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PROGRESS REPORT 3.

To the Office of Science Advisor
to the Administration

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

Program Title:
Seagrass Restoration in Caribbean Nearshore Areas

Grant Number: DAN-5542-G-SS-2101-00

Submitted by:

Department of Biological Sciences
Florida International University

Co-Sponsored by

Natural Resources Conservation Department
Ministry of Mining
Government of Jamaica

January 25, 1984

Principal Investigator

A. Thorhaug, Ph.D.
Department of Biological Sciences
Florida International University

Co-Principal Investigators

Beverly Miller, Principal Director
Natural Resources Conservation Department

Barry Jupp, Ph.D.
Department of Botany
University of the West Indies

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SUMMARY

The rehabilitation of seagrass in 19 sites damaged by industrial and urban development was attempted for the first time in any developing nation and for the first time in Jamaica. The transplanted seagrasses are progressing well in a number of sites. The training of Jamaican government staff of the Natural Resources Conservation Department and faculty of the University of the West Indies has progressed smoothly. Use of unemployed fishermen to implement this labor-intensive operation has proved highly successful. Work is in progress to transfer existing habitat restoration guidelines and policy from various United States government agencies to Jamaica with recommendations for its use in Jamaica.

In September 1983 Thalassia and Syringodium seeds were planted at 14 sites. In addition, a series of baffles to protect transplanted Thalassia sprigs were installed at 2 sites where sediment erosion is occurring. The large test plot at Fort Augusta has coalesced into a complete grass bed of Halodule. Fishermen were already seining for fish and shrimp in this bed. This is the most rapid growth recorded in the literature. Continued high growth of the seagrasses, particularly Halodule sprigs and plugs and Thalassia sprigs, was noted on dredge and fill sites, bauxite spill sites, and urban development sites. Computer analysis of survival and growth has been completed through the June 1983 field trip and is presented herein. Plans for a larger mitigation program are underway.

A feature article on this project appeared in the United Nations Environmental Program Regional Seas Program magazine, Siren, in December 1983. Two abstracts on the project have been submitted to the Symposium on the Biosphere for presentation in April 1984 in Miami.

Number 22 December 1983

THE SIREN

news from UNEP's Regional Seas Programme

Healing Caribbean Coastlines

AN INTERVIEW WITH

Anitra Thorhaug

Anitra Thorhaug is professor of biological sciences at Florida International University in Miami. She obtained a PhD in chemical and biological oceanography from the University of Miami, followed by postdoctoral work in biophysics and chemical oceanography. Her special interests include thermal pollution, trace metal ecology, coastal resource management and Caribbean nearshore ecology.

The Siren: What is the present state of seagrass beds in the Caribbean?

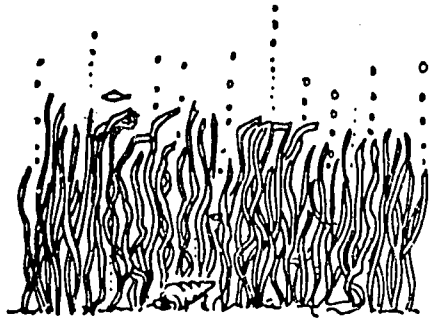
Anitra Thorhaug: Not very good. Large areas have been completely denuded of seagrass, especially those near urban centres.

Q: Why has this happened?

A: Seagrasses are particularly vulnerable to pollution, and they tend to grow close to shore where they are first to feel its effects. Also, they have been rather neglected in terms of conservation, in spite of their importance.

Q: How important are they?

A: Seagrasses are the dominant marine and estuarine submerged plants. They are a major source of food for coastal organisms, and contribute enormously to coastal productivity. They produce up to 2000 grams of dry weight per square meter per year, which rivals the productivity of a mangrove forest.



In addition, seagrasses are essential for coastal erosion control. Their roots help stabilize the sediments, which is particularly important in areas like the Caribbean which are susceptible to hurricanes.

And they provide a habitat for the larval and juvenile stages of innumerable marine organisms, including many commercially-important fish species. For this reason, managing a fishery has to begin with management of seagrasses.

Q: What kind of pollution is threatening Caribbean seagrass communities?

A: Particulate and chemical pollution from dumping and urban runoff are especially damaging. Another factor is the circulation of foreign substances from offshore waters; for example, from oil spills or dumping from ships. But the major cause of seagrass destruction is probably the modification of upland areas. Urbanization, deforestation, industrialization, and changing agricultural practices all contribute to an enormous pollutant load in the rivers -- and therefore of the estuaries and coastal waters.

Q: Is it really possible to restore seagrass communities?

A: It is not only possible, but it is being done. And although it is a relatively new technique, begun only in 1945, it is now commonly used in in the United States, England, Australia, France and Canada.

But the most recent success story occurred in Jamaica, which was the first developing country to receive and test an extensive technology of coastal rehabilitation with seagrasses. This was also the first time seagrass restoration had been successfully accomplished in the tropics.

Q: How was this programme carried out?

A: The Jamaica project was sponsored by U.S.AID and the Jamaican Natural Resources Conservation Department of the Ministry of Mining, and carried out by myself and my research team from Florida International University. We were assisted by government workers from NRCD as well as by faculty and students from the University of the West Indies.

