CEER M-66

THE IMPACT OF HEATED EFFLUENTS ON *THALASSIA* BEDS: A COMPARATIVE STUDY

by:

Vance P. Vicente

1977

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

THE IMPACT OF HEATED EFFLUENTS ON *THALASSIA* BEDS: A COMPARATIVE STUDY

by

Vance P. Vicente

1977

INTRODUCTION

Most of the existing ecological guidelines and models of seagrass ecosystems and their response to thermal effluents or other pollution sources originate from studies in temperate and subtropical latitudes. Application of temperate models to tropical ecosystems is questionable (Johannes and Betzer, 1975), principally because the mechanisms and processes that determine the structure, maintenance, organization and evolution in the tropics are different from those that operate in temperate latitudes (Sanders, 1968; Dobzhansky, 1950; Lowe & McConnell, 1969).

There are similarities between subtropical and tropical *Thalassia* beds. However, there are some major physical and biological differences which limit the extent to which subtropical guidelines could be applied to tropical Caribbean systems. The water temperature, for example, along Florida's coast drops in the winter, in some cases below 20°C, causing kills of *Thalassia* leaves (Phillips, 1960). Even extreme cold temperatures occur during winter which have caused massive kills of marine organisms on both coasts of Florida (Toner, 1977). In tropical Caribbean islands such as Puerto Rico, marine ecosystems are never exposed to cold stress.

There are also major differences in some of the biological components. In Puerto Rico the seagrass Syringdoium filiforme (Kutzing) normally occurs in the shallower zone of the seagrass bed (Vicente, 1975; Glynn, et al., 1964) whereas in Florida it inhabits deeper water (Phillips, 1960; Kirk, 1961). An important difference in the dynamics of subtropical and tropical seagrass bed ecosystems exists in the energy transfer. Intensive grazing on living seagrass by herbivorous fishes (Randall, 1965) and sea urchins (Ogden, et al. 1973; Camp, et al. 1973; Vicente and Rivera (in press)) occurs in the Caribbean Sea but apparently not significantly in other tropical or temperate regions (Kirk, et al., 1973; Brook, 1977). Intensive grazing in the Caribbean, then, may be an important mechanism in the energy transfer from the primary producer level to other trophic levels. In higher latitudes primary energy transfer is via the detrital food chain. Therefore, new ecological guidelines need to be developed for Caribbean seagrass ecosystems. This study intends to establish some of these guidelines, as well as to determine how thermal effluents from power plants alter the natural conditions of a seagrass bed.

The rising demand for electrical power has resulted in the possibility that by 1980, 5GW (5,000MW) power plants will become a reality (Sengupta and Lee, 1976). Power plants located close to shore utilize sea water as a coolant and return the water at temperatures higher than ambient. The impact that these heated effluents has on tropical seagrasses has been of much concern because tropical organisms live close to their upper thermal tolerance (Thorhaug et al., 1971; Mayer, 1914; Cairnes, 1956; Bieble, 1962; Bader et al., 1971; Drost-Hanzen, 1969; González, 1973).

The Guayanilla electrical power plant complex has a capacity of producing 1,100MW. It utilizes sea water as a coolant at a rate of 2,370M^3/min (Schroeder, 1975) and this water is heated 10°C above ambient. The heated effluent discharges into an enclosed cove of approximately 23 hectares, but the warming effect is extended over an area of approximately 50 hectares. The temperature in the effluent zone in the vicinity of the discharge canal had a maximum temperature of 40.5°C in August 1976 and a minimum of 31.3°C in January of the same year.

In view of the extensive damage that power plants have caused to seagrasses such as _Thalassia_ and their associated community (Schroeder, 1975; Zieman, 1970; Vicente, 1977a; Vicente, 1977b; Roessler, 1971; Thorhaug _et al_., 1973; Bader _et al_., 1971), a study was conducted to determine the impact of thermal effluents on the _Thalassia_ beds of Guayanilla Bay (Figure 1). _Thalassia_ beds in Jobos Bay (Figure 2) occurring under natural conditions were used as control, as well as for obtaining baseline information to draw some guidelines for _Thalassia_ in the Caribbean.

MATERIALS AND METHODS

Field Studies

Salinity, temperature, and turbidity were monitored on a monthly basis throughout the year 1976-1977 (Tables 1 to 8, appendix). Salinity ($^o/_{oo}$) measurements were made with a Goldbert T/C Refractometer Model 10423. Temperature was recorded from a YSI T/O meter model 33 and from a mercury thermometer with an accuracy of .1°C. Secchi disc readings (Z SD) were used as an

Figure 1: *Thalassia* bed stations in Guayanilla Bay, Southwest Coast of Puerto Rico.

