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PD-AAW-316
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PROGRESS REPORT 4.

To the Office of Science Advisor
to the Administration

U.S. Agency for International Development
Washington, D.C.

U.S.A.I.D. Program Title
Seagrass Restoration in Caribbean Nearshore Areas

Grant No: DAN-5542-G-SS-2101-00

Submitted By

Department of Biological Sciences
Florida International University

Co-Sponsored By

Natural Resources Conservation Department
Government of Jamaica

June 30, 1984

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Rec'd in SCI: JUL 5 1984

PROGRESS REPORT 4.

SUMMARY

This project has been continued with on-site monitoring, data analyses, and by the preparations and presentations of scientific papers by Mrs. Beverly Miller and Dr. Anitra Thorhaug from January to June, 1984. Policy preparations for the Jamaican government for coastal vegetative mitigation was initiated during a visit by Mrs. Miller to the United States through discussions with personnel of U.S. Agencies engaged in permitting and mitigation. In addition, special training of Jamacian workers for large scale rehabilitation logistics occurred as a result of a simultaneous seagrass rehabilitation project in the Miami area for Dade County.

I. Scientific Presentations

Two scientific papers were presented on this project and the information utilized for a third paper at the Miami International Symposium on the Biosphere, April 23 - 24, 1984. Mrs. Beverly Miller presented the major results to date of this project in a paper entitle "Management and rehabilitation of coastal resources in the Third World: Jamaican model for seagrass restoration" at a session on Streams, Rivers and Estuaries (see attached). Interest of attending Third World scientists was evidenced by the numerous questions put forth requesting additional information.

Dr. Thorhaug presented new results from the Old Harbour Power Plant site in a paper entitled "Thermal pollution effects on an estuary in a developing nation: Impact and rehabilitation of seagrass" (see attached) The information from this study was also used in "Thermal effluents in the tropics and subtropics" presented at the International symposium on Protection of the Marine Environment from Thermal Effluents and Their Use in Zagreb, Yugoslavia, May 14 and 15, 1984. This information will be published in two parts: 1) Marine Pollution Bulletin in an article for enginners on heated effluent effects; and 2) Thalassia Yugoslavia, a scientific summary of power plant effects in the tropics.

A final paper from the project, "Seagrass rehabilitation in the tropics: Jamaica as a model for developing nations" is in preparation, pending the results of computer analyses from the monitoring phase.

II. Monitoring and Data

Two monitoring periods occurred, January and May 1984. The data are being prepared for the computer and analyzed at FIU. A multivariate analysis highlighting differences between the variables, pollutants, types of sites, seagrass species, planting techniques, and planting seasons will be available in late July.

III. Products from the Project During this Period

1. Mrs. Beverly Miller presented an overview paper, "Management and Rehabilitation of Coastal Resources in the Third World: Jamacian Model for Seagrass Restoration" at the Miami International Symposium on the Biosphere.

2. Dr. Thorhaug presented a paper on "Thermal Pollution Effects on an Estuary in a Developing Nation: Impact and Rehabilitation of Seagrass" at the Miami International Symposium on the Biosphere.

3. Dr. Barry Jupp is writing a paper on "Seagrasses of Jamaica".

4. Several final papers resulting from this project are in preparation:
   a) A final scientific paper based on the computer analyses of data for Nature.
   b) A policy paper for Environmental Conservation.

IV. Policy Investigations for Regulation of Seagrasses

Policy for the utilization of seagrass rehabilitation technology is now under consideration. Mrs. Beverly Miller and Dr. Thorhaug, after receiving policy and regulation documents from the U.S. National Marine Fisheries and State of Florida Department of Environmental Regulation, conversed with heads of agencies and agency personnel directly involved in permitting for seagrass mitigation at the federal, state, and county levels in April, 1984. All relevant policies have been reviewed, and the formulation of an appropriate policy for Jamaica is now under way.

V. Training

To date, training has consisted of instruction on seagrass rehabilitation for each of the seagrass species, specific teaching of three planting techniques, monitoring techniques, and general seagrass biology and pollution effects to NRCD personnel. In the planting and monitoring phases management skills also were taught. In the one acre planting of Halodule plugs, transmittal of techniques for logistics was begun. It became clear that logistic techniques for large scale rehabilitation needed to be transferred to NRCD personnel.

Simultaneously with the ending of our Jamaican project, Dr. Thorhaug received a contract for a 20 acre project of Phase II planting from the Port of Miami (Dade County, Florida). This provided an opportunity for training NRCD personnel in large scale planting. Mr. Peter Gayle, one of the chief NRCD people consistently working on the Jamaican project since October 1982, was selected to participate in the training program. In addition, a fisherman who also had worked with the Jamaican project during three planting and two monitoring periods was selected to determine if fishermen could be trained in management techniques and could be utilized on a long-term basis. Donovan Henry from Montego Bay was the fisherman selected.

Mr. Gayle is progressing well in learning the methodology of large-scale collecting and planting, field crew management, set-ups, equipment requirements, and test site selection. Mr. Henry has been able to work to the level of the U.S. collecting and planting team.

VI. Appendices

Mrs. Miller's paper
Dr. Thorhaug's paper
Seagrass rehabilitation policy

THERMAL POLLUTION EFFECTS ON AN ESTUARY IN A DEVELOPING NATION: IMPACT AND REHABILITATION OF SEAGRASS

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ABSTRACT

Four fossil fuel generators of 213.5 megawatts supplying greater Kingston produced thermal effluents that denuded a 12,398 m^2 area; a 8,000 m^2 area inhabited only by the seagrass Halodule wrightii gradually merged into the natural shoreline community of Thalassia. For the first time in any global location, seagrass was rehabilitated while thermal pollution was ongoing. The heat tolerant species Halodule wrightii was able to survive and coalesce in barren areas when restored, although the other two species, Thalassia and Syringodium did not survive. Thus, the heat tolerant species of seagrasses can be restored in continually emitted thermal effluents. This will help to replace the lost functional characteristics of the original seagrass communities.

