closely to salinity were offshore forms such as echinoderms, sponges, wormshell gastropods and the checkered pheasant shell. Analysis of variance of the mean number of animals per trawl drag (approximately $100/m^2$) indicated that areas elevated 4 to 5°C above ambient produced few specimens of those species of animals which comprised one per cent or more of the total number of macroanimals.

Stations located in areas elevated between 3-4°C had low numbers of animals in the summer, but showed some recovery in winter; however, the average annual standing crop was lower than at control stations.

At stations elevated between 2-3°C, the catches were low in summer, but high in winter and spring; this produced above average annual standing crops. At stations elevated less than 2°C, no statistical differences between controls and affected stations could be detected.

Analysis of total number of individuals of major taxa comprising 80 species of fishes, 147 of mollusks, 66 of crustaceans, 23 of echinoderms and 22 of sponges, showed similar results to those found for the dominant indicator organisms.

Preliminary results from studies of the Card Sound effluent canal, opened in February, 1972, indicated the effluent was 2°C above Bay ambient and carried a considerable load of suspended matter. In the immediate area of the canal mouth, the macroplant community in approximately 2-3 ha disappeared. In the area where the water contained noticeably more suspended matter, the seagrasses decreased in production of dry weight blade material from 20 to 30% that in 1971. Control stations increased 10% compared with 1971, probably due to a slightly warmer winter. However, the animal populations in 1972 at the affected stations were similar in abundance and diversity to those found prior to the canal mouth opening. (Thorhaug, Roessler & Segar, 1974).

A second 9.7 km canal was constructed to discharge heat into Card Sound, and the Grand Canal was closed. The decision of siting of the canal mouth was made by Florida Power and Light Company with input from scientists at the University of Miami, AEC (now ERDA), EPA and Department of Interior as well as state and county agencies. A study before, during, and after release of effluents from this canal was made (Thorhaug et al., 1976). Except in an area of 2 to 3 ha adjacent to the canal mouth, little damage to the benthic community was observed (Thorhaug et al., 1976). This was quite different from the effect of the first canal at Turkey Point and points out the benefits of rational decision with cooperative input from industry, government and concerned scientists.

The thermal tolerances for many of the major species affected by heat disposed in Biscayne Bay have been determined in the laboratory and correlated to field data (Thorhaug, et al., 1971: Thorhaug and Hixon, 1975; Thorhaug, 1976: Thorhaug and Hixon, 1976; Albertson, 19 ; Hoberg, 1975). This is one of the few examples where exact limits of tolerance have been ascertained so that decisions may be made based on quantitative data.

5. Pesticides:

Few studies have been made in Biscayne Bay as to levels of pesticides in the water. Meyer (1972) and Corcoran (unpub.) have found levels of certain chemicals such as DDD, DDE, dieldrin, PCB and Silvex. Present work of Sallman et al., (this volume) promises more data. Toxic levels in certain fishes and invertebrates have been studied at other locations both in field and laboratory. Qualitative indication of pesticide kills of marine invertebrates (Voss, this volume) are available, but no quantitative study has been done to date.

6. Other Pollutants:

Certain other toxic substances such as oil, heavy metals, radioactive materials, chlorine, etc., do enter the Bay waters and could be affecting organisms. Little is known on their affect on tropical or subtropical species or their distribution and levels in Biscayne Bay.

7. Restoration:

Since man's early activities in Biscayne Bay were carried out with almost total disregard for the marine ecosystem there are many areas where the only solution for a viable, natural bay is restoration. Many other areas are marginal and restoration efforts along with cessation of activities causing damage might bring back a natural community. Cost of restoration also provides a measuring stick for the cost of measures designed to ameliorate the pollutant in an area where the decision-making on a new impact is being made.

In general, the bottom and certain physico-chemical parameters must be suitable for restoration. The problem then is to restore the major vegetation to provide a suitable food, shelter and water quality base into which the animals may return. Restoration techniques presently underway in Biscayne Bay include seagrasses, mangrove and shoreline modifications such as rip-rap and less bulkheading.

Seagrass restoration is now possible on a large scale. Efforts in North and South Biscayne Bay (Thorhaug,1974; Thorhaug & Hixon, 1975) have shown that thousands of seeds have taken root and grown in areas previously denuded by man's activities. Thalassia, the dominant species in the Bay is most feasibly planted by seed, although a technique for plugging has been devised by the Florida Department of Natural Resources. Plugging has the following unfortunate features: (1) existing beds of seagrasses are utilized to obtain the plugs, thus doing damage (2) plugs do not expand laterally to create growing beds as do seeds (3) the present method is limited to water in which one can wade (4) prodigious amount of hand labor which creates a high cost per acre.