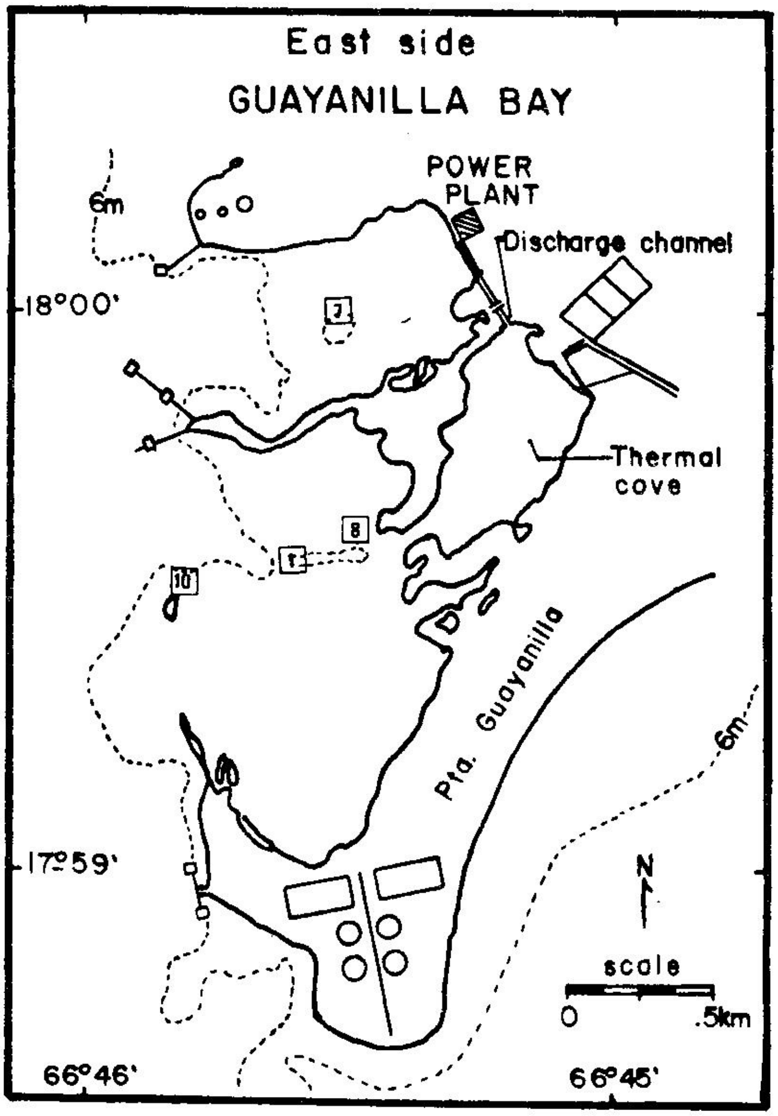


Figure 2. *Thalassia* bed stations in Jobos Bay, Southeast Coast of Puerto Rico

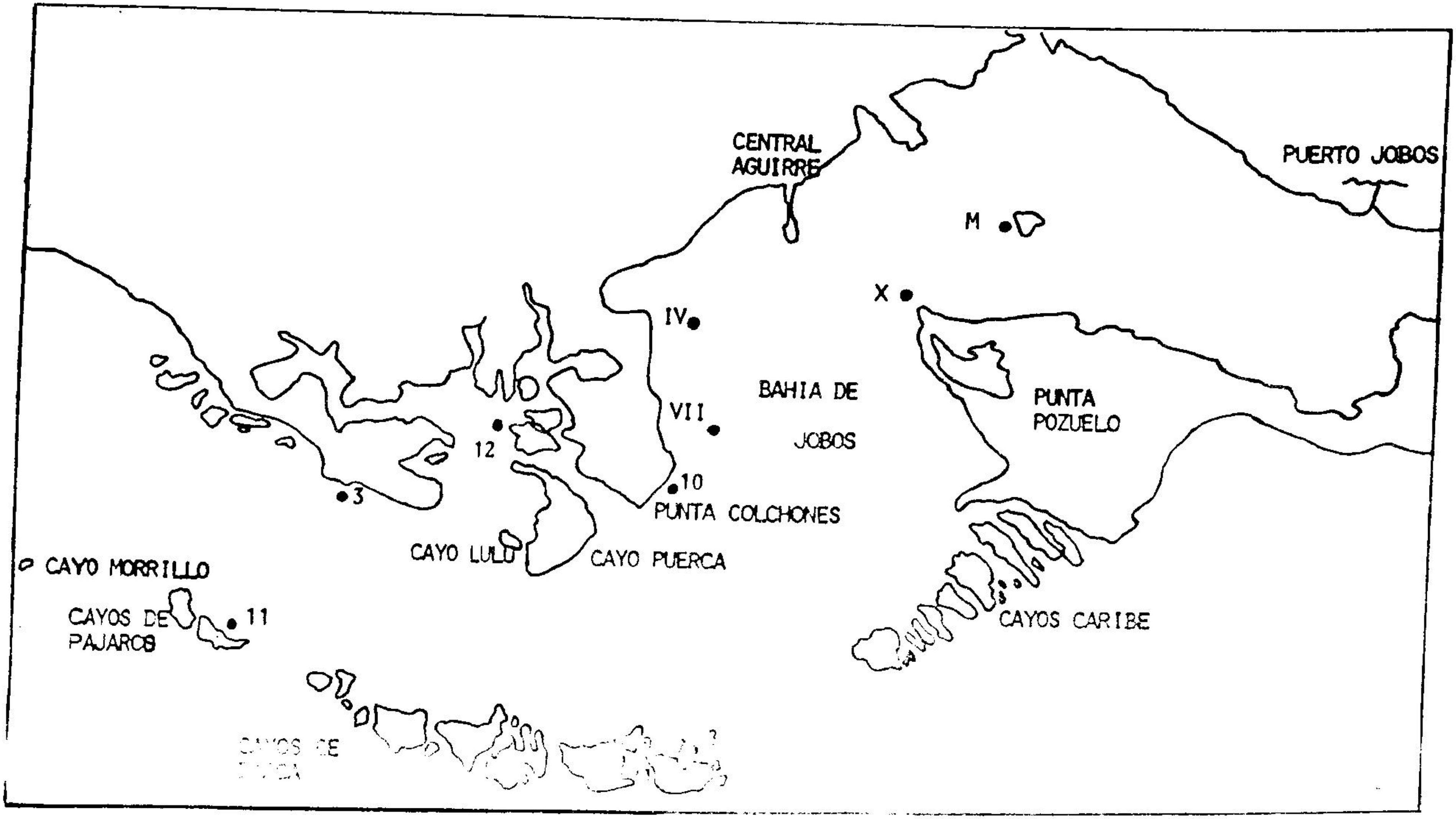
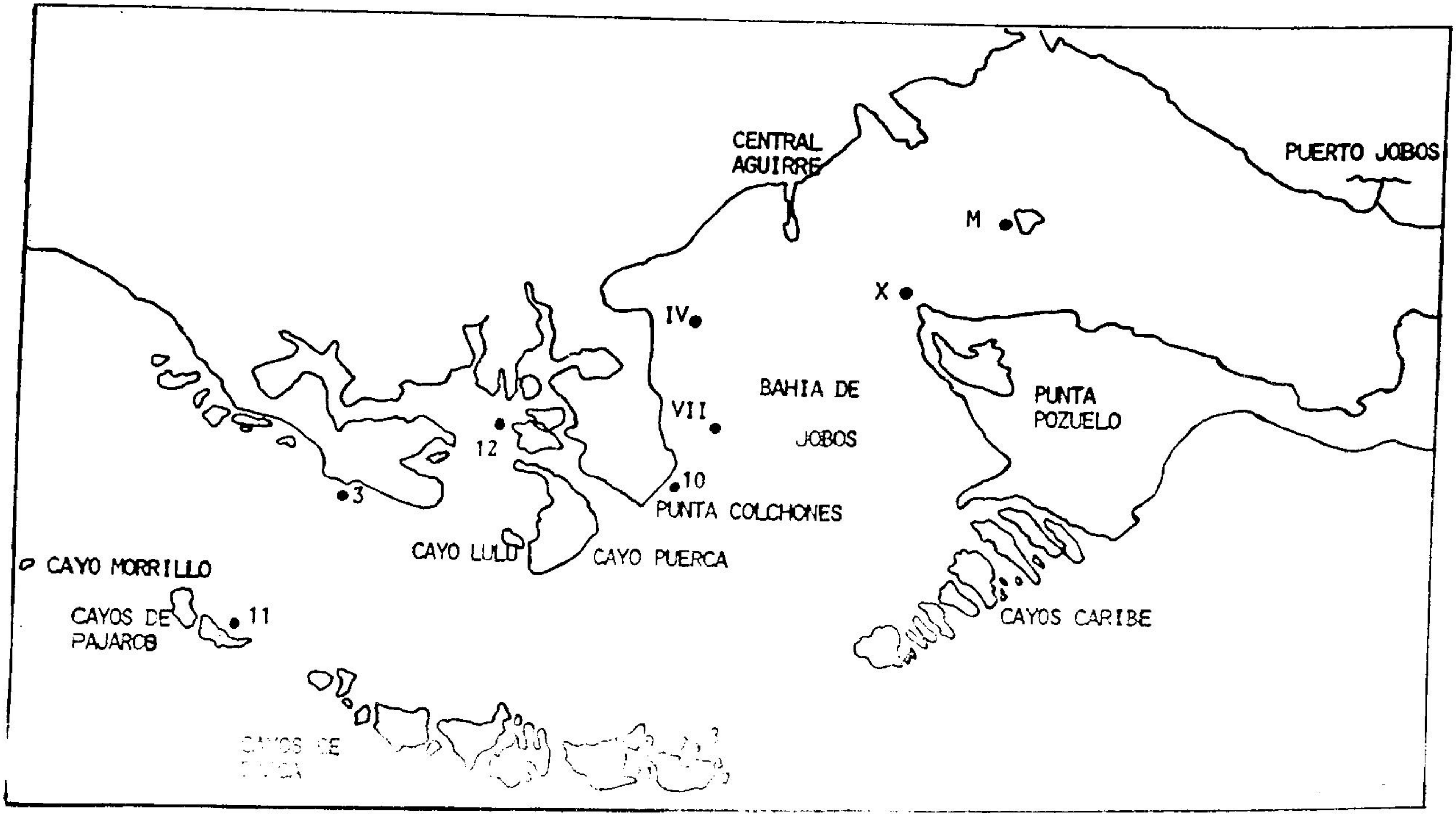


Figure 2. *Thalassia* bed stations in Jobos Bay, Southeast Coast of Puerto Rico



were made on these components. The plant material was dried in a Precision Thelco Oven Model 17 at 80°C until a constant dry weight was obtained (48 hrs). The dried material was weighed in a Mettler Top Balance type K7.

In order to determine morphological variations of *Thalassia* in different environments, measurements were made of the rhizome diameter (N= 1,150) number of leaves per shoot (N= 1,702), leaf diameter (N= 220), leaf length (N= 196), number of growing tips (N= 130), and number of new shoots (N= 130). The core samples, as well as random samples obtained at 15 seagrass beds around Puerto Rico, including the Jobos and Guayanilla stations, were used for this purpose. Rhizome diameters and leaf measurements were made with a Vernier Caliper. Seven-hundred fifty samples were taken in total on 15 *Thalassia* beds around Puerto Rico including Jobos and Guayanilla stations to determine sexual reproduction. Fifty random samples of short shoots were collected at each of the 15 *Thalassia* beds. The collecting period was in May 1976 during the sexual reproductive cycle of *T. testudinum*. In the laboratory presence or absence of sexual reproductive bodies were determined. Flowers, fruits and seeds were characterized. The depth limit of *T. testudinum* was determined in order to utilize it as an index of distribution for comparison. The depth limit of *Thalassia* for all stations was determined in January 1977 by diving to the maximum depth at which *Thalassia* occurred, then measuring the distance from the bottom to the surface in meter units by using a line and float.

Laboratory Studies

Laboratory studies were conducted to substantiate field observations. Laboratory experiments were undertaken to study the effect of temperature on the development of *Thalassia* seedlings which were raised in the laboratory. In addition, the effect of substrate on the development of seedlings was determined.

Four 200-gallon Fiberglas tanks were set up in the laboratory with running sea water. Ten young seedlings were conditioned and placed in each tank for a period of 28 days. Mixed *Halimeda* shell sediment was used as a growing substrate. The tanks were raised to the temperatures indicated below. Values are in °C.

TANK	MEAN	S	RANGE
A	39.03	±.23	38.5 - 39.4
B	37.04	±.17	36.7 - 37.5
C	35.06	±.16	34.8 - 35.6
D(Ambient)	29.70	±2.2	24.8 - 32.6

The means were obtained from four readings per day with a mercury thermometer. Continuous temperature recordings were made with a YSI Thermistor, a YSI multipoint switching unit and a Honeywell Millivolt Strip Chart Recorder (Banus, personal communication).

Laboratory substrate studies were conducted by growing young *Thalassia* seedlings in different sediments as shown below:

TANK	TYPE OF SEDIMENT	SEDIMENT SIZE
E	Halimeda-shell fragments	4mm
F	Halimeda-shell fragments	1-2mm
G	Halimeda-shell fragments	.25-.50mm
H	Mangrove mud	<.63mm

Chemical analyses of Thalassia leaves were done by the Laboratorio Central Analítico of the Agricultural Experimental Station in Río Piedras. Mineral composition (P, K, Mg, Ca), protein, total fiber, lignocellulose, lignin, ash, and Si were determined in leaves collected at the heated stations (8 and 1) and at the temperature control station (7) in Guayanilla Bay.

The fiber analysis was done according to the method of Goering and Soest (1970). The neutral detergent fiber (NDF) is a measure of the total fiber fraction. The acid detergent fiber (ADF) represents the lignocellulose fraction. Lignin content, acid in soluble ash, and silica were also analyzed.

DESCRIPTIONS OF STATIONS

Guayanilla

The thermal effluents from the Guayanilla Power Plant complex discharge inside the thermal cove (see Figure 1). No station for Thalassia biomass determination was set there since the bottom of the cove is devoid of seagrasses. The high temperature (≥ 30°C throughout the year), the very turbid water (Z SD ≤ 1.0m), the unstabilized fine sediment in the bottom, and the strong effluent currents could account for this. However, close to the entrance of the cove there are a number of Thalassia beds exposed to the thermal plume. In order to evaluate the effect of this heated effluent on Thalassia, three stations on eastern Guayanilla Bay were selected along a thermal gradient within the plume. These are stations 8, 1 and 10. Station 7 is located at the intake and can be considered as a temperature control station only.