We began by selecting sites according to Jamaica's major coastal problems. We chose areas where seagrass beds had been destroyed by industrial pollution (bauxite, oil spills, cement plants, and thermal effects); urban development (filled areas, jetties, turbidity, river runoff, sewage); and general coastal development (causeways, ports, channels, airports).

Test plots of the three major seagrasses were planted at twenty different sites around the Jamaica coastline, using different anchoring and planting methods.

Q: What seagrass species did you use?

A: The dominant species in the Caribbean is Thalassia testudinum, or turtle grass, which is interspersed with other species such as Halodule wrightii and Syringodium filiforme. Most of our tests involved these three species, although a euryhaline species, Ruppia maritima, was tested at a high salinity site.

Q: With what success?

A: All three species grew at many of the sites for the three planting methods used (seeds, plugs, and shoots). Other sites demonstrated specificity for both species and planting method, according to the particular pollution problem in that area.

We found that Thalassia is best for sites threatened by erosion and bauxite spills; Halodule is best for thermal pollution since it is most tolerant of high temperatures. Ruppia, as expected, is best in areas of high salinity.

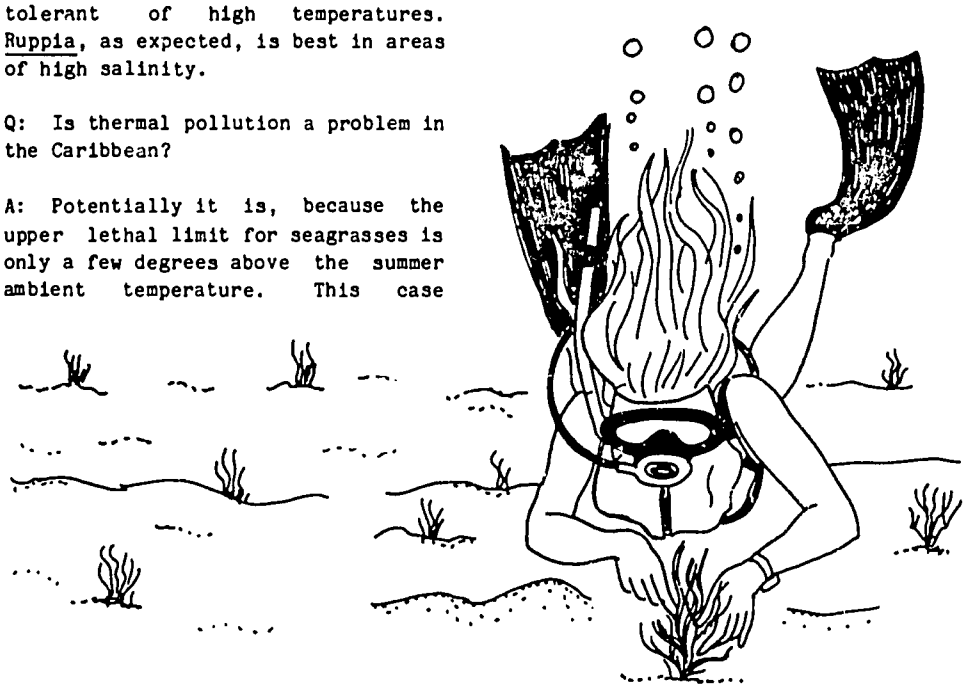
Q: Is thermal pollution a problem in the Caribbean?

A: Potentially it is, because the upper lethal limit for seagrasses is only a few degrees above the summer ambient temperature. This case illustrates very well why we cannot adopt in tropical areas technology and pollution standards developed for temperate regions. A temperature change of a few degrees which might be innocuous -- or even beneficial -- to a temperate community could be devastating to a tropical community.

Q: Where else has seagrass restoration been successful?

A: After power plant effluents had destroyed a seagrass area off the tip of South Florida, 6000 seeds were planted in the restoration zone. It took only four years for both the seagrasses and the associated animal community to recover completely in the restored area.

Q: But wouldn't the seagrass eventually recover by natural means, once the pollutant source was removed?



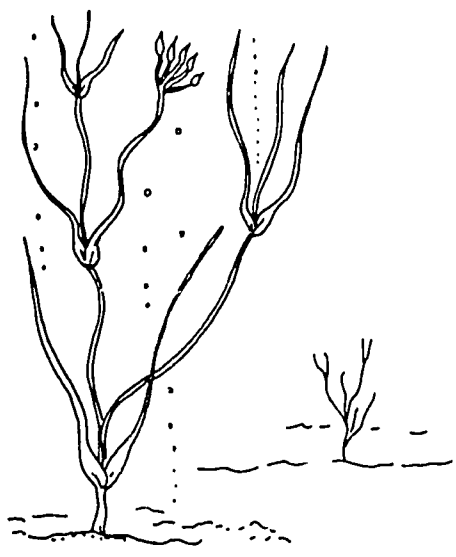
A: In one area of Biscayne Bay, near Miami, a dredge and fill operation destroyed a seagrass bed. Twenty years later still no seagrass was growing in the area. However, three years after planting Thalassia seeds the grass was growing and spreading densely.

Q: Is seagrass restoration economical?

A: It is certainly far more expensive than initial planning and conservation would be. The cost varies between US$ 2,000 and 10,000 per acre in the U.S., although in Jamaica we were able to cut the costs to about $500 per acre.

On the other hand, UNEP estimates that the resource value of the seagrass bed is $86,000 per acre. So yes, it is worth the effort.