1. INTRODUCTION

The effects of thermal effluents on a variety of ecosystems have been studied in detail for developed nations, most of which are in the temperate zone [1]. In a review for GESAMP (FAO)[2], only a few tropical nations had studied tropical or subtropical effluents. Puerto Rico, subtropical Florida, Hawaii, India, tropical Australia, Venezuela, and Guam were chief among these. The tolerance limits between lethal limits and summer ambient temperatures for fishes, invertebrates and dominant plant species in temperate ecosystems appear to be a greater absolute interval or "margin of error" than that of tropical and subtropical species' lethal limits to thermal effluents. Species of tropical and subtropical ecosystems live close to their upper thermal limits and are more effected by heated additions. It is apparent that much of the information gathered in the tropics has been in the U.S. territories, especially in Caribbean locations. Large areas such as Africa and Southeast Asia are without any quantitative indications of upper thermal limits of local plant and animal species.

Summarizing the information from the subtropical/tropical systems, the upper thermal limits for corals and seagrasses appear to be between 32 and 34^{0}C on a sustained basis. Frequently, summer effluents from power plants are in the range of 32 to 35^{0}C. Thus, large isotherms surrounding the power plant effluents are moribund.

Both field [3,4] and laboratory studies have shown a difference in upper temperature tolerance limits among the various species of seagrasses: Syringodium filiforme has the least temperature tolerance; Thalassia testudinum,

between 31 and 33°C; and Halodule wrightii, the highest.

No rehabilitation of thermally damaged seagrasses has ever occurred while effluents were still being emitted.

2. SITE

The Old Harbour Power Plant is located on the southwest coast of the Caribbean island, Jamaica. There are four turbines with generating capacities of 30, 60, 55 and 68.5 megawatts that were commissioned in 1968, 1969, 1971 and 1973, respectively. The coolant is circulated by two pumps for each turbine that can each pump 30,000, 54,000, 60,000 and 60,000 gallons per minute, respectively. The temperature of the discharged effluent is approximately 7-8°C above ambient. The power plant supplies most of the electricity to the Kingston urban and industrial area. A 212 m cooling canal from the plant delivers the effluents into the northern shore of a major southern estuary, Old Harbour Fig. 1). There is a fairly low degree of development and urbanization in this estuary. Two bauxite loading facilities, both several kilometers from the power plant are the only industries. Several small villages, primarily populated by fishermen, are scattered near the shoreline. Much of the Old Harbour area is relatively undisturbed mangrove shoreline with sublittoral seagrasses.

3. METHODS

3.1. Transects for Zonation

Starting at the mouth of the effluent canal and proceeding down the shoreline at 30 m intervals, measured transects were taken of community types in June, September, November (1983) and January (1984) by diver-biologists. The