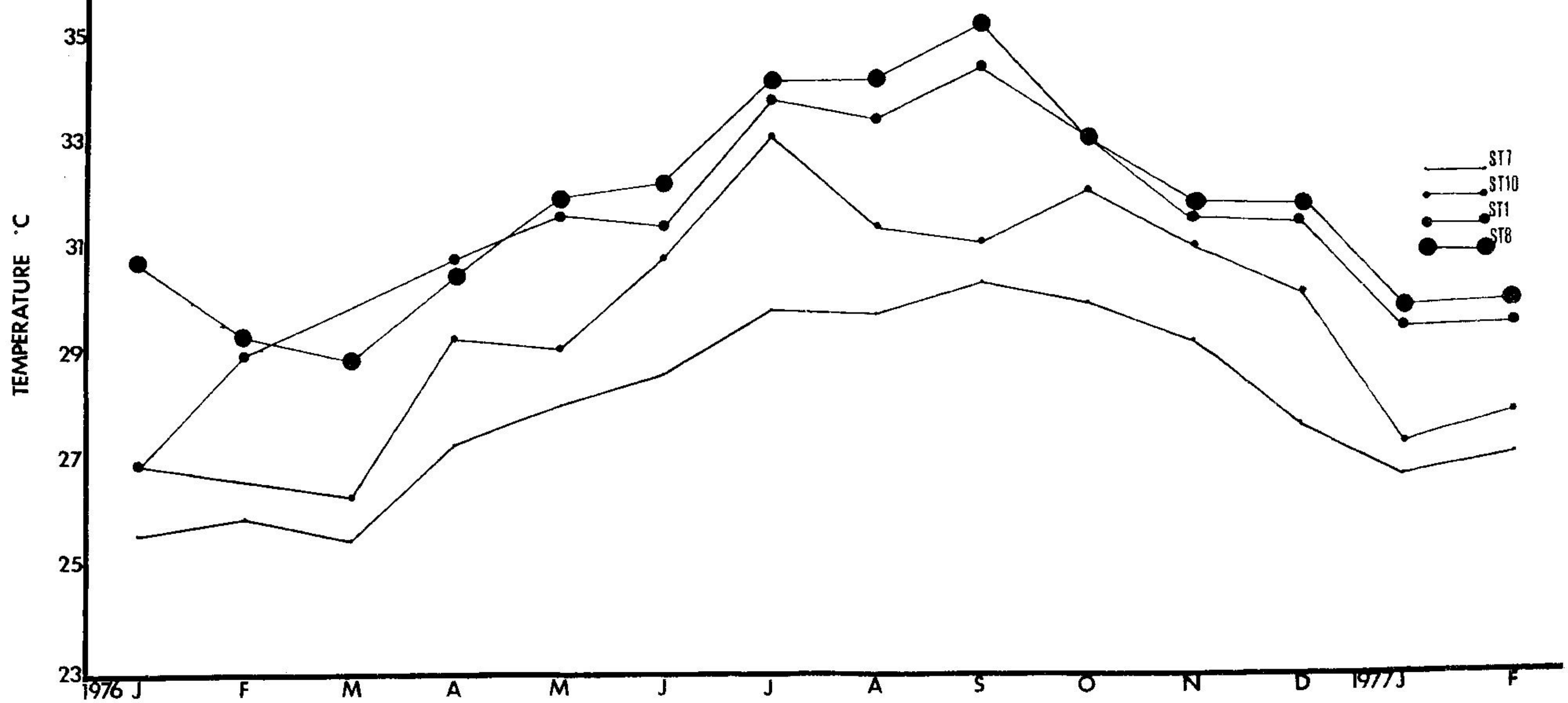
The most thermally stressed Thalassia bed station is station 8, always with temperatures higher than ambient because of its proximity to the outlet of the heated cove. Stations 8, 1 and 10 had temperatures above ambient throughout the year with an annual mean ΔT of 3.7°C (range + 2.4 to + 5.1) for station 8, ΔT of 3.2°C (range + 1.3 to + 4.1) for station 1, and ΔT of + 1.8°C (range + .6 to + 3.5) for station 10. The differences in temperature between the Guayanilla station and between seasons are illustrated in Figure 3. July through September were found to be the warmest months for the Guayanilla stations. Mean annual temperatures for Guayanilla stations are 31.7°C for station 8, 31.2°C for station 1, 30.0°C for station 10 and 28°C for station 7. Stations 8, 1 and 10 are located 91; 273; and 637 meters from the outlet of the heated cove.

The Thalassia bed stations in Guayanilla are considered turbid (Vicente and Rivera, in press). Z SD readings at stations 8 and 1 range from .1m to 2.1m. Salinity was relatively constant (34-35$^{\circ}/_{oo}$) at all the stations. The substrate at stations 8 and 1 is composed of coral rubble and large shell fragments. At station 7 the substrate is mostly fine mud, and at station 10 the substrate is mostly coarse sand.

Jobos

Thalassia bed stations in Jobos Bay were used as control stations. However, there may be situations where natural conditions are altered, especially at those stations located in the inner bay such as station M, IV, and X. Station 3 is in a

FIGURE 3: MEAN MONTHLY VARIATIONS IN TEMPERATURE (°C) IN GUAYANILLA STATIONS (Jan. 1976-Feb. 1977)



totally undisturbed environment. The temperature fluctuations at all stations are considered ambient (see Figure 4) and salinity varies slightly ($33°/_{oo}$-$35°/_{oo}$). Turbidity measurements indicate that Jobos Bay is less turbid then eastern Guayanilla Bay. There are some differences in substrate between the Jobos Bay stations. The substrate at station M is highly reduced, black fine mud, where at station 3 the substrate is Halimeda sand. Stations X and IV have a mixed sediment composition of fine mud, Halimeda, shell and Porites fragments.

Other Stations

In addition to the stations mentioned above, 10 additional Thalassia beds occurring in other localities around the island and in other localities within Jobos Bay were used to compare some parameters measured for Thalassia to provide guidelines. The stations, their localities and the parameters measured for each station are given in Table 1.

RESULTS

Biomass: Thalassia testudinum

The mean biomass values (roots + rhizome + leaves + stems) of Thalassia for each station at each sampling period in Guayanilla and Jobos Bays are given in Table 2. The mean annual biomass for Jobos was 1,115 ± 495 gr DW/m^2 (N=80) and that for Guayanilla was 330 ± 215 gr DW/m^2 (N=80). Statistical analysis (Student t test) indicates that the higher value for Jobos Bay is significantly different ($P \leq .01$) from Guayanilla Bay. The

FIGURE 4: MEAN MONTHLY VARIATIONS IN TEMPERATURE AT JOBOS BAY STATIONS (Jan. 1976 - March 1977)

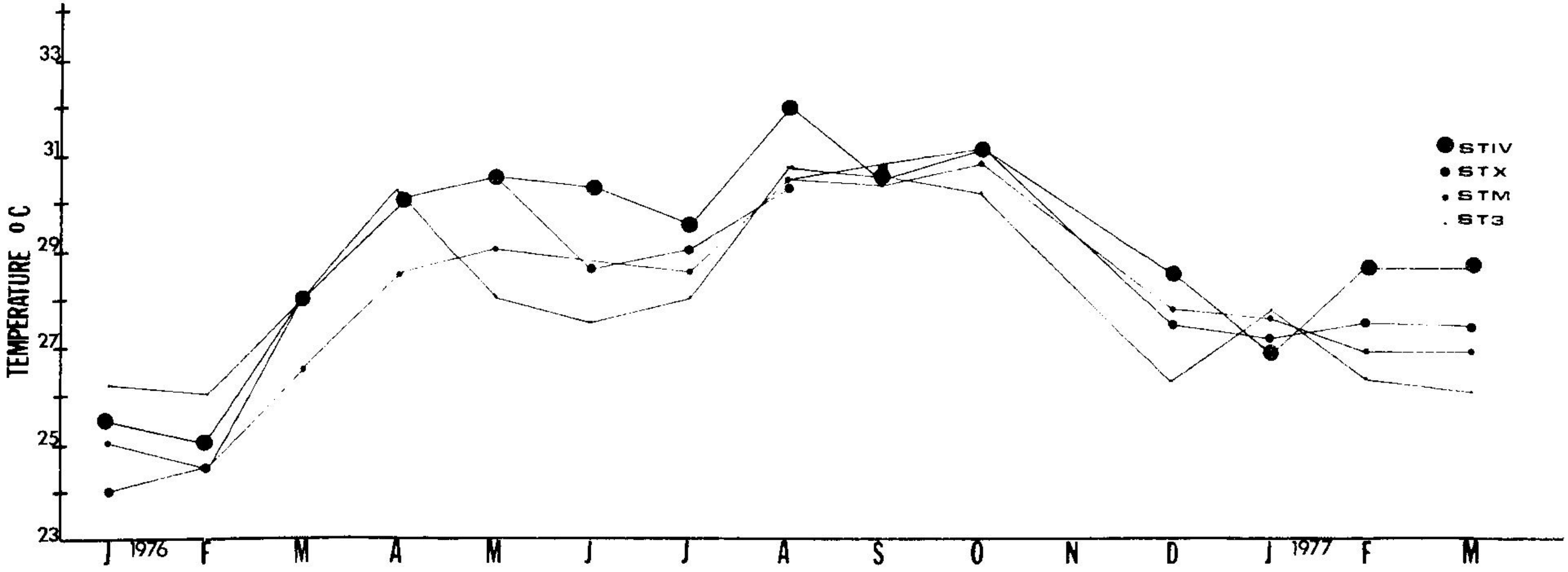


TABLE 1. Parameters measured in <u>Thalassia</u> bed stations.

		MORPHOLGY				INVERTEBRATES	
STATION	DEPTH LIMIT	TOTAL	NO. LEAVES	SEX REP.	BIOMASS	FOUND	LOCATION
8G	X	X	X	X	X	X	Guayanilla-Southwest Coast
1G	X	X	X	X	X	X	Guayanilla-Southwest Coast
10G	X	X	X	X	X	X	Guayanilla-Southwest Coast
7G	X	X	X	X	X	X	Guayanilla-Southwest Coast
MJ	X	X	X	X	X	X	Jobos-Southeast Coast
IVJ	X	X	X	X	X	X	Jobos-Southeast Coast
XJ	X	X	X	X	X	X	Jobos-Southeast Coast
3J	X	X	X	X	X	X	Jobos-Southeast Coast
11J	X	X	X	X			Jobos-Southeast Coast
8J	X						Jobos-Southeast Coast
10J	X						Jobos-Southeast Coast
VIIJ	X						Jobos-Southeast Coast
LUQ			X	X			Luquillo-Northeast Coast
LUQ. Est.			X	X			Luquillo-Northeast Coast
PLM			X	X			P. Las Marias-North Coast
PA			X	X			P. Arenas- West Coast
L. Cr.			X	X			Las Croabas-East Coast
L. Cr. M			X	X			Las Croabas-East Coast

TABLE 2. Total biomass (rhizomes, roots, stems and leaves) of *Thalassia testudinum* in Jobos (J) and Guayanilla (G) Bays. Each number represents the mean value (N=5; gr/DW/.02m^2).