Unfortunately, many of the Caribbean nations are not yet aware of the value of their seagrass beds, or of their importance for the Caribbean artisanal fishery, which produces about 500,000 metric tons of fish per year. It is difficult to put a dollar value on the protection that seagrasses give the shoreline from hurricanes, or on the tourism that is stimulated by the clear water.



Q: How did you cut the costs so drastically of the Jamaican restoration programme?

A: In order to ascertain the maximum cost-efficiency of seagrass restoration in Jamaica, we studied the feasiblity of training unemployed fishermen to plant the seagrass. This idea proved very successful, because the fishermen were enthusiastic and already had sufficient water skills to enable them to pick, sort and plant the seagrass easily.

Perhaps more important, the members of this ready-made labour force also had a great deal of understanding of the relationship between a thriving seagrass bed and the availability of the fish, crustaceans and molluscs they caught for a living. They had seen first-hand the destruction of seagrass beds around Jamaica brought on by development, and the subsequent effect on fisheries.

These people were willing to work very hard to bring back the seagrass and the fishery. Involving them and other local people in restoration projects is one way the costs can be reduced, but substantial funding will still be needed.

We will keep monitoring the results of the Jamaica project to determine the most cost-efficient formulas for each type of problem area. In the meantime, we hope that our work will convince others of the need to protect their seagrass communities, and of the feasibility of restoring those that have already been destroyed.

Preface

In accordance with the SCHEDULE, Section E. Reporting and Evaluation, Item 1. Progress Reports, for Grant No. DAN-5542-G-SS-2102-22 for the AID program titled, "Seagrass Restoration in Caribbean Nearshore Areas," awarded August 31, 1982, the attached is PROGRESS REPORT 3. for the reporting period ending December 31, 1983.

As suggested in Item 1. Progress Reports, the Principal Investigator's overseas colleagues were involved in the preparation of this report by:

1. Review and comments on the PROGRESS REPORT 3. during preparation by B. Jupp, Ph.D. in Kingston; and
2. Review and comments on the PROGRESS REPORT 3. before formal submission by B. Miller, Principal Director, NRCD, in Kingston.

In accordance with Section E. Reporting and Evaluation of the SCHEDULE, the Grantee is requested to submit the Financial Status Report (SF-269) as an attachment to the PROGRESS REPORT. This report, prepared by the Controller's Office of Florida International University, is attached.

Respectfully submitted,

A. Thorhaug, Ph.D.
Principal Investigator

January 25, 1984
(Four copies)

Acknowledgements

I wish to thank the Agency for International Development of the United States Department of State for supporting this grant, and the Biology Department of Florida International University and the Natural Resources Conservation Department of the Ministry of Mining, Government of Jamaica, for sponsoring this grant. The Division of Sponsored Research and the Controller's Office of Florida International University are thanked for administering the grant.

At the AID Mission in Jamaica, I wish to thank Mr. Dan Rathburn, the AID Project Officer, for his assistance and cooperation during our work there. Mr. William Davis, U.S. Embassy Counselor, Information Services, is thanked for his personal interest and promotion of the project.

The Principal Director, Mrs. Beverly Miller, and staff of the Natural Resources Conservation Department are gratefully acknowledged for their cooperation, assistance, and support of this project.

Barry Jupp, Ph.D. from the Botany Department at the University of the West Indies and Peter Gayle from the Natural Resources Conservation Department are thanked for their field work and interest in the project. Lastly, I specially thank Fitzgerald Booker from the Biology Department at Florida International University for his field work in Jamaica, the data analysis, and general management of the project.

Seagrass Restoration in Caribbean Nearshore Areas

PROGRESS REPORT 3.

Table of Contents

		Page
	Summary	i
	Siren article	ii
	Preface	vi
	Acknowledgements	vii
I.	Introduction	1
A.	Purpose of Grant	1
B.	Specific Objectives	1
II.	Methods	1
III.	Results	2
A.	Planting Techniques	2
1.	Old Airport Site	2
2.	Cement Plant Site	2
3.	Fort Augusta Site	2
4.	Hellshire Beach Site	3
5.	Old Harbor Power Plant Site	3
6.	Port Esquivel Site	4
7.	Rocky Point Site	4
8.	Rocky Point Mangrove Planting Site	4
9.	Negril Point Site	5
10.	Negril River Site	5
11.	Montego Bay Seawinds Site	5
12.	Fisherman's Jetty Site	5
13.	Pelican Jetty Site	6
14.	Carlyle Beach Site	6
15.	Discovery Bay Site	6
16.	Ocho Rios Site	7
17.	Yallahs Pond Site	7
18.	Alligator Pond Site	7
19.	South Port Beach Site	7
IV.	Discussion	8
V.	Final Product Utilization	9
VI.	Appendices	13

- 1 -

Seagrass Restoration in Caribbean Nearshore Areas

PROGRESS REPORT 3.

I. Introduction

A. Purpose of Grant

The research will test whether one can accelerate the re-establishment of seagrass beds destroyed by natural disasters and man-made pollution in Kingston Harbor and other sites along the coastline of Jamaica using seagrass restoration techniques developed in subtropical Florida and Texas.