The seeding method of Thorhaug, has none of the above drawbacks. Optimum location for revegetation is a peaty sediment such as found along the Western side of Biscayne Bay. Studies show that areas of high current, extensive wave action or very coarse sediment are less optimum for planting; although these areas, once planted, are often excellent for expansion of the community.

Qualitative observations have shown a large recolonization of these replanted areas by certain invertebrates and fish which are members of the *Thalassia* community. No quantitative study has been undertaken in this area, but it is necessary to ascertain the restoration potential of the *Thalassia* community. Planting of other grasses is also underway.

North Biscayne Bay is capable of being restored in many areas based on our results at 10 stations. The best place to begin restoration would be between the 36th and 79th Street Causeways and work outward from this area.

Mangrove restoration is also a highly viable technique as accomplished by Teas (this volume) in a series of locations around Biscayne Bay. Propagules of three species have been planted in a series of locations including different bottom types, various energy regimes, tidal levels and geographic areas (including Viet Nam via helicopter). Success of growth and maturity has been high, so that a fairly extensive technology now exists in this area. It appears to be an excellent tool for restoration of shoreline in many Biscayne Bay areas.

Other methods for physical restoration of parts of Biscayne Bay have been mentioned in this volume which include causeway, canal, and shoreline modification. Most notable from a biological point of view is the discussion by Voss (this volume) on replacing bulkheaded sea walls by rip-rap. This makes a far better habitat for organisms and in some cases in Biscayne Bay has shown a lobster fisheries potential.

DISCUSSION

An intensive survey of biological resources in Biscayne Bay, especially North Bay would be a valuable first step in evaluating changes which have occurred. However, even these studies would not lead to the capability to predict changes in biota which will occur as the result of management decisions on use of the Bay. The basic processes (photosynthesis, detritus production, nutrient uptake and cycling through the biological feed web) must be learned first and then the effect of pollutants on these processes and tolerance limits of major organisms to each pollutant must be understood before impact can be quantified or predicted.

Thus basic scientific research in food webs, cycling of matter, flow of energy and effects on these systems by pollutants is needed. In the meantime, the advice of competent scientists must be sought and utilized in deciding if a proposed use of the Bay will be a biological catastrophy as predicted by the preservation extremists or an economic boon, comparable to introducing tourists to Florida, as claimed by backers of the proposed use.

In the event that hard management decisions must be made in the absence of the above-named definitive research, then such decisions probably can best be made using a review board composed of responsible laymen and scientists working together.

A recommendation for the intermediate period before a full scientific understanding is available for management is a review board of professional scientists balanced as to familiarity with various aspects of Biscayne Bay, who could evaluate permits for controversial projects if local and/or state scientists and developers could not agree. Such a panel should be paid for their time and must also be held responsible for their decisions so that proper decisions are rewarded and improper ones would be a liability.

ACKNOWLEDGEMENTS

The author would like to gratefully acknowledge the long-term support given to field studies of Biscayne Bay communities by ERDA (formerly AEC) Grants, for studies of macrovegetation and animal communities, and by EPA. Florida Power and Light Company has sponsored a series of investigations centering around the thermal effluent impact. The authors thank the University of Miami Sea Grant for publication of this volume.

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FIGURE 1.

Approximate 1940 boundaries and bay shore community types.