STATION	Feb/Apr.'76	July	Oct.	Feb. '77
IV J	27.1	44.5	14.2	14.2
3 J	25.9	41.4	18.8	24.3
X J	16.1	28.2	12.2	16.9
M J	12.1	28.5	16.7	15.4
7 G	9.2	14.4	8.0	9.3
10 G	4.2	15.4	9.6	7.8
1 G	3.9	7.7	3.3	4.8
8 G	1.7	2.0	2.3	2.3

maximum value for Jobos was 2,225 gr DW/m^2 and for Guayanilla 725 gr DW/m^2. Both maximum values were obtained in July 1977. The maximum value of biomass ever obtained in Jobos was 5,800 gr DW/m^2 (Vicente, 1975b).

The differences in biomass values between stations and the seasonal variations are illustrated in Figure 5. A statistical analysis (2 way ANOVA) was performed utilizing the data in Table 2 to determine if differences were significant between stations and seasons. The results were the following: a) All of Jobos stations (IV, 3, X and M) are significantly different ($P \leq .05$) from the low biomass values obtained at stations 8 and 1 in Guayanilla, which are closest to the outlet of the heated cove. The higher biomass values in the month of July are significantly different ($P \leq .05$) from the values obtained in the February-April and October periods.

Station 8, the station closest to the outlet of the heated effluents in Guayanilla Bay, exhibited no seasonal fluctuations (see Figure 5) and always had the lowest mean biomass values. There was no significant difference between stations in Jobos nor between stations in Guayanilla.

The individual plant components of *Thalassia* are expressed in biomass values in Table 3. The mean values of all plant components in the heated stations 8 and 1 in Guayanilla are lower than at all other stations. On the other hand, stations 3 and IV in Jobos show optimum developments of each of the components. All of the mean values of rhizomes, roots, stems and leaves for Guayanilla are lower than the Jobos Bay *Thalassia* beds.

FIGURE 5: SEASONAL FLUCTUATIONS IN TOTAL BIOMASS OF *THALASSIA* AT JOBOS AND GUAYANILLA STATIONS.

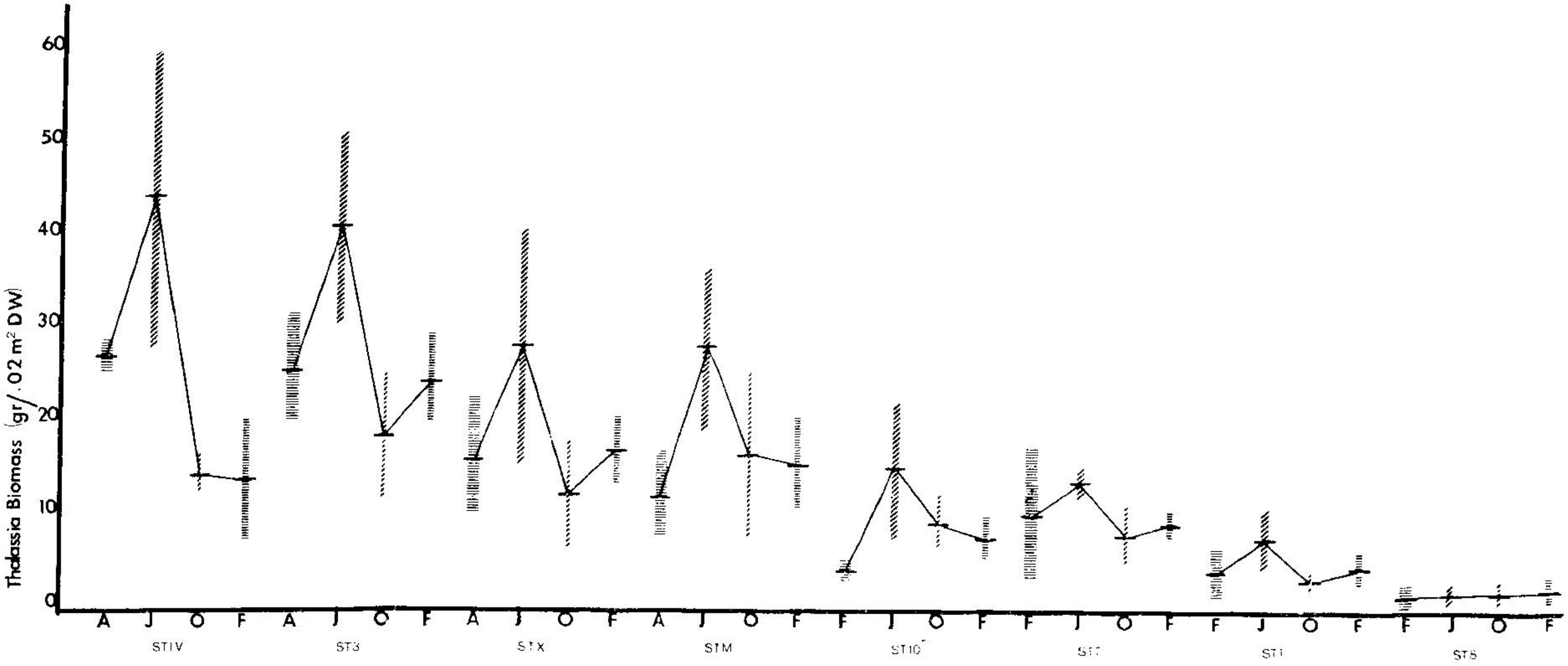


TABLE 3 . Root, (gr DW/.02 m^2) Rhizome, Stem and Leaf Biomass of *Thalassia testudinum* in Jobos Bay and Guayanilla Bay.

STATION		ROOTS			RHIZOMES			STEMS			LEAVES		
		N	$\overline{X}$	SD	N	$\overline{X}$	SD	N	$\overline{X}$	SD	N	$\overline{X}$	SD
X	JOB	20	6.5	4.1	20	5.8	3.3	10	3.0	1.4	20	4.5	3.0
M	JOB	20	5.2	3.4	20	4.9	3.9	10	3.8	1.8	20	6.1	2.6
IV	JOB	20	9.0	3.7	20	5.9	4.1	10	2.9	1.4	20	4.6	3.0
3	JOB	20	7.3	2.6	20	6.7	4.1	10	5.9	1.4	20	7.4	2.7
7	GUAY	20	2.8	1.5	20	3.4	1.9	10	1.2	.6	20	3.4	1.3
10	GUAY	20	1.2	.7	20	2.3	.9	10	1.3	.6	20	3.2	1.9
1	GUAY⬅	20	.8	.5	20	1.3	.8	10	.8	.3	20	2.3	2.1
8	GUAY⬅	20	.2	.2	20	.7	.4	10	.5	.3	20	.8	.5

Morphological variations of *Thalassia testudinum*

The morphological characteristics of *Thalassia testudinum* were compared from material collected in Jobos, Guayanilla, and other localities around the island (Tables 4 and 5).

The diameter of *Thalassia* leaves on the heated stations (8 and 1) in Guayanilla Bay was thinner than at all other stations. However, at station 11 in Jobos Bay, a physically undisturbed *Thalassia* bed also had thinner leaves. Stations 8 and 1 are physically stressed by the heated effluents and station 11 is biologically stressed by the grazing pressure of *Diadema antillarum* (Vicente and Rivera, in press). *Thalassia* from thermally stressed stations did not have shorter leaves than *Thalassia* from other stations. Station 11 which is under heaviest grazing pressure had shorter leaves and station 3 which is under less grazing pressure had the longest leaves. The number of leaves per shoot (Table 5) seems to be a constant morphological characteristic for *Thalassia testudinum* irrespective of where they occur. The mean rhizome diameter, number of growing tips and number of new shoots have lower values in station 8 which is the warmest station.

Depth limits of *Thalassia testudinum*

The depth limits of Thalassia testudinum were determined in 12 stations. Table 6 presents the depth limit and mean Secchi disc readings $\overline{(Z\ SD)}$ obtained at each station. The maximum depth limit recorded was 5.0 m at station 8 in Jobos and the minimum depth limit (1.2 m) was obtained at stations 8 and 1 in the Guayanilla heated stations. The Spearman's Rank correlation

TABLE 4. The morphological characteristics of *Thalassia testudinum* in different environmental conditions.

STATION	(May 1976) No. of leaves per shoot			(Feb-Mar 1976) Leaf Diam. (in MM)			(Feb-Mar 1976) Leaf length (MM)			Mean Annual values 76-77 Rhizome Diam. (in MM)			Mean Annual Values 76-77 No. gr. tips (per .02^{m2})			No. of new shoots (per .02^{m2})		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
IVJ	50	3.9	.8	25	9.8	1.6	25	102	25	200	3.8	.4	20	5.4	1.7	20	8	1.2
3J	46	3.7	1.0	25	11.4	1.3	25	206	45	200	4.7	.3	15	4	1.9	15	4.9	6.8
XJ	50	3.4	.8	25	9.3	1.1	25	117	33	150	3.7	.2	15	4.8	2.7	15	8.1	5.0
MJ	47	4.0	.8	24	9.4	1.4	-	-	-	200	4.0	.1	20	3.7	1.6	20	5.0	1.9
11J	51	3.2	.6	25	7.6	1.0	25	60	12	-	-	-	-	-	-	-	-	-
8G ⬅	50	4.0	.7	24	7.1	.8	24	151	45	200	3.1	.3	15	.7	.5	15	1.1	.4
1G ⬅	49	3.8	.8	24	7.3	.7	24	164	46	200	3.3	.9	15	3.0	2.0	15	4.5	2.2
7G	50	3.9	.9	24	9.6	1.5	24	130	44	200	3.7	.3	15	3.6	2.1	15	6.6	1.6
10G	49	3.6	.6	24	9.7	1.4	24	158	54	200	4.2	.2	15	3.1	1.8	15	3.3	1.1

TABLE 5. The number of leaves per shoot of *Thalassia testudinum* collected from 15 seagrass beds around the island of Puerto Rico.