B. Specific Objectives

1. To test whether shallow, tropical nearshore waters around Jamaica are capable of receiving seagrass restoration.

2. To test if successional seagrass stages (*Halodule* and/or *Syringodium* species) should be planted first (to provide ground cover and sediment stabilization) with the dominant species (*Thalassia*) planted later, or whether equal success and cost/benefit can be achieved by planting the dominant stage directly with no successional stage.

3. If the testing in Objective 1. is positive, to test whether seagrasses can be successfully restored into areas where one of the pollution impacts listed below has occurred, damaged the area, but no longer causes additional damage in the area, or where one of the pollution impacts occurs on a chronic but tolerable level:

    a. Industrial accidental spills;
    b. Land development induced impacts;
    c. Urban run-off and urban abuse.

II. Methods: Submitted in Progress Reports 1. and 2.

III. Results

A. Planting Techniques

The seagrasses Thalassia and Halodule are growing well, but the species Syringodium is growing well at only two sites. Halodule plugs have coalesced in a number of sites, and Halodule sprigs have expanded laterally and grown vigorously in most sites. Thalassia sprigs have survived and grown well, but grow slower than Halodule due to their larger size and greater sub-sediment biomass. The Thalassia seeds are also growing well.

Survival differed from site to site, but Thalssia survived best and Syringodium worst. Halodule did far better in fine sediment and medium to low wave energy sites. Thalassia did well in a wide variety of site conditions. Per site survival is described below.

1. Old Airport Site

This site represents an inner bay dredge site with coarse sandy sediment. Damage to the site occurred more than 40 years ago. In the spring planting, 90 percent of the Halodule plugs survived (June 1983 monitoring); 82 percent of the Halodule sprigs on clips survived; 70 percent of the Thalassia sprigs on clips survived; 68 percent of the Syringodium sprigs on clips survived; and 36 percent of the Syringodium sprigs on rods survived.

In the fall planting, only 56 percent of the Thalassia sprigs on rods survived and 8 percent of the Thalassia seeds survived. No other species or technique survived. Growth of the plants in both plantings was medium.

2. Cement Plant Site

This site represents a land fill project with cement tailings at the Inner Harbour area of Kingston Harbour. Continued cement tailing input occurred after the November planting which smothered the plants. No spring planting was attempted, and the site was terminated.

3. Fort Augusta Site

This site represents a typical dredge and fill project on top of a former excellent seagrass bed and fisheries nursery and fishing grounds. The Causeway was constructed by piling sand dredged nearby. Siltation and direct dumping killed many acres of seagrass. Some patches have re-established. A large bare section still remains. Both fall and spring plantings for all three species was good with high survival and vigorous growth.

For the fall planting, 100 percent of the Halodule plugs survived and coalesced after eight months; 88 percent of the Halodule sprigs survived and were growing vigorously; 84 percent of the Thalassia sprigs and 62 percent of the seeds survived and were growing well; 96 percent of

the Syringodium sprigs on clips and 94 percent of the Syringodium sprigs on rods survived and growth was excellent.

For the spring planting, 92 percent of the Halodule plugs and 94 percent of the Halodule sprigs survived and were growing well. 84 percent of the Thalassia sprigs survived. 44 percent of the Syringodium sprigs on clips survived.

4. Hellshire Beach Site

This site represents an eroding beach shoreline with heavy boat, car, and fishing useage. The sediment and existing shoreline seagrass beds are eroding rapidly. The high wave action, exposed shoreline, and compression by vehicles and useage all contribute to the problem. An inner test plot and outer test plot were set up here to test nearshore and offshore restoration potential. The nearshore site was 1 m deep, and the offshore site was 2 m deep. The inner site was immediately adjacent to the heavily eroding present seagrass bed. The fall planting was far less successful than the spring planting probably due to heavy wind and wave action on newly planted specimens that had not established their root and rhizome system to hold themselves in place.

For the fall planting, 16 percent of the Halodule plugs and 18 percent of the Halodule sprigs on rod survived. 8 percent of the Thalassia sprigs on rods survived and 14 percent of the Thalassia seeds survived. No Syringodium sprigs survived.

For the spring planting, 48 percent of the Halodule sprigs on rod survived. 34 percent of the Thalassia sprigs on rod survived. 18 percent of the Syringodium sprigs on rod survived.

5. Old Harbor Power Plant Site

This site represents the effects of thermal effluents from power plants on seagrass beds in estuaries, nearshore coastline, and lagoons. It is so similar to the reports of effluent effects on seagrass beds in southwest Puerto Rico and in southeast Florida that this site can probably be a model for Caribbean island rehabilitation of seagrasses affected by thermal effluents. The thermal plume extends from a 212 m cooling canal in isotherms which are parallel to the shoreline. The fall planting of Halodule and Thalassia went well until the summer effluents reached a temperature of 34°C. 54 percent of the Halodule plugs survived with a high number of blade groups per m^2 ($442/m^2$). Only 16 percent of the Halodule sprigs survived. The Thalassia sprigs and seeds died back to less than 2 percent. No Syringodium survived.

For the spring planting, 46 percent of the Halodule plugs survived with a blade groups density of $469/m^2$. 36 percent of the Halodule sprigs on clips survived. 48 percent of the Thalassia sprigs on clips survived. Only 8 percent of the Syringodium plugs and none of the sprigs survived.