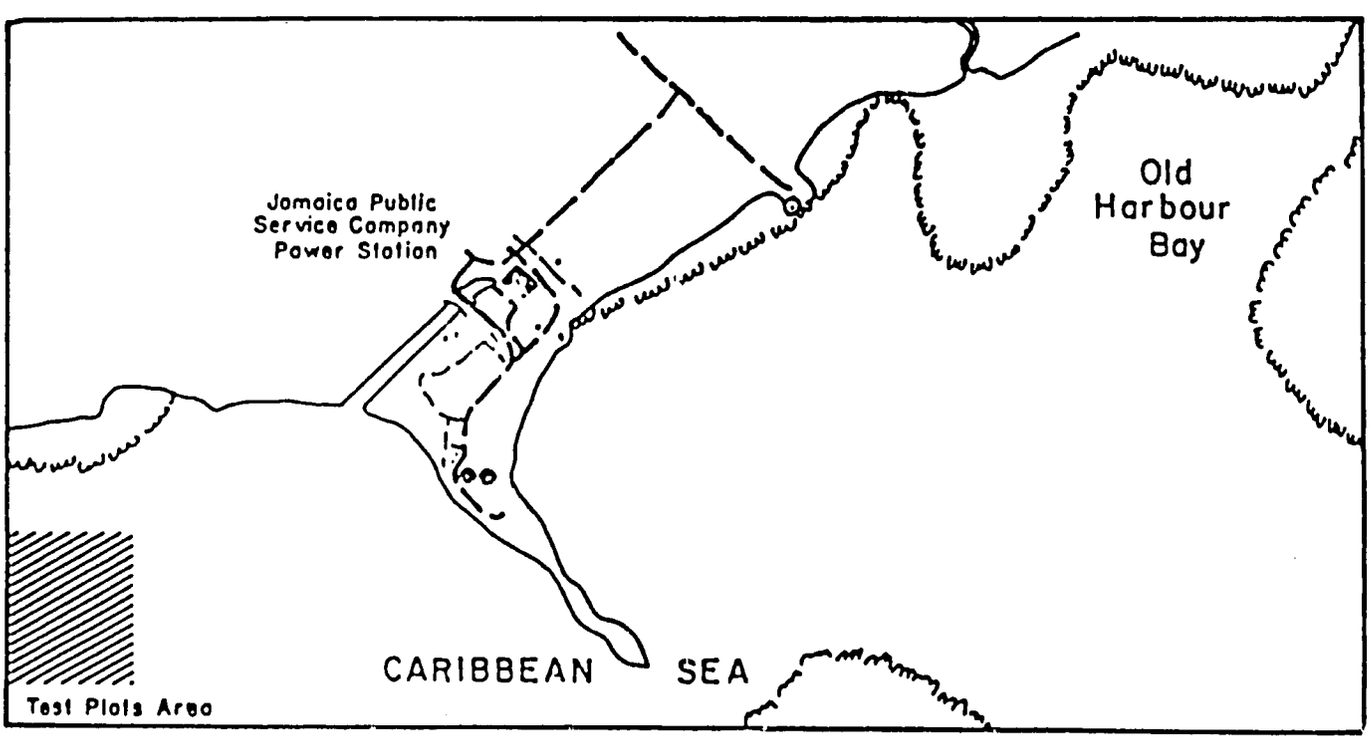


Fig. 1. Site of the Old Harbour Power Plant with Planting Test Plots Area Indicated.

dimensions of zones and dominant vegetation types were recorded.

3.2. Rehabilitation

Two transplantings in November 1982 and April 1983 at separate test plots were made in the barren to patchy Halodule zones of the effluent (Fig. 2). Each test plot had three species of seagrass transplanted by two methods. The plantings were at 0.9 m intervals within a 4.6 x 9.1 m subplot along transect lines so the transplants could be relocated. Earth anchors with attached buoys were placed at each corner for demarcation. Thalassia testudinum was transplanted by sprig and seed; Syringodium filiforme was transplanted by plug and sprig; and Halodule wrightii was transplanted by plug and sprig.

Monitoring of the test plots proceeded on an approximately 65 day basis from February 1983 onward. Monitoring included blade length, rhizome length, number of short shoots, number of rhizomes, number of seeds and physical/chemical parameters: temperature, salinity, light (Li Cor quantum light meter), dissolved oxygen, sediment type and current.

4. RESULTS

4.1. Physical/Chemical Results

Temperatures 185 m from the mouth of the effluent were recorded as follows: February 1983, 30°C; April 1983, 34°C; June 1983, 34°C; September 1983, 35°C; November 1983, 34.5°C; and January 1984, 33.5°C. Ambient bay temperatures on these same dates were, respectively: 28°C; 29°C; 28°C; 30.4°C; and 27°C.

The flow pattern from the effluent ran parallel to shore toward the west from the effluent for approximately 300 m before curving south toward the sea. This could clearly be ascertained by temperature, turbidity, surface patterns and ecological zonation. The effluent stayed 15 to 30 m offshore due to an uneven mangrove thicket along the shore, except when southeast winds pressed it toward the shore. The average width of the effluent was 80 to 100 m. Other data from the physical/chemical monitoring is seen in Table 1.

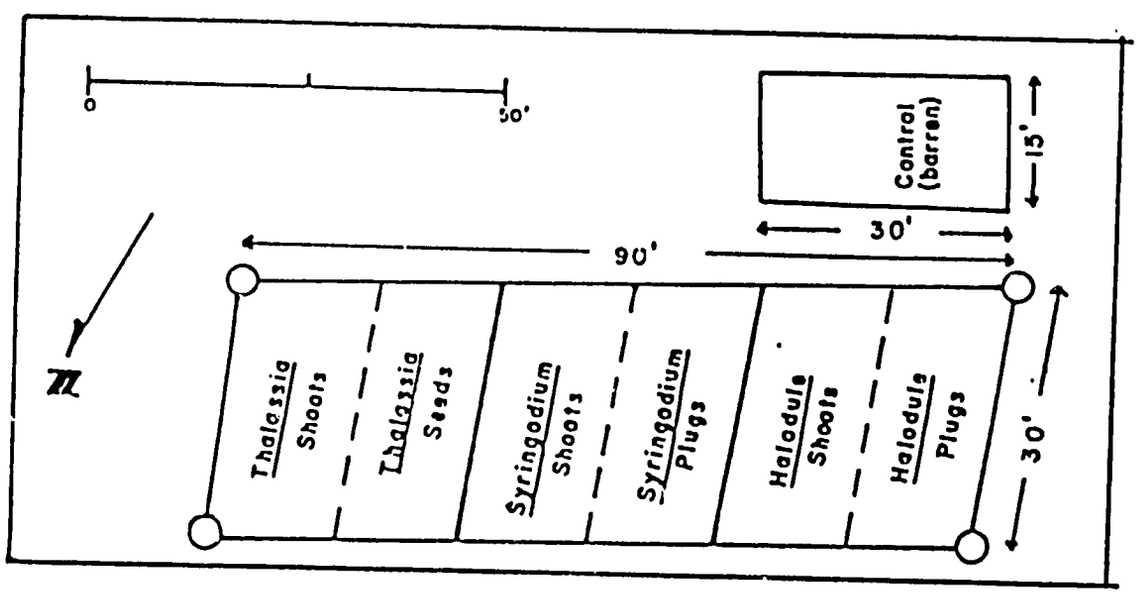


Fig. 2. Configuration of each test plot and its control.

Table 1. Physical/Chemical Parameters

	Temp. °C	DO ppm	Sal. o/oo	Current cm/sec.	Light Sur. QUA	Light Bot. QUA
February	30.0	6.6	33.90	4.0	340	310
April	34.0	6.8	36.20	7.0	---	---
June	34.0	5.0	35.90	0.0	235	80
September	35.0	5.4	36.30	1.0	270	150
November	34.5	6.4	34.90	---	200	125

4.2. Zonation of Vegetation

The natural vegetation along this shoreline was upper intertidal mangroves (Rhizophora mangle), lower intertidal Halodule wrightii, Thalassia testudinum about 100m, interspersed Thalassia and Syringodium filforme, then either Thalassia extending bayward or patchy Syringodium extending bayward.