Station	Location	Date	N	$\bar{x}$	S.D.
Luquillo	N.E. Coast	5/22/76	51	3.8	.9
Luquillo Estuarine	N.E. Coast	5/22/76	50	4.3	1.0
P. Las Marias	N. Coast	5/22/76	54	3.4	1.0
Punta Arenas	W. Coast	5/27/76	45	3.3	.7
Las Croabas	E. Coast	5/23/76	47	3.3	1.0
Las Croabas (middle)	E. Coast	5/23/76	50	3.1	.9
St. 10 Guay.	S.W. Coast	5/14/76	49	3.6	.6
St. 8 Guay.	S.W. Coast	5/14/76	50	4.0	.7
St. 7 Guay.	S.W. Coast	5/14/76	50	3.9	.9
St. 1 Guay.	S.W. Coast	5/14/76	49	3.8	.8
St. 3 JOB	S.E. Coast	5/19/76	46	3.7	1.0
St. *x* JOB	S.E. Coast	5/19/76	50	3.4	.8
St. M JOB	S.E. Coast	5/19/76	47	4.0	.8
St. IV JOB	S.E. Coast	5/19/76	50	3.9	.8
St. 11 JOB	S.E. Coast	5/19/76	51	3.2	.6
St. 10 Guay.	S.W. Coast	5/14/76	41	3.3	.6
St. 10 Guay.	S.W. Coast	5/14/76	33	3.3	.8
St. 10 Guay.	S.W. Coast	5/14/76	44	3.4	.8
St. 8 Guay.	S.W. Coast	5/14/76	38	3.6	.9
St. 8 Guay.	S.W. Coast	5/14/76	26	3.2	.9
St. 8 Guay.	S.W. Coast	5/14/76	24	3.4	.8
St. 7 Guay.	S.W. Coast	5/14/76	37	3.2	.8
St. 7 Guay.	S.W. Coast	5/14/76	26	3.6	1.0
St. 7 Guay.	S.W. Coast	5/14/76	21	3.2	.9
St. 1 Guay.	S.W. Coast	5/14/76	31	3.7	1.1
St. 1 Guay.	S.W. Coast	5/14/76	41	3.9	.9
St. 1 Guay.	S.W. Coast	5/14/76	45	3.4	.9
St. *x* JOB	S.E. Coast	4/29/76	66	3.1	.7
St. *x* JOB	S.E. Coast	4/29/76	54	3.1	.8
St. *x* JOB	S.E. Coast	4/29/76	60	3.3	.7
St. 3 JOB	S.E. Coast	4/29/76	24	3.5	.8
St. 3 JOB	S.E. Coast	4/29/76	39	3.0	.9
St. 3 JOB	S.E. Coast	4/29/76	25	3.4	.9
St. M JOB	S.E. Coast	4/29/76	21	4.3	1.6
St. M JOB	S.E. Coast	4/29/76	52	3.8	.9
St. M JOB	S.E. Coast	4/29/76	37	4.5	1.0
St. IV JOB	S.E. Coast	4/29/76	59	3.4	.8
St. IV JOB	S.E. Coast	4/29/76	60	3.7	.9
St. IV JOB	S.E. Coast	4/29/76	59	3.6	.7

TABLE 6. Secchi depth readings and depth limit of _Thalassia testudinum_. Monthly Secchi depths measurements. The depth limit of _Thalassia_ for all stations was determined in January 1977.

STATION	LOCATION	PERIOD OF SECCHI RECORDINGS	N	SECCHI X	S.D.	DEPTH LIMIT _Thalassia_ (M)
M	Jobos	Aug. 76-Mar. 77	7	2.4	.5	2.0
X	Jobos	Aug. 76-Mar. 77	7	2.5	.4	2.6
IV	Jobos	Aug. 76-Mar. 77	7	2.6	.3	2.0
3	Jobos	Aug. 76-Mar. 77	7	3.9	1.0	3.0
11	Jobos	Aug. 76-Mar. 77	7	4.2	1.4	1.0
8	Jobos	Sept. 76-Mar. 77	6	4.7	1.7	5.0
VII	Jobos	Oct. 76-Mar. 77	5	2.9	.4	2.0
10	Jobos	Oct. 76-Mar. 77	5	2.9	.3	4.0
7	Guay	Aug. 76-Mar. 77	8	1.8	.6	1.8
10	Guay	Aug. 76-Mar. 77	8	1.4	.5	2.1
1	Guay	Aug. 76-Mar. 77	8	1.3	.6	1.2
8	Guay	Aug. 76-Mar. 77	8	1.1	.6	1.2

coefficient between mean Secchi depth ($\overline{Z\ \mathrm{SD}}$) readings and the lower limit of *T. testudinum* was $r = +.82$ and significant at the 1% level. However, at station 11 the depth limit of *Thalassia* was recorded at 1.0m where the $\overline{Z\ \mathrm{SD}}$ was 4.2 meters which suggests that some other factor such as grazing, (Vicente and Rivera, in press) is regulating the depth limit of *Thalassia* at this station. Figure 6 illustrates the correlation between Z SD and depth limit of *Thalassia*. From this figure it can be seen that the Guayanilla stations occur in more turbid water and are not distributed as deep as the Jobos Bay station.

Sexual Reproduction

The percentages of short shoots with sexual reproductive bodies in 15 *Thalassia* beds around Puerto Rico, including Jobos and Guayanilla stations, are given in Table 7. Inhibition of sexual structures occurs at the heated stations (8 and 1) and at the temperature control station (7) in Guayanilla Bay. Even where sexual bodies were found in Guayanilla (Station 10), only 4% of the shoots were found to be fertile. Jobos Bay stations were proliferous when compared to Guayanilla Bay. At Punta Las Marias on the north coast of Puerto Rico no reproductive bodies were found. This *Thalassia* bed occurs under extreme heavy wave action and sand abrasion.

FIGURE 6: THE CORRELATION BETWEEN MEAN SECCHI DEPTH READINGS $(\overline{Z \quad SD})$ AND THE DEPTH LIMIT OF *THALASSIA TESTUDINUM.*

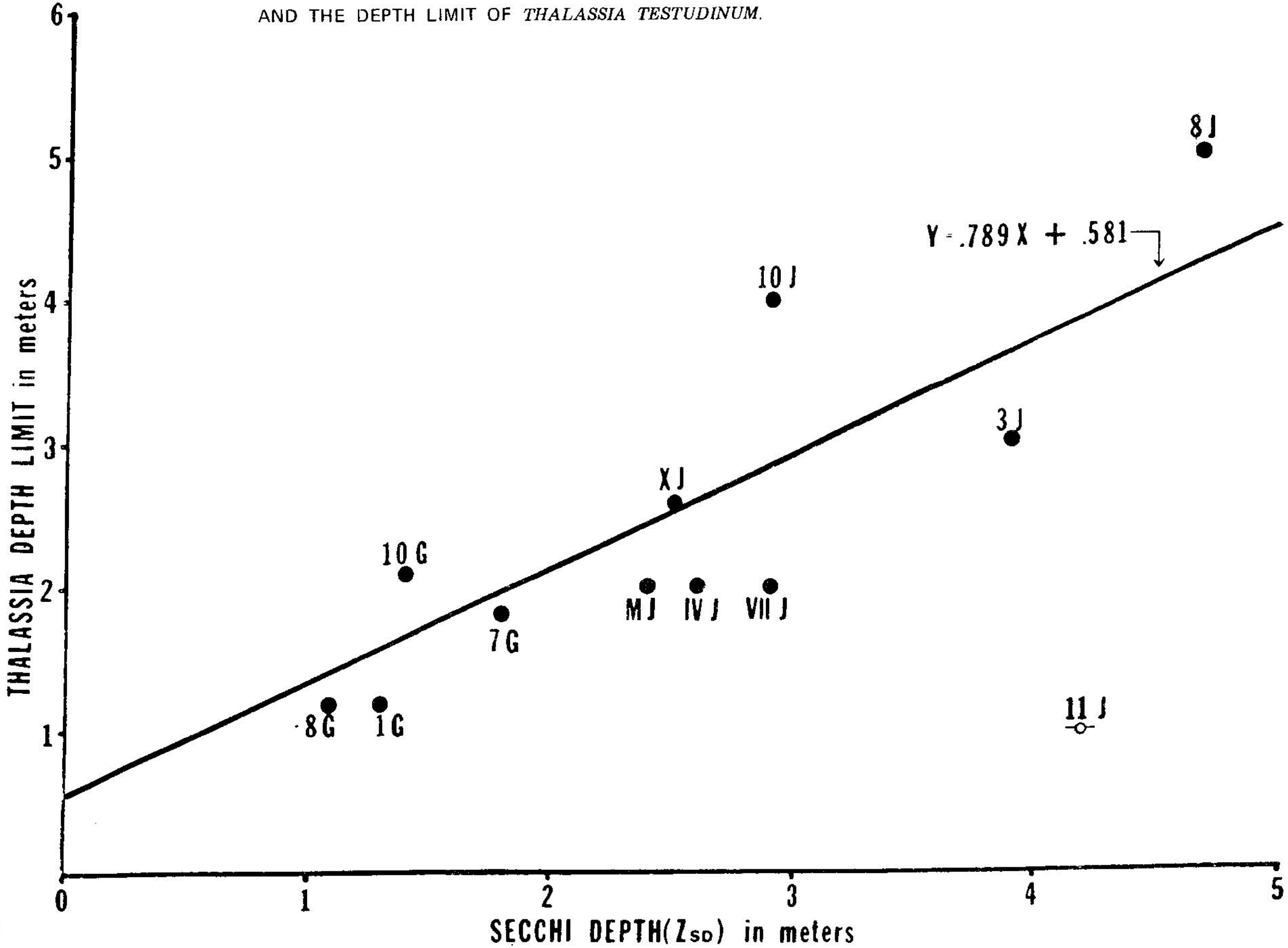


TABLE 7. Percentage of *Thalassia* shoots with reproductive bodies (buds, flowers, or fruits) in seagrass beds around the island. Fifty shoots were collected at random in order to determine the percentage.