6. Port Esquivel Site

This site represents a multiple industrial-impact site with land filling, channel dredging, and bauxite spills. Much unvegetated bottom appears in the area which apparently once had an extensive, lush seagrass bed. However, this is one of the top three sites for growth and survival. Interestingly, this is a high growth site so that, like Fort Augusta, multiply damaged sites with continued chronic levels of contaminants do not appear hopeless at all to restore. The spring planting once again had higher survival than the fall planting.

For the fall planting, 82 percent of the Halodule plugs survived and had 505 blade groups per m^2. 56 percent of the Halodule sprigs on clips survived and had 122 blade groups per m^2. 30 percent of the Thalassia sprigs on clips and 20 percent of the Thalassia seeds survived. 6 percent of the Syringodium on clips survived, but no Syringodium on rods survived.

For the spring planting, 94 percent of the Halodule plugs survived and had 16 blade groups per m^2. 82 percent of the Halodule sprigs on clips survived and had 13 blade groups per m^2. 50 percent of the Thalassia sprigs survived. 78 percent of the Syringodium on clips and 82 percent of the Syringodium on rods survived.

7. Rocky Point Site

This site represents an industrial lagoon cut off from natural tidal exchange with the ocean when a road and railroad were built to the bauxite plant. The salinity regime within the lagoon became very high during the summer drought and exceeded the tolerance limit of the seagrass and mangroves transplanted there. When the salinity was within the seagrass tolerance such as in February when it was 59.6 o/oo, the plants were growing. When the salinity reached 75.8 o/oo in April and 69.4 o/oo in June 1983, the plants died. If the salinity was restored to normal by providing exchange with ocean, one could expect an excellent restoration.

For the fall planting, survival in June 1983 was 0 percent for all three species.

For the spring planting, 62 percent of the Halodule plugs survived, but none of the Halodule sprigs survived. 78 percent of the Thalassia sprigs on clips survived, but growth was not occurring, and the plants appeared dormant.

8. Rocky Point Mangrove Planting Site

For the fall planting, 26 percent of the red mangrove propagules survived, and 16 percent of the plants had two leaf pairs. 18 percent of the black mangrove seedlings survived.

For the spring planting, none of the red propagules survived.

9. Negril Point Site

The site represents a peat-damaged situation. The site receives peat and other flocculant material from the Negril River which settles out as the river water and seawater mix. It is deep (6 m). From aerial photographs, apparently a large seagrass bed was present in this area. One should keep in mind other sites that receive urban run-off, as this one does, such as Fort Augusta have done well. The results appear to be due to the peat siltation.

For the fall planting, none of the species survived.

For the spring planting, 34 percent of the Halodule sprigs on clips survived, but growth was poor. 26 percent of the Syringodium sprigs on clips survived, but none of the Thalassia sprigs on clips survived.

10. Negril River Site

This site, in the mouth of the Negril River, receives fresh water as well as urban run-off and peat effluents. For the fall planting, no species survived.

For the spring planting, 30 percent of the Halodule sprigs survived, 64 percent of the Syringodium sprigs survived, and 96 percent of the Thalassia sprigs survived. All sprigs were anchored with clips.

11. Montego Bay Seawinds Site

This site represents an ocean front dredge and fill situation. It is fairly high energy wave action, coarse and rocky sediment, and unstable. Since the filling several decades ago, Thalassia has begun to move in from offshore. For the fall planting, no species survived the winter storms.

For the spring planting, 76 percent of the Halodule plugs and 42 percent of the Halodule sprigs on inert anchors survived. 84 percent of the Thalassia sprigs on inert anchors survived.

12. Fisherman's Jetty Site

This was an area damaged by land fill or urban development and extensive rip-rap jetties. The bottom was completely denuded of vegetation. The fall planting did not survive. Fishermen at the site suggested that South Port Beach might be a better place, and thus the site was terminated for one several thousand meters away.

13. Pelican Jetty Site

This site represents extensive shoreline filling with sand retained by large rip-rap jetties. It is one of three such enclosed basins on the downtown Montego Bay shoreline.

For the fall planting, 76 percent of the Halodule plugs and 70 percent of the Halodule sprigs on rods survived. 42 percent of the Thalassia sprigs on rod survived, and 26 percent of the seeds survived.

For the spring planting, 64 percent of the Halodule plugs, and 76 percent of the Halodule sprigs on clips survived. 44 percent of the Thalassia sprigs on clips survived.

This site shows that a fall planting, when buffered from winter storms, can be effective when compared to exposed sites in Montego Bay such as the Seawinds and Carlyle Beach sites. This is the best area in Montego Bay in which to put more effort.

14. Carlyle Beach Site

This site represents an area of high erosion where extensive filling has disrupted the natural shoreline stabilization process. The filled shoreline road and bulkhead has collapsed in several places because of undermining by wave action.

For the fall planting, 34 percent of the Halodule plugs survived, and 8 percent of the Halodule sprigs anchored by rods survived. 2 percent of the Thalassia sprigs on rod, and 16 percent of the seeds survived.

For the spring planting, 82 percent of the Halodule plugs survived, and 58 percent of the Halodule sprigs on inert anchors survived. 44 percent of the Thalassia sprigs on inert anchors survived.

15. Discovery Bay Site

This site represents the damage from a bauxite loading facility. Land fill and construction of a large pier have occurred here decades ago. Continual spills of bauxite dust from the loading process occurs here and has heavily coated the plants.