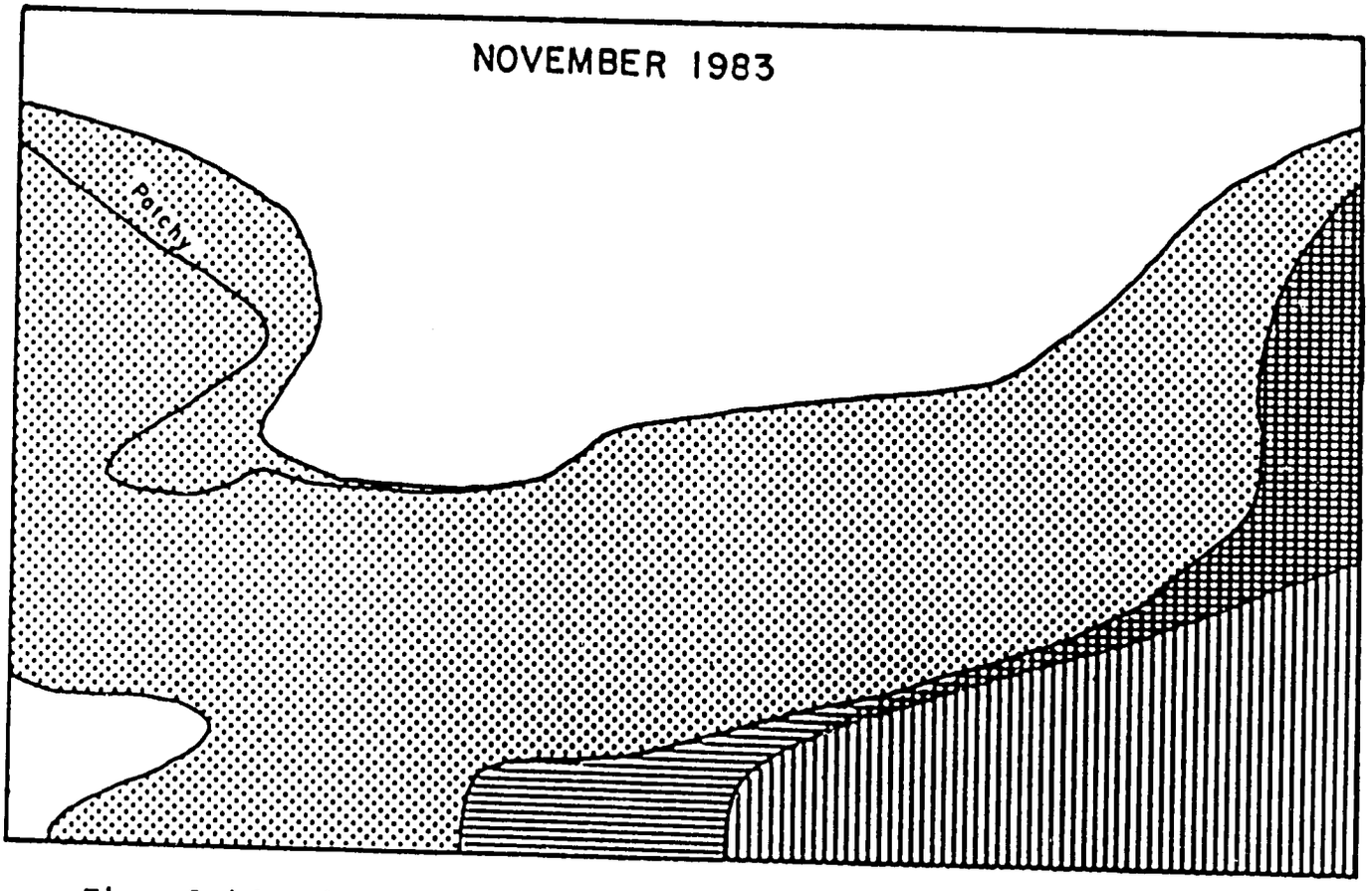
The thermally affected area had a totally different zonation. Areas formed isopleths based on outflow temperature. These were tongue shaped (Figs. 3, 4). Closest to the effluent canal mouth was a large barren area, 12,398 m^2. Next an area of patchy Halodule was found. This gradually merged into a Halodule zone, 7,729 m^2 in area. On the bayward side of the Halodule zone a mixed Thalassia and Syringodium zone occurred. This extended outward to a pure Thalassia zone usually. In some areas it was a pure Syringodium zone extending bayward (2000 shoot groups per m^{-2}). At the far end of the length of the thermal zone along the shore there was a mixed Thalassia and Syringodium zone, followed by a pure Thalassia zone (about 750 short shoots per m^{-2}).

The dimensions of the zones were somewhat dynamic depending on season during the study period (Figs. 3, 4). In the summer period when temperatures were 34 to 35°C in much of the effluent, the barren area was larger. In late fall and winter, Halodule began to invade the barren area and to coalesce and expand in patchy areas. Dense Halodule populations up to 2800 short shoots per m^{-2} could be found in the winter.

The restoration effort in the fall showed growth of both Halodule (plugs and shoots) and Thalassia, and some Syringodium growth. By summer, both Thalassia seeds and shoots as well as Syringodium had died. Halodule remained planted both as plugs and shoots. The spring planting showed less survival for Halodule and no long term survival for Thalassia and Syringodium (Table 2).