SITE	LOCATION	DATE	NUMBER COLLECTED	NO. WITH REPROD. BODIES	% WITH REPROD. BODIES
Luquillo	NE Coast	5/22/76	50	10	20
Luquillo Estuarine	NE Coast	5/22/76	50	10	20
P. Las Marias	N Coast	5/22/76	50	0	0
P. Arenas	W Coast	5/27/76	46	15	33
Las Croabas	E Coast	5/23/76	47	14	30
Las Croabas (middle)	E Coast	5/23/76	50	2	4
Sta. 3 Jobos	SE Coast	5/19/76	46	13	27
Sta. X Jobos	SE Coast	5/19/76	50	9	18
Sta. M Jobos	SE Coast	5/19/76	50	7	14
Sta. IV Jobos	SE Coast	5/19/76	50	12	24
Sta. 11 Jobos	SE Coast	5/19/76	50	27	54
Sta. 10 Guayanilla	SW Coast	5/14/76	50	2	4
Sta. 8 Guayanilla	SW Coast	5/14/76	50	0	0
Sta. 7 Guayanilla	SW Coast	5/14/76	50	0	0
Sta. 1 Guayanilla	SW Coast	5/14/76	50	0	0

Temperature Laboratory Study

The results of the temperature effect on the development of Thalassia seedlings are given in Table 8. There was no root development at 35°C, 37°C and 39°C. Root growth was only evident at the temperature control tank (D). Leaves were all dead at 39°C and 37°C. Extensive defoliation was evident at 37°C. At 35°C the leaves were still green after the experiment; however, there were no indications of leaf growth. Besides, since roots did not develop at 35°C, the seedlings can be considered non-viable since the inhibition of root development prevents the seedlings from attachment to the substrate.

TABLE 8. The effect of elevated temperatures on the development of Thalassia seedlings under laboratory conditions

Tank	Temp. °C	s	Range °C	Formation of Roots	Color of Leaves
A	39.0	.23	38.5-39.4	0	Brown
B	37.0	.17	36.7-37.5	0	Yellow-Green
C	35.0	.16	34.8-35.6	0	Green
D	29.7	2.2	24.8-32.6	+	Green

Chemical Analysis of Thalassia Leaves

Chemical analyses of the crude fiber fraction of Thalassia leaves in the past have been done by proximate analysis. Some data indicate that the crude fiber fraction is more digestible than the nitrogen-free extract which demonstrates that this method fails to separate the carbohydrates into soluble and insoluble, digestible or indigestible fractions. This is the main criticism against the use of proximate analysis scheme (Kayongo-Male, et al. 1976). A more refined method of determining the fibrous carbohydrate fractions as described by Goering and Van Soest (1970) was utilized. This method has been used for tropical forage grasses analysis (Kayongo-Male, et al. 1976); (Arroyo-Aguilú and Lord 1974);(Lord et al. 1974);(Arroyo-Aguilú and Evans 1975); (Arroyo-Aguilu et al. 1975).

Crude protein as Kjeldhal nitrogen X6.25 was determined by the methods described by the Association of Official Analytical Chemists (1970). Mineral composition also followed standard methods. Thalassia leaves were collected from stations 8 and 1 exposed to the thermal effluents and at station 7, the temperature control station. The results of the analysis are presented in Tables 9 and 10. The NDF (neutral detergent fiber) is a measure of the total fiber fraction. The neutral detergent solubles (NDS) is the difference between 100 and the NDF value which, roughly, is equivalent to 40% in Thalassia leaves. The NDS represents the neutral detergent solubles such as proteins, lipids, soluble carbohydrates and ash. The NDS value for Thalassia, and the ADS (Acid detergent fiber) which represents the lignocellulose fraction, are comparable with tropical forage grasses (Lord et al., 1974). However, the lignin fraction is much higher in Thalassia (22.9%) than forage tropical grasses. This fraction determines, to a great degree, the digestibility of Thalassia leaves. The lignin component in the thermally stressed station (8) is significantly ($P \leq .05$) higher than station 1 (less thermally stressed) and station 7 (thermal control station). Evidence has been shown that high

TABLE 9. The chemical composition of Thalassia leaves at the thermal stations (8 and 1) and at the temperature control station (7). Carbohydrate fibrous fraction: NDF - Neutral detergent fiber; ADF = Acid detergent fiber; Lig = Lignin; Ins. Ash = Acidinsolubleash; Si= Silica. Values are given as percentages (5).

	STATION 1			STATION 8			STATION 7		
	N	$\bar{X}$	s	N	$\bar{X}$	s	N	$\bar{X}$	s
NDF	2	63.84	.10	2	59.37	1.29	2	55.1	12.7
ADF	3	38.84	.84	3	41.80	1.8	3	40.50	1.6
Lig.	1	22.27	-	2	24.20	-	2	22.25	.82
Ins. Ash	1	.27	-	1	.24	-	1	.09	-
Si	1	0	0	1	0	0	1	0	0
Protein	2	17.82	.09	2	17.56	.80	2	16.06	.44
P	2	.195	.007	2	.20	0	2	.23	0
K	2	3.295	.007	2	2.54	.10	2	3.16	.33
Mg	2	1.31	.0	2	1.38	0	2	1.1	.01
Ca	2	1.45	.03	2	1.22	.01	2	1.30	.02

TABLE 10. Mineral Composition, Crude Protein of *Thalassia testudinum* compared to 10 Tropical forage grasses.

SPECIES	CALCIUM	PHOSPHORUS	MAGNESIUM	POTASSIUM	PROTEIN
African Crab	.22	.19	.27	2.57	9.1
Venezuela elephant	.20	.17	.30	3.03	7.7
Giant Pangola	.18	.14	.32	2.50	7.5
Pangola	.25	.19	.23	1.66	7.2
Signal	.20	.18	.24	2.38	6.8
Buffel	.16	.13	.23	2.96	6.6
Jaragua	.33	.17	.28	1.94	6.6
Limpo	.15	.13	.20	1.85	6.3
Congo	.23	.20	.30	2.54	5.6
Guinea	.29	.15	.36	2.43	5.1
Thalassia	1.32	.21	1.26	3.00	17.2

The values for terrestrial grasses were taken from:

Arroyo-Aguilû, J.A. and J. Coward-Lord. 1974
Kayongo-Male, *et al*. 1976.
Lord *et al*. 1974.
Arroyo-Aguilû and Evans 1975.
Arroyo-Aguilû *et al*. 1975.

environmental temperatures can induce higher concentration of lignin. The protein (17.2%) and minerals such as P, K, Mg, and Ca concentrations in Thalassia leaves are much higher, especially the protein fraction, than in tropical forage grasses (Arroyo-Aguilú and Lord, 1974; Lord et al., 1974).

The Development of Thalassia seedlings grown in different Sediment Size Substrates

This study was conducted in order to compare the development of young Thalassia seedlings grown in different sediment size substrates. The number of new shoots formed by the seedlings, rhizome length and diameter, leaf length, leaf width, root length and wet weight of the seedlings was determined after a growing period of 12 months. The results are given in Table 11. Rhizome and root development, which determine the viability of a seedling by substrate attachment, were lower in seedlings grown in coarse sediment (> 4 mm). The seedlings developed healthier in Tanks F and G where the Halimeda calcareous sediment size was in the range of .25-1-2 mm. Although seedlings developed well in mud collected in mangroves, generally speaking, they did not develop as well as those seedlings grown in Tanks F and G.

DISCUSSION

The following characteristics of Thalassia testudinum occurring within the thermal plume (Sta. 8 and 1) suggest that these seagrass beds are under stress conditions: a) their low biomass, b) the thinner leaves and rhizomes, c) the small number of growing tips and new shoots (Sta. 8), d) their shallow depth limit and e) inhibition of sexual reproduction.

TABLE 11. Sediment size and the development of *Thalassia* seedlings under laboratory conditions.

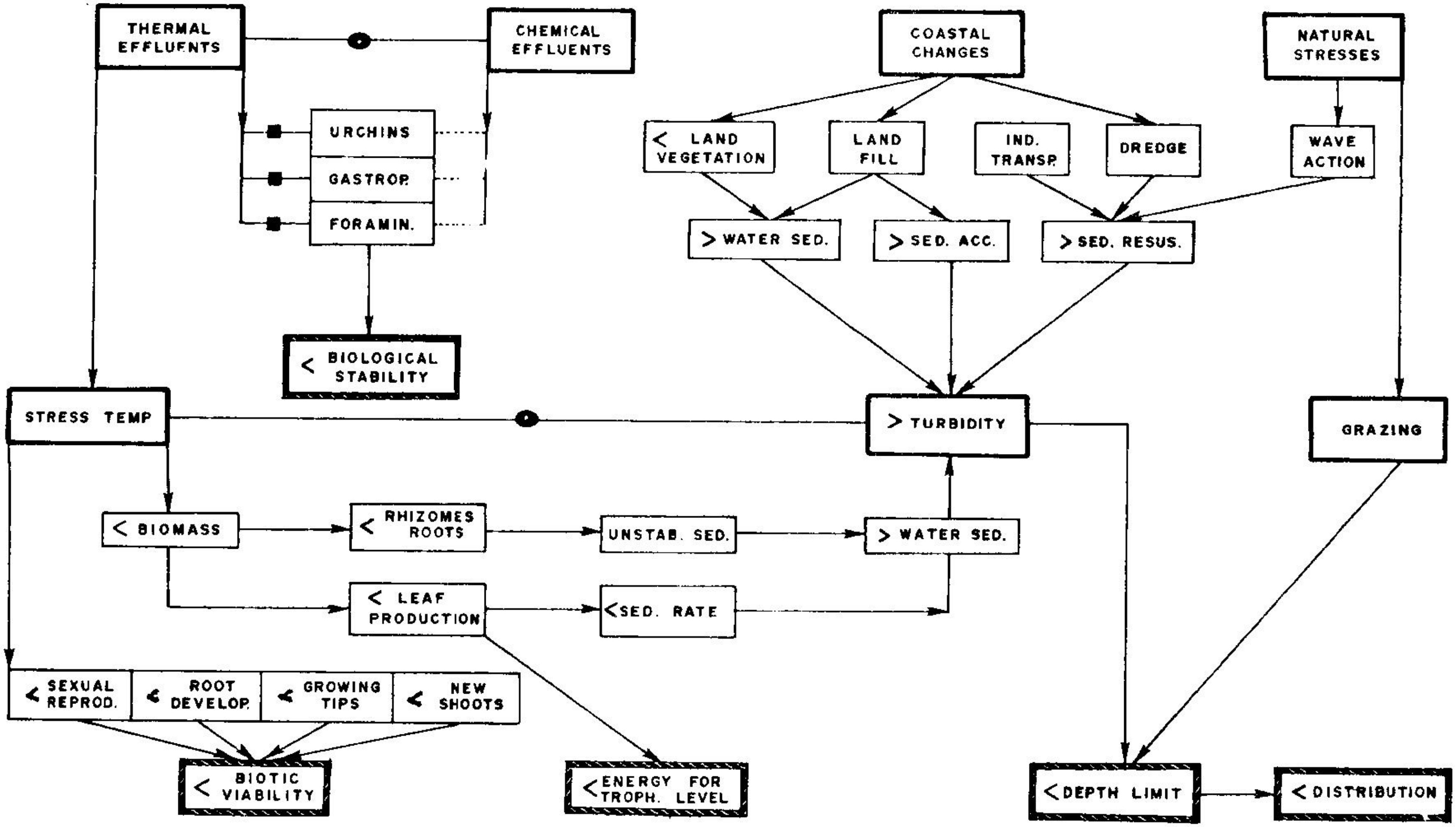
	TANK E > 4mm			TANK F 1-2mm			TANK G .25-50mm			TANK H Fine mud		
Thalassia seedlings	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
New shoots	9	1.6	1.0	9	2.6	1.7	10	3.2	1.0	10	1.8	1.6
Rhizome length(cm)	9	3.0	3.4	9	5.6	4.9	10	7.2	4.0	10	4.5	3.8
Rhizome diameter(mm)	20	2.7	.4	24	3.1	.5	26	3.1	.6	35	3.1	.9
Leaf length(cm)	83	5.9	2.5	112	7.8	3.5	110	7.9	3.2	101	7.0	3.5
Leaf width(mm)	83	5.3	.6	112	4.9	1.1	110	4.9	.1	101	5.6	.2
Root length(cm)	93	4.7	2.3	103	5.9	3.2	211	7.4	8.9,	117	6.3	3.3
Wet weight(g)	9	4.5	2.2	9	6.2	3.4	10	6.0	2.7	10	4.7	1.9