For the fall planting, 28 percent of the Halodule plugs and 62 percent of the Halodule sprigs in clips survived. 10 percent of the Thalassia sprigs on clips and 62 percent of the seeds survived. Growth was good here.

For the spring planting, 92 percent of the Halodule plugs and 84 percent of the Halodule sprigs on clips survived. 62 percent of the Thalassia sprigs on clips survived.

16. Ocho Rios Site

This site also represents a bauxite loading facility situation. Dredging for a ship channel and land fill occurred several decades ago at the northeast part of the bay for development. Bauxite does continue to enter the water as seen from layers of floating in the water column and residual dust. No fall plantings was installed here.

For the spring planting, 90 percent of the Halodule plugs survived, and 74 percent of the Halodule sprigs on inert anchors survived. 62 percent of the Thalassia sprigs on inert anchors survived.

17. Yallahs Pond Site

The Inland Fisheries Department of Jamaica asked us to examine the possibility of transplanting seagrass in this large saline pond. The salinity in June 1983 was 163.6 o/oo which is beyond the tolerance of Thalassia, Syringodium, or Halodule. A salt tolerant species, Ruppia maritima was transplanted here. All four species survived, but only Halodule contained green, living tissue. Our recommendation for a potential mariculture facility here is to open the area to ocean flushing by culverts, passages in the sand dunes between the pond and the ocean, or by pumping seawater into the pond (exit of water would be the one passage to the sea on the east side of the pond). Without a more normal salinity, this site could not support seagrass. With a normal salinity, the possibility of a successful transplantation are high.

18. Alligator Pond Site

On the southwest coast, a large oil spill occurred several years ago. Evidence of residual oil was observed over a long period and can still be seen. It is a high energy beach exposed to the wave action of the Caribbean Sea. The NRCD had selected this site as the only one with a recent oil spill impact. This site was planned to examine the effects of residual oil on restoration; however, the high energy regime of the beach wave action caused a variable, which did not allow a proper assessment of only the factor residual oil because the plants were not able to properly stabilize. Only a spring planting was done here. 20 percent of the Syringodium sprigs on clips survived, but no other species or technique did.

19. South Port Beach Site

This is an estuarine dredge and fill site somewhat similar to Fort Augusta Causeway site, but closer to the source of urban run-off from the Montego and Pies rivers than Fort Augusta. The site was slightly shallower than Fort Augusta which may have exposed the transplants to high wave action than Fort Augusta (shallow station at Hellshire Beach had poor survival).

This site was selected with the advice of local fishermen after Fisherman's Jetty site failed as another sample of this area of Montego Bay, thus no fall planting was installed.

For the spring planting, 8 percent of the Halodule plugs in the test plot survived, but none of the Halodule sprigs on clips survived. 1 percent of the Halodule plugs in the large test planting adjacent to the test plot survived. 22 percent of the Thalassia sprigs on clips survived.

IV. Discussion

Specific objectives 1. - 3. are being tested. Jamaican shorelines can be restored with seagrass within seven months, which is a record time for regrowth, when conditions are appropriate. Where continual bauxite spills, minor oil spills, or thermal effluents affect seagrass beds, one or two species of seagrass can be restored. Land development impacts such as those tested at Fort Augusta, Port Esquivel, Old Airport, Pelican Jetty, and Seawinds can be rehabilitated. Urban run-off and pollution impacts present at such stations as Fort Augusta, Old Airport, and South Port Beach can also be rehabilitated, but recovery occurs at variable rates.

In terms of cost, we have found that spring is a far better time than late fall or winter for restoration of seagrass successfully. Unemployed fishermen make excellent workers for portions of the project such as plugging, picking, and sorting. Thus, the total cost per acre can be reduced substantially from the cost in the United States ($2000 - $5000 per acre). A larger scale planting would be necessary to verify actual costs in Jamaica.

The training of NRCD and UWI personnel in seagrass physiology, restoration management and facilitation is progressing well. A great deal of scientific information on rehabilitation techniques and seagrass biology has been transferred to these personnel. A large-scale rehabilitation would get the training of NRCD personnel up to operational levels.

The public relations through newspapers and television has contributed to the Jamaican people's awareness of their seagrass and coastal resources as valuable for fisheries nurseries, erosion control, water quality, and nearshore ecosystem health. A feature article on the project was published in the UNEP Regional Seas magazine, The Siren, in December 1983.

V. Final Product Utilization

A. Final Product
B. Termination of Project
2. Acts of Termination: Papers Presented
f. Project Noted in UNEP newsletter

The article, "Healing Caribbean Coastlines," an interview with Anitra Thorhaug, appeared in the UNEP Regional Seas magazine, The Siren, in December 1983. It appears in this Progress Report from pp. ii - v. The article discusses seagrass resources in the Caribbean, the restoration of seagrasses by transplantation, and uses this project as an example.

g. The following papers will be presented at the Symposium on the Biosphere in Miami in April 1984. The symposium is sponsored by the University of Miami Clean Energy Research Institute.

Miller, B. and A. Thorhaug. 1984. Management and rehabilitation of coastal resources in the Third World: Jamaican model. International Symposium on the Biosphere, Miami Beach, Florida. 14-16 April. (abstract).

Thorhaug, A. 1984. Thermal pollution effects on an estuary in a developing nation: Impact and rehabilitation of seagrass. International Symposium on the Biosphere, Miami Beach, Florida. 14-16 April. (abstract).