5. DISCUSSION

A classic pattern of tongues of isotherms which denoted benthic vegetation types of varying tolerance to heat resulted at the mouth of the effluent: bare area, patchy Halodule, thicker Halodule, then mixed Thalassia and Halodule, and



Figs. 3 (above) & 4 (below). Zonation of thermally effected area. Horizontal scale: 1" = 10'. Vertical scales: 1" = 100' (3) and 50' (4). Bare, Halodule; Thalassia, Syringodium; Mixed Thal/Syr

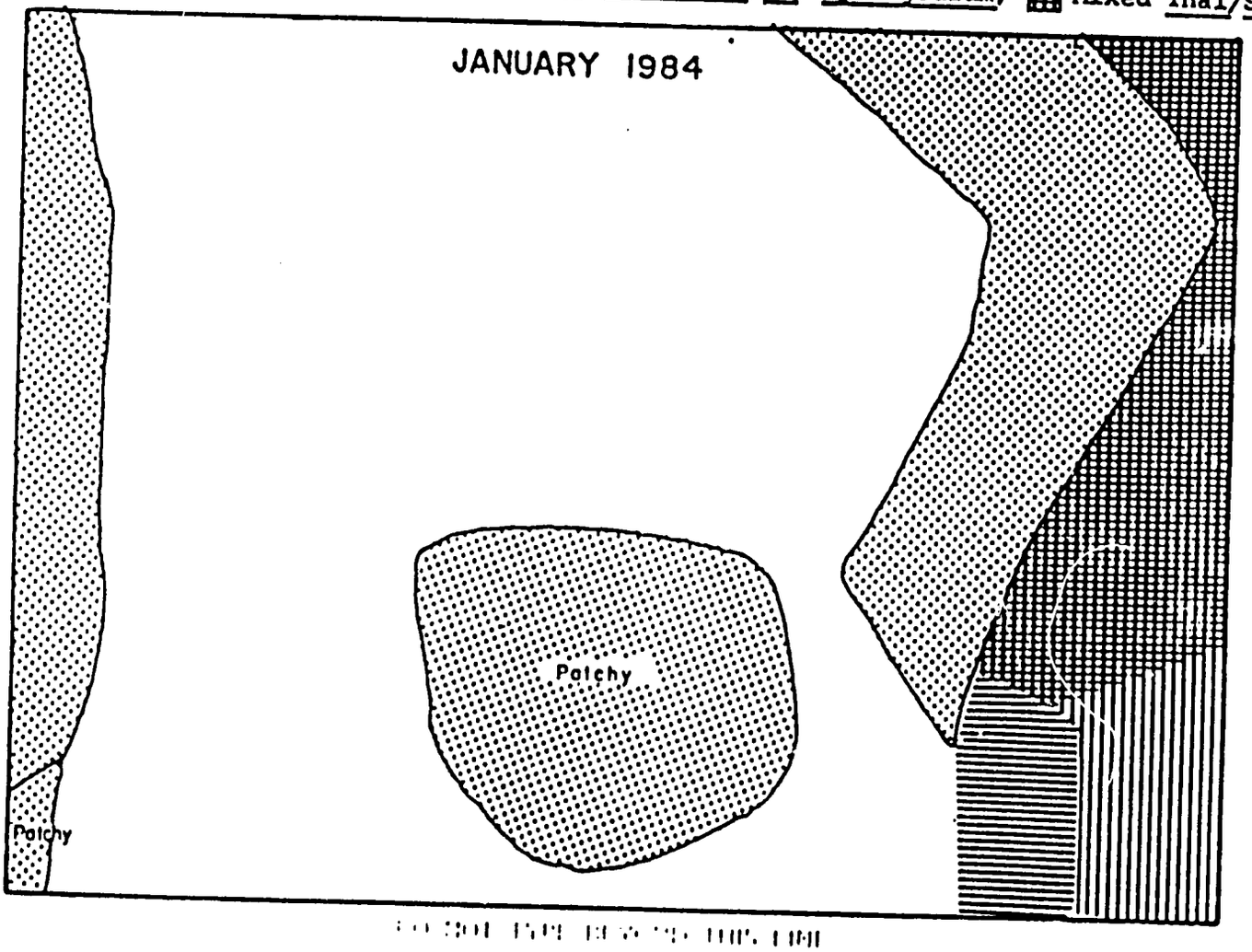


Table 2. Results of Growth Measurements for Three Species of Restored Seagrasses in a Thermal Effluent

HALODULE

	FALL												SPRING											
	Plugs						Shoots						Plugs						Shoots					
	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD
Jan	49	4	-	-	10	16	44	2	6	7	-	-	Not Planted Yet						Not Planted Yet					
Apr	46	7	-	-	8	25	4	0	0	0	0	-	Just Planted						Just Planted					
Jun	27	7	442	-	41	44	8	5	16	35	4	-	23	8	469	-	99	65	18	2	2	5	2	-
Sep	6	9	3	-	.3	2	19	8	16	-	-	-	6	10	18	-	.2	6	7	10	5	5	2	-
Nov	32	17	1128	-	-	85	16	16	1232	-	88	-	19	14	1602	-	-	85	14	6	10	25	4	-

THALASSIA

	FALL												SPRING											
	Seeds						Shoots						Seeds						Shoots					
	#	B	SN	RL	RN	S	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	S	#	B	SN	RL	RN	PD
Jan	9	3	2	-	-	1	27	1	2	8	-	-	Not Yet Planted						Not Yet Planted					
Apr	2	10	2	0	0	2	14	8	1	9	-	-	Not Yet Planted						Just Planted					
Jun	2	10	0	2	1	2	No Survival						Not Yet Planted						24	2	0	0	1	-
Sep	No Survival						No Survival						Just Planted						No Survival					
Nov	No Survival						No Survival						7	4	1	-	-	1	No Survival					