Although it is believed that there are various disturbing factors operating simultaneously, the following evidence suggests that temperature is an important source of stress to _Thalassia_: a) there is a negative correlation between temperature and _Thalassia_ biomass (r = -.69), b) laboratory studies indicated that temperatures of equal, greater, or somewhat lower than 35°C inhibit root development and growth in _Thalassia_ seedlings, and c) the higher lignin content of _Thalassia_ in station 8.

The harder substrate at stations 8 and 1 could also account for the low biomass values of _Thalassia_ as laboratory experiments show. However, the lack of fine sediment layer within the _Thalassia_ rhizomes and roots may be a result of sediment erosion due to a decrease in the biomass of these components as a result of high temperature and high turbidity.

It is difficult to define which disturbing factor is responsible for the deterioration of seagrass beds in the high thermal zone in eastern Guayanilla Bay. There are many factors operating simultaneously at this locality, both natural and industrial. A model has been prepared which tries to explain the mechanisms by which seagrass beds can be disturbed or deteriorated by these factors (Fig. 7). High water temperatures in the thermal effluents, turbidity, chemicals in the effluents, changes in coastal morphology and natural physical and biological stresses are considered as the major determinants of seagrass bed stability. The high temperatures, as well as chemicals in the Eastern Bay, may have been responsible for the deterioration

FIGURE 7: A MODEL ILLUSTRATING SOME OF THE MECHANISMS OF DISTURBANCE IN A *THALASSIA* BED AT AN INDUSTRIAL SITE.



of urchin, gastropod and foraminiferan fauna within these seagrass beds. Although chemicals were not taken into consideration in this part of the study they are included in the model (therefore, their effects are represented by dotted lines). The high temperature at the thermally stressed Thalassia beds may account, for example, for the absence of Lytechinus at these beds since it is known that they, as well as most tropical marine organisms, live only a few degrees from their upper thermal limit. Whatever the situation between temperature and toxic chemicals, the absence of (or insignificant) population levels of these three biological components (urchins, gastropods, and forams) represents a reduction in the biological stability of the system.

High temperatures acting synergistically with turbidity at the thermal effluent stations may be responsible for reducing the biomass of Thalassia. A reduction of Thalassia biomass to low levels has serious consequences for the whole system as illustrated in the diagram: a) it will reduce the growth or biotic potential of the plant in the system; b) the reduction of roots and rhizomes will destabilize the sediments and enhance turbidity; c) reduction in leaf production will decrease the food for the maintenance of upper trophic levels as well as decreasing the sedimentation rate; this will maintain the finer sediment in the water column thus contributing to a higher turbidity. Turbidity, in turn, will decrease the depth limit of Thalassia. This may lead to a decrease in the distribution of the plant as well as to a decrease in the light available to the system. Heavy grazing is included in the model to illustrate that a natural biological factor can be as important as a physical factor in determining the depth distribution of Thalassia (Vicente, in press).

Changes in coastal morphology, both during the construction and operational phase in Guayanilla Bay have had a detrimental impact, either directly or indirectly, on the marine environment. For example, almost all vegetation in the surrounding construction sites has been removed. This destabilizes the soil which will enter the marine environment either by wind or rain erosion which in turn increases the turbidity in the near shore. This has been observed in aerial photographs of Guayanilla Bay. Transporation of tugboats, high wave energy periods and dredging resuspend bottom sediments, accounting in part for an increase in turbidity.

Based on this model, recommendations are made to the local industries of the Guayanilla site to take some action to reduce the temperature of power plant effluents, as well as action to reduce the turbidity of the site. Heat from the thermal effluents can be reduced by implementing cooling towers or cooling ponds, provided that secondary effects of these are taken into consideration. Turbidity, which is high in Guayanilla Bay,could be reduced by reforestation of mangroves and other land vegetation, as well as of Thalassia.

REFERENCES

Anderson, R.R. 1969. Temperature and rooted aquatic plants. Chesapeake Sci. 10(3-4): 157-167.

Arroyo-Aguilú, J.A. and J. Coward-Lord. 1974. Mineral composition of 10 tropical grasses in Puerto Rico. The Journal of Agriculture of the University of Puerto Rico, Vol. LVIII (4): 426-436.

Association of Official Analytical Chemist. 1970. Official methods of analysis, 11th ed., Washington, D.C.

Bader, R.G., M.A. Roessler and A. Thorhaug. 1971. Thermal effects on a tropical marine estuary. FAO Symp. on Mar. Poll. Rome. Fishing Newsbooks, Ltd., London.

Bieble, R. 1962. Temperaturresusten of tropicher meere salgen (rierglichen mit Jener Von Algen in Temperierten Meeresgebieten) Botanica Mar. 4, 241-254.

Brook, I.M. 1977. Trophic relationships in a seagrass community (Thalassia testudinum) in Card Sound, Florida. Fish Diets in relation to macrobenthic and cryptic faunal abundance. Trans. Am. Fish. Soc. 106(3): 219-229.

Cairnes, J. 1956. Effects of increased temperatures on aquatic organisms. Industrial Wastes. 1(4): 150-152.

Camp, D.K., J.F. Cobb, Van Breedveld. 1973. Overgrazing of seagrasses by a regular urchin, Lytechinus variegatus. Bioscience 23(1): 37-38.

Dobzhansky, T. 1950. Evolution in the tropics. Amer. Sci. 38: 209-222.

Drost-Hansen, W. 1969. Allowable thermal pollution limits - a physico-chemical approach. Chesapeake Sci. 10(3-4): 281-288.

Glynn, P.W., L.R. Almodóvar and J.G. González. 1964. Effects of Hurricane Edith on marine life in La Parguera, Puerto Rico. Carib. Jour. Sci. 4(2-3): 335-345.

Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). AH 379, USDA.

González, J.G. 1974. Critical thermal maxima and upper lethal temperatures for the calanoid copepods _Acartia tonsa_ Dana and _Acartia clausi_ Giesbrecht. Marine Biology. 27: 219-223.

Grace, J.B. and L.J. Tilly. 1976. Distribution and abundance of submerged macrophytes including _Myriophyllum spicatum_ L. (Angiospermae) in a reactor cooling reservoir. Newsletter No. 9. International Association of Aquatic Vascular Plant Biologists (IAAVPB); June 1976.

Johannes, R.C. and S.B. Betzer. 1975. Introduction. Marine Communities respond differently to pollution in the tropics than at higher latitudes. Elsevier Oceanography Series. Vol. 12. Tropical Mar. Poll. 199 pp.

Kayongo-Male, H., J.N. Thomas, D.E. Ullrey, R.J. Deans, and J.A. Arroyo-Aguilú. 1976. Chemical composition and digestibility of tropical grasses. Jour. of Agriculture. University of Puerto Rico LX(2): 186-200.

Kikuchi, T. _et al_. 1973. Consumer Ecology. Seagrass ecosystems: Research recommendations of the International Seagrass Workshop. 61 pp.

Kirk, S. 1961. Factors influencing the zonation of submerged monocotyledons at Cedar Key, Florida. Jour. of Wildlife Mge. 25(2): 178-189.

Lord-Coward, J.A. Arroyo-Aguilú, and O. Garcia Molinari. 1974. Journal of Agriculture of the University of Puerto Rico. Vol. LVIII, No. 3: 293-304.

Lowe-McConnell, R.H. 1969. Speciation in tropical fresh water fishes. Biol. Jour. of the Linn. Soc. London. 1: 50-75.

Mayer, A.G. 1914. The effects of temperature upon tropical marine animals. Papers from Tortugas Laboratory. The Carnegie Institution of Washington. VI: 3-23.

Ogden, J.C., R.A. Brown and N. Salecky. 1973. Grazing by the echinoid _Diadema antillrum_ (Phillipi): Formation of halos around West Indian patch reefs. Science 182: 715-717.