Management and Rehabilitation of Coastal Resources in the Third World: Jamaican Model

Beverly A. Miller
Natural Resources Conservation Department
Ministry of Mining
Government of Jamaica

A. Thorhaug, Ph.D.
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Jamaica is an island nation of the Caribbean with approximately 200 miles of coastline dominated by mangrove forests, offshore coral reefs, abundant seagrasses, rapid development. Historically, development occurred by ship and major urban centers grew around estuaries, which have now been seriously damaged. Natural resource utilization of bauxite, cement, and tourism have added to shoreline disturbance. A program to test the potential for rehabilitation of shoreline resources, specifically, seagrasses has begun.* A very recent technology now utilized in developed nations, but never before tested in any developing nation was initiated.

Seagrasses are an important coastal resource because they serve as the fisheries nursery, aid sediment consolidation and retard erosion, act as a food source for nearshore ecosystems, and improve water clarity. A nineteen test site system for rehabilitation of the three major species of seagrasses found in Jamaica has been implemented. We are testing our ability to rehabilitate urban and industrial impact of thermal pollution, dredge and fill, bauxite, oil, and cement emissions, shoreline modifications, and erosion. Successful rehabilitation in several sites has already occurred. Monitoring and cost-benefit analysis is now underway.

*The authors gratefully acknowledge the support of the U.S. Agency for International Development and Government of Jamaica for this project.

Thermal Pollution Effects on an Estuary in a Developing Nation: Impact and Rehabilitation of Seagrass

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Power plant impacts and environmental protection in the tropics, especially in the developing nations, has received far less attention than in the temperate zone developed countries. Most tropical power plant studies have been done in territories or colonies of developed nations with the exception of India. Thus, this is the first report of a major power plant impact from an independent third world nation. It is also the first report of an attempted restoration with seagrass while the effluent continues to be emitted. The Government of Jamaica has a well informed, trained, but relatively new Natural Resources Conservation Department which is partly responsible for managing the environmental resources of the country. In cooperation with this department,this study sponsored by the U.S. Agency for International Development was conducted.

The Old Harbour Power Plant on the southwest coast of Jamaica near Kingston is a major electricity producer for the metropolitan and industrial center of Jamaica. The plant is administered by the Jamaica Public Service Company. The plant has four fossil fuel generating units, and the effluent from the plant enters the Old Harbour estuary through a 212 m cooling canal. Current, tide, and effluent flow patterns are such that the plume ran along shore for several hundred meters and then proceeded southwest across the mid-section of the estuary.

In October 1982 definite bands of seagrass were present in the estuary. The area adjacent to the effluent canal was devoid of bottom vegetation. The next area had patches of *Halodule wrightii* which was followed by a zone of dense *Halodule*. Then a mixed *Halodule* and *Thalassia* zone was present which graded into a dense *Thalassia* bed. *Thalassia* was the dominant non-impacted

nearshore seagrass system in this estuary. Finally, on the bayward side of the effluents, where at high tide a cooler lense of water covered the area, Syringodium was abundant. The zones look like widening arcs radiating from the core effluent plume. The red mangroves along the shoreline did not appear to be affected.

In November 1982 and April 1983 test plots of Halodule, Thalassia, and Syringodium were planted within the barren and patchy Halodule areas. Results shows Halodule plugs and shoots to survive and grow at a higher rate than the other two species. The area continues to be monitored through 1983 and winter 1984.

VI. Appendices

A. Appendix I: Executive Summary, September 27, 1983

B. Appendix II: Field trip schedules

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September 27, 1983

U.S. Agency for International Development

Seagrass Restoration in Caribbean Nearshore Areas
Grant No. DAN-5542-G-SS-2101-00

EXECUTIVE SUMMARY

Seagrass Planting and Monitoring
September 1983

The September 1983 planting of seagrass (Thalassia testudinum and Syringodium filiforme) seeds and monitoring of the test sites occurred from the 9th through the 22nd of September, 1983 in Jamaica. Personnel involved in the field trip were Mr. E. Kelly, Mr. P. Gayle, and Ms. B. Chow from the Natural Resources Conservation Department, Ministry of Mining, Jamaica; A. Thorhaug, Ph.D., Mr. F. Booker, and Mr. G. Townsend from the Department of Biological Sciences, Florida International University; and B. Jupp, Ph.D., Botany Department, University of the West Indies.

Planting of the seeds and bulbs of the three major seagrasses in Jamaica (T. testudinum, S. filiforme, and Halodule wrightii) was done at thirteen of the nineteen test sites for the first time anyplace in the world. That is, never before have seeds and bulbs of all three seagrasses been planted, in particular, Syringodium has not been planted on a test plot scale previously. The implementation included the planting of 2,490 Thalassia seedlings from Jamaica and the United States, 192 Syringodium seeds from the United States, and 384 bulbs* of Halodule from Jamaica. A new anchoring method for the seeds was devised for this planting. Previous anchoring methods did not work well in the high wave energy test sites such as Hellshire Beach and Carlyle Beach. Thus, an entirely new inert anchor specifically designed for the seeds was developed with the assistance of two civil engineers from the University of Miami during the summer of 1983, tested in Florida, and produced in large scale in Jamaica by this team and used in thirteen test sites. Syringodium was planted by seed in an anchoring device, and Halodule bulbs were planted with clips and the new anchor. The results will be apparent by the November 1983 monitoring trip.