SYRINGODIUM

	FALL												SPRING											
	Plugs						Shoots						Plugs						Shoots					
	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD	#	B	SN	RL	RN	PD
Jan	No Survival						31	16	6	11	-	-	Not Yet Planted						Not Yet Planted					
Apr	No Survival						No Survival						Just Planted						Just Planted					
Jun	No Survival						No Survival						4	13	0	-	.7	0	No Survival					
Sep	No Survival						No Survival						No Survival						No Survival					
Nov	No Survival						No Survival						No Survival						No Survival					

B = blade length (cm); SN = number of shoots (m^{-2}); RL = rhizome length (cm); RN = number of rhizomes (m^{-2}); PD = plug diameter (cm); S = number of seeds.

finally Thalassia or Syringodium. This is directly comparable to other power plants in the tropics and subtopics examined and reported in estuaries such as Florida and Puerto Rico.

The first time any attempt at rehabilitation of vegetation with ongoing effluents was made at the Old Harbour power plant. This was successful. In the test plots we were able to substitute one seagrass functional group, Halodule wrightii which had a higher thermal tolerance, for the original ecosystem Thalassia which had a lower thermal tolerance.

6. RECOMMENDATIONS

My recomendation for preservation of estuarine resources of developing nations is not to use once-through cooling in estuaries. The best alternative is the siting of power plants for open ocean outfalls with pipes to put effluents into fast moving ocean currents or deep water.

Other alternatives for power plants presently existing in estuarine locations are canals directing once-through cooling to deeper, better flushed water with less fisheries nursery potential. This is cost-effective. More expensive solutions include cooling ponds, spray ponds, cooling towers and expensive pipelines or dikes. Dilution in estuaries usually carries problems of entrainment of fish larvae or plankton and therefore is not a suitable environmental solution.

It appears possible to restore heat tolerant seagrass species in the outer areas that are now denuded. This can increase fisheries areas, especially in the winter when effluents in the tropics range from 30 to 33^{0}C in their outer isopleths. It would probably not be cost-effective to attempt to rehabilitate inner isopleths while effluents were still being emitted.

ACKNOWLEDGEMENTS

I thank the U.S. Agency for International Development for supporting this research grant. I also thank the Department of Biological Scineces at Florida International University and the Natural Resources Conservation Department of Jamaica for sponsoring this research grant. Special thanks for restoration and field procedures are due Fitzgerald Booker and Peter Gayle. Gratitude is expressed for the cooperation received from Beverly Miller, Director, NRCD, who was co-principal investigator on this project, from U.S. AID, Science and Technology who was the principal sponsor, and Florida International University and the Ministry of Science, Technology and Environment who also served as sponsors.

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MANAGEMENT AND REHABILITATION OF COASTAL RESOURCES IN THE THIRD WORLD: JAMAICAN MODEL FOR SEAGRASS RESTORATION

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ABSTRACT

The Global Conservation Strategy launched by the United Nations Environmental Program emphasized the importance of wise resource use and management of coastal resources. The Caribbean Action Plan signed in 1982 pointed out the importance of coastal resources to environmental health of the Caribbean. Some developing nations such as Jamaica already had realized the importance of their coastal resources. Jamaica has approximately 200 miles of coastline which is fringed by mangrove forests and beaches, has large seagrass meadows and offshore corals.

In the process of development of urban centers, infrastructure, and industries, tens of thousands of acres of seagrasses have been decimated. An important step in making seagrass resources and their fisheries nursery function sustainable was to transfer the technology of seagrass rehabilitation to Jamaica. It had never before been attempted in the tropics or the Third World.

A set of 20 test locations for seagrass rehabilitation was jointly decided upon, including various portions of the coastline, various major types of pollution impacts and different environments (open ocean, coastline and estuary). At each site, the major types of seagrasses found in the area were planted. The results of this project show that the technology of seagrass rehabilitation can be transferred to the tropics. Test plots grew well on a variety of impacts. In some cases, seagrass beds coalesced in four months.

1. INTRODUCTION

The "World Conservation Strategy" (IUCN, UNEP and WWF, 1980) launched and signed in March, 1980 by Jamaica, as well as many other developing nations, emphasized under priority requirements for life support systems, the following natural resources management policy:

> "Ensure that the principle management goal for estuaries, mangrove swamps and other coastal wetlands and shallows critical for fisheries is the maintenance of processes on which the fisheries depend."

Following the "World Conservation Strategy", the Regional Seas Program for the Caribbean Action Plan carefully drafted for the Montego Bay, Jamaica meeting in March, 1981 and signed in Cartegena, Colombia in March, 1983, emphasized that

the Caribbean Islands were essentially coastal areas. It also emphasized the need for research on mitigation of coastal resources in the face of development impacts (UNEP/CEPAL, APCEP 13/5.4., 1980).

Jamaica has taken these guidelines seriously and is the first developing nation in the world to attempt to rehabilitate "shallows critical for fisheries", that is seagrasses, in Jamaica's attempts to preserve for future generations the natural resource of fisheries nurseries in the face of national development.

Jamaica, the second largest island nation in the Caribbean Sea, has approximately 330 miles of coastline which is fringed by mangrove forests and beaches, has large seagrass meadows and offshore corals, as well as extensive coastal plains backed by a major mountain range. Large estuaries and bays have long made this an extremely attractive island.