Legend

1 - **Tidal mangrove**

2 - **Marl prairie, brackish phase**

3 - **Marl prairie, fresh water phase**

4 - **High hammock**

5 - **Live oak/pine**

6 - **Pineland**

7 - **Marl swale, Snapper Creek Lake**

8 - **Rockland edge**

9 - **Sand**

10 - **Vegetated shallows**

11 - **Old tidal channels**

—— **Community margins**

⌒ ⁄ **Creek channels**

.... **Subaqueous boundaries**

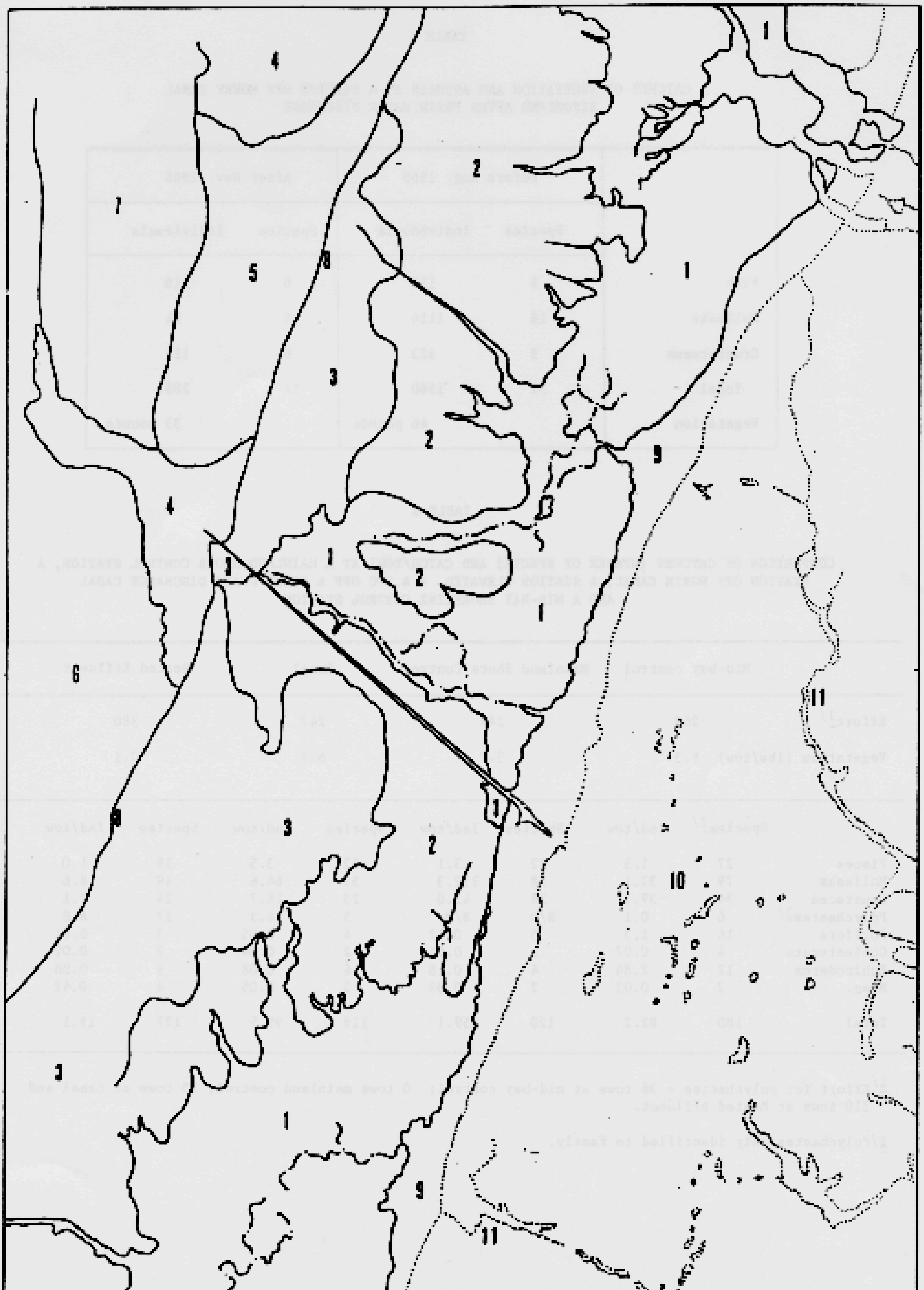

Figure 1

TABLE 1

CATCHES OF VEGETATION AND ANIMALS AT A STATION OFF MOWRY CANAL BEFORE AND AFTER FRESH WATER DISCHARGE

	Before Aug. 1968		After Nov. 1968	
	Species	Individuals	Species	Individuals
Fish	4	123	6	110
Mollusks	18	1114	5	54
Crustaceans	9	323	6	124
Total	31	1560	17	288
Vegetation		46 pounds		33 pounds

TABLE 2

COMPARISON OF CATCHES (NUMBER OF SPECIES AND CATCH/TOW) AT A MAINLAND SHORE CONTROL STATION, A STATION OFF NORTH CANAL, A STATION ELEVATED + 4.5°C OFF A POWER PLANT DISCHARGE CANAL AND A MID-BAY SHORELINE CONTROL STATION

	Mid-bay control		Mainland Shore Control		Canal		Heated Effluent	
Effort[1/]	268		247		247		380	
Vegetation (lbs/tow)	6.3		5.7		6.7		0.1	
	Species[2/]	Ind/tow	Species	Ind/tow	Species	Ind/tow	Species	Ind/tow
Pisces	27	1.5	22	3.1	22	3.5	19	1.0
Mollusks	79	37.1	58	112.3	57	64.6	49	8.6
Crustacea	34	39.3	28	43.0	23	26.7	24	2.1
Polychaetes[2/]	6	0.1	N/D	N/D	5	4.3	17	6.8
Porifera	16	1.3	5	0.47	4	0.05	3	0.01
Coelenterata	4	0.07	1	0.01	2	0.04	2	0.02
Echinoderms	12	2.84	4	0.18	4	0.08	9	0.88
Misc.	2	0.02	2	0.03	2	0.05	4	0.42
Total	180	82.2	120	159.1	119	99.5	127	19.1

1/Effort for polychaetes - 36 tows at mid-bay control; 0 tows mainland control, 35 tows at canal and 210 tows at heated effluent.

2/Polychaetes only identified to family.

APPENDIX A

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