Monitoring of the test sites continued. In general, the Spring 1983 planting had higher survival and faster growth per month than the Fall 1982 planting. In some cases, after six months, the spring planting almost equaled the fall planting after ten months.

*Terminology and anatomy being confirmed by P.B. Tomlinson, Harvard University.

Executive Summary
September 1983
Continued.

In many of the high wave energy sites, Thalassia testudinum shoots appeared as the best technique. In lower wave energy sites and particularly on former dredge sites, Halodule wrightii shoots and plugs were growing extremely well. Syringodium continued to show poor survival.

The large test site (subsite 3) at Fort Augusta which was planted with Halodule plugs in the spring 1983 planting has begun to coalesce since the June 1983 monitoring. Indeed, three fishermen were observed commercially seining in the planted area. They were catching small bait fish and shrimp.

Management techniques, preparation for large scale plantings, and discussions on use of the data in permitting policies, procedures, and regulations was continued with Natural Resource Conservation Department staff during this site visit as information transfer from A. Thorhaug to conservation department staff.

In summary, the larger-scale seed planting was done at thirteen test sites, which has never been accomplished in the world before in the September period. The vigorous growth of many of the transplanted test sites, particularly for the Thalassia shoots and Halodule shoots and plugs, is being monitored. It shows that Jamaica is an excellent recipient site for the technology of seagrass restoration.

Mr. William Davis of the U.S. Information Service reports that Ms. Pat Lazarus of the Jamaica Broadcasting Corporation is almost finished with a video tape documentary of the project. Dr. Noel Brown of the United Nations Environmental Program has reviewed it and given it his approval. Copies will be made available for distribution.

Sincerely,

A. Thorhaug, Ph.D.
Principal Investigator
Research Scientist

General distribution

AT/ fl

General Distribution August 23, 1983

U.S. AID Grant

Seagrass Restoration in Caribbean Nearshore Areas

FIU Personnel: A. Thorhaug, F. Booker, G. Townsend
NRCD Personnel: B. Chow, P. Gayle, E. Kelly
UWI Personnel: B. Jupp

Location: Coastline of Jamaica

SCHEDULE

SEPTEMBER 1983 MONITORING FIELD TRIP
PERIOD #5

Sept. 12 Monday	Sept. 13 Tuesday	Sept. 14 Wednesday	Sept. 15 Thursday	Sept. 16 Friday	Sept. 17 Saturday
Prepare seeds and anchors Terra Nova Hotel 926-2211	Old Airport & Hellshire Beach	Fort Augusta	Port Esquivel & Power Plant & Rocky Point	Travel & Ocho Rios & Discovery Bay Chatham Beach Hotel Montego Bay 952-4780	Carlyle Beach & Pelican Jetty

Sept. 18 Sunday	Sept. 19 Monday	Sept. 20 Tuesday
South Port Beach & Seawinds	Negril Point & Negril River & Travel	Clean-up Terminate

16

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October 10, 1983

U.S. AID Grant

Seagrass Restoration in Caribbean Nearshore Areas

FIU Personnel: F. Booker
NRCD Personnel: B. Chow, P. Gayle, E. Kelly
UWI Personnel: B. Jupp, Ph.D.

Location: Coastline of Jamaica

SCHEDULE

NOVEMBER 1983 MONITORING FIELD TRIP
PERIOD #6

Nov. 7 Monday	Nov. 8 Tuesday	Nov. 9 Wednesday	Nov. 10 Thursday	Nov. 11 Friday	Nov. 12 Saturday	Nov. 13 Sunday
Old Airport & Hellshire Beach	Fort Augusta	Port Esquivel	Power Plant & Rocky Point	Travel & Ocho Rios & Discovery Bay	Carlyle Beach & Pelican Jetty	Open
F. Bonnick, 929-2940	Kingston			Chatham Beach Hotel Montego Bay 952-4780		

Nov. 14 Monday	Nov. 15 Tuesday	Nov. 16 Wednesday
South Port Beach & Seawinds	Negril Point & Negril River	Clean-up Terminate

17

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December 12, 1983

U.S. AID Grant

Seagrass Restoration in Caribbean Nearshore Areas

FIU Personnel: A. Thorhaug, Ph.D. and F. Booker
NRCD Personnel: P. Gayle and B. Chow
UWI Personnel: B. Jupp, Ph.D.

Location: Coastline of Jamaica

SCHEDULE

JANUARY 1984 MONITORING FIELD TRIP
PERIOD #7

Jan. 16 Monday	Jan. 17 Tuesday	Jan. 18 Wednesday	Jan. 19 Thursday	Jan. 20 Friday	Jan. 21 Saturday	Jan. 22 Sunday
Arrival EAL #465 Terra Nova Hotel 926-2211	Old Airport & Hellshire Beach	Fort Augusta	Port Esquivel	Power Plant & Rocky Point	Travel & Ocho Rios Chatham Beach Hotel Montego Bay 952-4780	Open

Jan. 23 Monday	Jan. 24 Tuesday	Jan. 25 Wednesday	Jan. 26 Thursday
Discovery Bay & Carlyle Beach	Pelican Jetty & Seawinds & South Port Beach	Negril River & Negril Point	Clean-up Terminate EAL #970