Development has occurred almost since Christopher Columbus discovered the island in 1494, and has been steady since Britain seized the island from Spain in 1655. Estuaries were made into ports around which cities developed. Large plantations were created from coastal plains and upland forests. Bauxite and limestone (for cement) have been mined intensively with loading ports built along the coastline. Infrastructure such as causeways, roads, bridges, airports, ports, power and sewage treatment plants also have been built on the edge of the coastline causing shoreline and subtidal damage. Effluents of sewage, chemicals and urban run-off have historically been discharged into the estuaries around which the major urban centers were developed. Tourism is a major industry that uses the natural resources, beaches, reefs and seagrass meadows, but this is confined mainly to the north and west coastlines. Fisheries historically have been an important protein source for the island's inhabitants.

The Natural Resource Conservation Department of the Ministry of Science, Technology and Environment has the responsibility for creating policy, regulating, planning and doing scientific research on environmental resources in Jamaica. The investigation reported here was a portion of their plan to bring the important resources of estuarine and offshore seagrass meadows into a sustainable balance for the future. The "World Conservation Strategy" estimated that the cost of damage to U.S. marine fisheries caused by degradation of coastal wetlands has been almost $86 million a year (IUCN et al., 1980). Seagrasses play an important role in coastal processes by serving as a fisheries nursery, controlling erosion and by providing a matrix for habitat for coastal ecology.

In the process of development of urban centers, infrastructure and industries, thousands of acres of seagrasses have been decimated in Jamaica. An important step in making seagrass resources and their fisheries nursery function sustainable was to transfer the technology of seagrass rehabilitation from the United States, where it is required on a regular basis for development, to Jamaica as a model for the Caribbean. The techniques have never before been attempted in the tropics or the Third World.

This was a completely cooperative program among the U.S. Agency for International Development, Jamaica's Natural Resources Conservation Department (NRCD) and Florida International University (FIU). All were highly cooperative parties in planning the original design of the program, contributing many ideas to solve problem areas of development to be investigated and facilitating the operation of the project. It is indeed a model of cooperation and two-way flow, and creation of new knowledge between a developed and a developing nation. The high level of ecological knowledge and training of NRCD technical staff and director was as important a factor as the seagrass restoration knowledge of FIU personnel. The joint knowledge of future development problems of NRCD and U.S.

AID Kingston Mission was important to formulating sites of future usage of this information.

2. METHODS

2.1. Site Selection

A joint team from NRCD, FIU and UWI selected sites where developmental impact had occurred. Criteria were: 1) aerial photos, literature or interviews showed that seagrasses had existed prior to impact; 2) sites be scattered around various parts of the Island; 3) major types of present and future development be represented. After a long list of sites were compiled and examined, a feasible subset of sites were finalized. Within each site location appropriate areas for test plots were selected by the restoration biologists.

2.2. Test Plot Setup

The test sites usually measured 27 x 9 m; the long dimension was divided to make six subplots 4.5 x 9 m. Each of the three species of seagrass was planted in two adjacent subplots. A different planting technique was attempted in each subplot. The four technique variables were plant seeds, roots, plugs and anchors; with plants installed in a 0.9 x 0.9 m matrix. Each subplot contained 50 planted units except where noted. Plots of similar size were designated as controls at each site.

2.3. Planting

Both fall and spring planting were carried out to test feasibility. Three species were planted at each site, each by two methods. A joint U.S.-Jamaican team of biologists and fishermen were utilized in the planting efforts.

2.4. Monitoring

Sampling at each consisted of counting all the surviving planted units and measuring 25 percent of the planted units (every fourth plant) for length of blades, rate of rhizome laterial growth, number of blades per shoot, rate of blade growth and coalescence of plantings into homogeneous cover. Measurements were made along line transects set over the planted rows. Physical, chemical and biological parameters that had been noted in the preplanting survey (location, depth, sediment depth and type, indigenous seagrasses, dominant algae, visibility, wave energy regime and current) were noted during the monitoring. In addition, oxygen, light penetration, salinity and temperature were measured. Sediment cores were taken from selected sites for hydrocarbon residue and trace metal content analyses. Monitoring periods were approximately 60 days.

3. RESULTS

3.1. Dredge and Fill

This was the most successful impact type in terms of success of seagrass rehabilitation. All three species survived and grew successfully in former

dredge sites on both north and south coasts.

3.2. Bauxite Sites

Although bauxite was evidently continually being emitted at periodic intervals from ship loading facilities, Thalassia in particular did well in survival and growth at these sites on bith the north and south coasts.

3.3. Thermal Pollution

One species only, Halodule wrightii, survived and grew in the thermal plume where effluents were being emitted.

3.4. Artifically Constructed Industrial Lagoons

While the salinity range was below 60 o/oo, Halodule wrightii survived. Found in the lagoon was a fourth seagrass, Ruppia. It should be noted that the period of study took place during a 55 year drought on the central south coast of Jamaica where the lagoon was found. Therefore, lagoons must be tested for upper dry season salinity. Basically, survival could be expected under more normal rain conditions.

3.5 Riprap and Jetties

Behind artifivally jettied areas restoration of seagrasses worked differently. One area exhibited high survival for Thalassia and Halodule, whereas another, with river discharge as an additional factor, failed completely.

3.6. Erosion

Repeated work was done on the north and south coast erosion sites using a wide variety of anchors. At certain medium erosion sites the Thalassia (seeds with heavy anchors and well-anchored sprigs) survived moderately well. At the highest energy site low survival of Thalassia occurred.

3.7. Cement Trailings

The site was a land fill of cement tailings into Kingston Harbor. Continuous wind-blown fine particles were entering the site when the planting took place. The submerged slope from this fill was very steep and composed of these fine particles. This site failed for all species.

4. DISCUSSION

For the first time in any developing nation, and for the first time in the tropics, seagrasses, essential to tropical fisheries nurseries, have successfully been rehabilitated from a variety of impacted sites. Dr. Mustafa Tolba, Director of the United Nations Environmental Program recognized this program and its success as a contribution by Jamaica to the world environment in his "Earth Day" address, delivered from Jamaica in June, 1983.

However, the problem is not yet solved. Development is proceeding rapidly in Jamaica. Yearly impacts by oil spills, infrastructure and other urban development and coastal industries are still damaging seagrasses. Plans are underway in Jamaica to begin to solve this particular coastal management problem. Coastal mapping of seagrass resources is being planned. Consideration of policy, regulations and implementation to protect and mitigate seagrasses is now underway at NRCD. A large scale restoration project to rehabilitate an impacted fisheries nursery, using the trained NRCD staff and fishermen, is being planned between U.S. AID and NRCD. The NRCD staff is being trained in large scale mitigation logistics in the world's largest seagrass rehabilitation program in Dade County, Florida, for the Port of Miami (251 acres of seagrasses).

In summary, the technology for seagrass rehabilitation has been tested and transferred to Jamaica. Since other Greater Caribbean nations have the same species of seagrasses with equivalent fisheries nurseries associated with them, similar environmental conditions and similar developmental impacts, this can be considered an extrapolatable model for the Greater Caribbean basin. Plans are now underway to utilize this technology in coastal management by NRCD.

5. A REVIEW OF APPLICABLE POLICIES FOR FISHERIES NURSERY PROTECTION AND COASTAL WETLAND MITIGATION

5.1. International Policy

"World Conservation Strategy".
5.7 "Ensure that the principal management goal for estuaries, mangrove swamps and other coastal wetlands and shallows critical for fisheries is the maintenance of the processes on which the fisheries depend."
7.7 "Maintain habitats of resource species."
"Caribbean Action Plan".
"To determine the impact of coastal development activities and land use on the ecological integrity of coastal swamps and lagoons in order to develop guidelines for conservation, management and recovery of these resources."

5.2. Federal U.S. Policies

National Marine Fisheries Services (NMFS). Habitat Conservation Policy (1983)
"The goal of NMFS activities will be to maintain or enhance the capability of the environment to ..., maintain fish and shellfish populations which are used ... (see appendix for complete policy)". "At a minimum, Fishery Management Plans should include identification and descriptions of habitat requirements and habitats of the stock(s) comprising the management unit; assessment of the conditions of these habitats, to the extent possible, as they relate to the continued abundance and distribution of the species; identification, where possible, of causes of pollution and habitat degradation; description of programs to protect, restore, preserve and enhance the habitat of stock(s) from destruction or degradation; and, where appropriate, proposal of measures intended to preserve, protect, and restore habitat determined to be necessary for the life functions of the stock(s)."
National Environmental Policy Act.
"Every federal agency shall consider ecological factors when dealing with activities which may have an impact on man's environment."
Federal Legal Background. The legal background for mitigation is found in statutory programs dealing with conservation of fisheries and wildlife resources

includes the Clean Water Act § S 402, 404, 102 (b, 303), Coastal Zone Management Act, program authorities of the Federal land managing agencies, Water Resources Planning Act of 1965, Federal Power Act, program authorities of NMFS, NOAA and EPA, River and Harbor Act of 1973, NEPA, Endangered Species Act of 1973, several authorities of the Corps of Engineers, FWCA, Etc.

Mitigation. In the 1958 amendements to FWCA, Congress provided authority to the federal water project agencies to modify or add fish and wildlife mitigation and enhancement measures to the structure and operation of such projects.

5.3. Proposed Florida State Policy

403.--Mitigation

"(1) It is the policy of this state to preserve wetland functions. The object of mitigation shall be to alleviate unavoidable loss of wetlands and estuarine systems, but not to justify the destruction of wetlands.

(2) For the purposes of this section, mitigation shall mean:

(a) avoiding the impact altogether by not taking a certain action or parts of an action;

(b) minimizing impacts by limiting the degree or magnitude of the action and its implementation;

(c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

(d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; or

(e) compensating for the impact by replacing or providing substitute resources or environments.

Mitigation shall not include payment of fees in lieu of other measures, dedication of land to natural uses, transfer of land or easements into public ownership, or the creation or restoration of wetlands not similar in nature to those being damaged.

(3) When deciding whether to issue a permit to dredge or fill pursuant to this chapter or chapter 253, the department may consider mitigation proposed by the applicant. Mitigation may be considered only after a dredge or fill activity has been proposed in a manner that minimizes loss of wetland functions to the greatest extent practical.

(4) The department shall not issue a permit to dredge or fill if the permitted activity, as mitigated, will result in a flat loss of wetland functions."

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the suport of the U.S. Agency for International Development, the Ministry of Science, Technology and Environment's National Resources Conservation Department, and Florida International University for support. We were particularly grateful to have a great deal of cooperation from the administrators in charge of the grant: Drs. Asher and Miners, Science and Technology U.S. AID, Washington, D.C.; Dr. James Smith U.S. AID, Washington, D.C.; Mr. Dan Rathburn, Mr. Tapper and Mrs. Ross, NRCD; Dr. T. Breslin, Miss K. Kennedy and Mrs. H. Walsh, FIU; and Dr. G. Sidrak, UWI. Extremely helpful discussions with Dr. Mustafa Tolba and Dr. Noel Brown, UNEP, are also gratefully acknowledged. The technical assistance of Dr. B. Jupp, UWI, Peter Gayle, Barbara Chow and Everton Kelly of NRCD and Mr. W. Davis, U.S. .S., and Miss E. Thomas, NRCD, Kingston were enormously helpful in creating media coverage which generated public awareness.