Phillips, R.C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Prof. Pap. Ser. Mar. Lab. Fla., No. 2: 1-72.

Randall, J.E. 1965. Grazing effects on seagrasses by herbivorous fishes in the West Indies. Ecology 46(3):255

Randall, J.E. 1961. Overgrazing of algae by herbivorous marine fishes. Ecology 42(4) p. 812.

Roessler, M.A. 1971. Effects of a steam electric station on a subtropical estuary in Florida. Contribution No. 0000. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Rickenbacker Causeway, Miami, Florida 33149.

Schroeder, P. 1975. Thermal stress in Thalassia testudinum. Ph.D. dissertation. University of Miami. pp 1-157.

Sengupta, S. and S.S. Lee. 1976. Physical impact of waste heated disposal. Waste Heat Management and Utilization. Eds. Samuel S. Lee and Subrata Sengupta. I - 15-16.

Sanders, H.L. 1968. Marine benthic diversity. A comparative study. Am. Nat. 102: 243-282.

Smith, R.C. and H.J. Teas. 1976. Biological effects of thermal effluent from the cutler power plant in Biscayene Bay, Florida. Waste Heat Management and Utilization. Eds. Samuel S. Lee, Subrata Sengupta, II - B-91.

Thorhaug, A., D. Seagar, and M.A. Roessler. 1973. Impact of a power plant on a subtropical estuarine environment. Mar. Poll. Bull. 7(11) 166-169.

Thorhaug, A. and P. Schroeder. 1976. A comparison of the biological effects of heated effluents from two fossil fuel plants: Biscayne Bay, Florida in the subtropics; Guayanilla Bay, P.R. in the tropics. Waste Heat Management and Utilization. Eds. Samuel S. Lee, Subrata Sengupta. XI-B-134.

Thorhaug, A., H.B. Moore, and H. Albertson. 1971. Laboratory thermal tolerances in an ecological study of South Biscayne Bay. Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, Fla. XI: 1-33.

Toner, M. 1977. Lasting freeze kills fish, imperils coral reefs. The Miami Herald, Friday, Jan. 21. p 14a.

Vicente, V.P. 1975a. Seagrass bed communities of Jobos Bay. Aguirre Environmental Studies, Jobos Bay, Puerto Rico. Final Report, Vol. I. PRNC 196: 27-45.

Vicente, V.P. 1975b. Aguirre Environmental Studies, Jobos Bay, Puerto Rico. Final Report Vol. II. Tables: p. 127-131.

Vicente, V.P. 1977a. The effect of an industrially disturbed environment on the ecology of Thalassia beds in the South Coast of Puerto Rico. Proceedings A.I.M.L.C. 12: 17 Curacao, March 1977.

Vicente, V.P. 1977b. Impact of heated effluents from a power plant on seagrass beds. In press. Paper presented at the 13th Meeting of the Association of Island Marine Laboratories of the Caribbean, A.I.M.L.C., October.

Vicente, V.P. and J.A. Rivera (in press). Depth limits of the seagrass Thalassia testudinum (Konig) in Jobos and Guayanilla Bays, Puerto Rico. Paper accepted for publication (August 25, 1977) in the Caribbean Journal of Science (Vol. 17).

Zieman, J.C. 1970. The effect of a thermal effluent stress on the seagrasses and macroalgae in the vicinity of Turkey Point, Biscayne Bay, Florida. Ph.D. disseration. University of Miami, Coral Gables, Fla.

Zieman, J.C. 1975. Quantitative and dynamic aspects of the ecology of turtle grass, Thalassia testudinum, pages 541-562 in L.E. Cronin, ed. Estuarine Research. Academic Press, New York.

APPENDIX

TABLE 1. Temperature(°C), Salinity(°/oo), Visibility (Secchi(m) at Station #8, Guayanilla Bay, Puerto Rico - 1976/1977

DATE	TEMP.(°C)	SALINITY(°/oo)	SECCHI(m)
Jan.	30.8	33.0	.9
Feb.	29.3	33.6	.7
March	29.0	34.2	.7
April	30.6	35.0	.6
May	32.6	34.5	1.0
June	32.3	34.0	-
July	34.2	32.0	.6
Aug.	34.2	34.0	.6
Sept.	35.3	35.0	1.1
Oct.	33.0	32.0	.9
Nov.	31.7	35.0	.1
Dec.	31.7	34.5	.6
Jan.	29.7	34.5	1.2
Feb.	29.9	35.5	1.0

TABLE 2. Temperature (°C), Salinity(°/$_{oo}$), Visibility (Secchi(m)) at Station #1, Guayanilla Bay, Puerto Rico 1975/1977

DATE	TEMP. (°C)	SALINITY(°/$_{oo}$)	SECCHI(m)
Jan.	27.0	34.0	.9
Feb.	29.1	34.0	.9
March	29.0	34.2	1.3
April	30.9	34.5	.9
May	31.7	34.5	.8
June	31.5	34.0	-
July	33.9	32.0	.6
Aug.	33.5	34.0	.8
Sept.	34.5	35.0	1.1
Oct.	33.1	32.0	.9
Nov.	31.6	34.5	1.8
Dec.	31.6	34.5	1.0
Jan.	29.5	34.5	1.0
Feb.	29.6	35.5	1.0

TABLE 3. Temperature(°C), Salinity($^{\circ}/_{\circ\circ}$), Visibility(Secchi(m) at Station 10, Guayanilla Bay, Puerto Rico - 1976/1977

DATE	TEMP.(°C)	SALINITY($^{\circ}/_{\circ\circ}$)	SECCHI(m)
Feb.	29.5		N/O
March	26.4	34.5	1.8
April	29.4	34.5	3.1
May	29.2	35.0	1.2
June	30.9	34.0	1.6
July	33.2	34.0	0
Aug.	31.5	34.0	1.2
Sept.	31.2	34.0	.8
Oct.	32.1	34.0	1.8
Nov.	31.1	32.0	1.8
Dec.	30.2	34.5	1.2
Jan.	27.3	34.5	1.7
Feb.	27.9	35.0	1.0
March	-	34.5	1.3

TABLE 4. Temperature(°C), Salinity(°/₀₀), Visibility (Secchi (m) at Station #7, Guayanilla Bay, Puerto Rico 1975/1977

DATE	TEMP. (°C)	SALINITY (°/₀₀)	SECCHI (m)
Jan.	25.7	34.2	1.6
Feb.	26.0	34.5	1.4
March	25.6	34.5	1.8
April	27.4	35.0	1.3
May	28.1	34.1	1.3
June	28.7	34.0	1.8
July	29.9	34.0	1.2
Aug.	29.8	34.2	1.0
Sept.	30.4	35.0	2.1
Oct.	30.0	32.0	1.8
Nov.	29.3	34.5	1.5
Dec.	27.7	34.5	1.5
Jan.	26.7	34.5	1.9
Feb.	27.1	35.0	1.5

TABLE 5. Temperature(°C), Salinity(°/$_{oo}$), Visibility(Secchi(m) at Station M, Jobos Bay, Puerto Rico - 1976/1977

DATE	TEMP.(°C)	SALINITY(°/$_{oo}$)	SECCHI(m)
Jan.	25.0	N/O	N/O
Feb.	24.5	N/O	N/O
March	26.5	N/O	N/O
April	28.5	N/O	N/O
May	29.0	N/O	N/O
June	-	N/O	N/O
July	28.5	34.5	
Aug.	30.4	34.5	2.3
Sept.	30.4	33.5	2.7
Oct.	30.8	33.5	2.7
Nov.	-		
Dec.	27.8	35.0	1.5
Jan.	27.6	34.5	3.0
Feb.	26.9	35.0	2.0
March	26.9	-	2.5

TABLE 6. Temperature (°C), Salinity (°/$_{oo}$), Visibility (Secchi: (m) at Station IV, Jobos Bay, Puerto Rico. 1976/1977

DATE	TEMP. (°C)	SALINITY (°/$_{oo}$)	SECCHI (m)
Jan.	25.5	N/O	N/O
Feb.	25.0	N/O	N/O
March	28.0	N/O	N/O
April	30.0	N/O	N/O
May	30.5	N/O	N/O
June	30.3	N/O	N/O
July	29.5	35.0	N/O
Aug.	32.0	34.0	2.6
Sept.	30.4	34.0	2.7
Oct.	31.0	33.0	2.7
Dec.	28.5	35.0	2.5
Jan.	27.0	34.5	3.0
Feb.	28.7	35.0	2.0
Mar.	28.7	-	2.6

TABLE 7. Temperature(°C), Salinity($^{\circ}/_{\circ\circ}$), Visibility(Secchi(m) at Station X, Jobos Bay, Puerto Rico - 1976/1977.

DATE	TEMP.(°C)	SALINITY($^{\circ}/_{\circ\circ}$)	SECCHI(m)
Jan.	24.0	N/O	N/O
Feb.	24.5	N/O	N/O
March	28.0	N/O	N/O
April	30.1	N/O	N/O
May	30.5	N/O	N/O
June	28.6	N/O	N/O
July	29.0	34.5	N/O
Aug.	30.3	34.0	2.2
Sept.	30.7	35.0	3.2
Oct.	31.1	33.0	2.7
Nov.	-	-	-
Dec.	27.5	35.0	2.1
Jan.	27.2	34.5	2.5
Feb.	27.5	35.0	2.0
March	27.4	-	2.8

TABLE 8. Temperature(°C), Salinity(°/$_{oo}$), Visibility(Secchi(m), at Station 3, Jobos Bay, Puerto Rico - 1976/1977

DATE	TEMP.(°C)	SALINITY(°/$_{oo}$)	SECCHI(m)
Jan.	26.2	N/O	N/O
Feb.	26.0	N/O	N/O
March	28.0	N/O	N/O
April	30.2		
May	28.0		
June	27.5		
July	28.0		
Aug.	30.7	34.5	3.0
Sept.	-	-	4.5
Oct.	30.2	34.0	3.6
Dec.	26.3	35.0	5.0
Jan.	27.8	35.0	5.0
Feb.	26.3	36.0	2.5
March	26.0	-	3.5

Plate 1. The location of Jobos and Guayanilla bays on the caribbean coast of Puerto Rico.

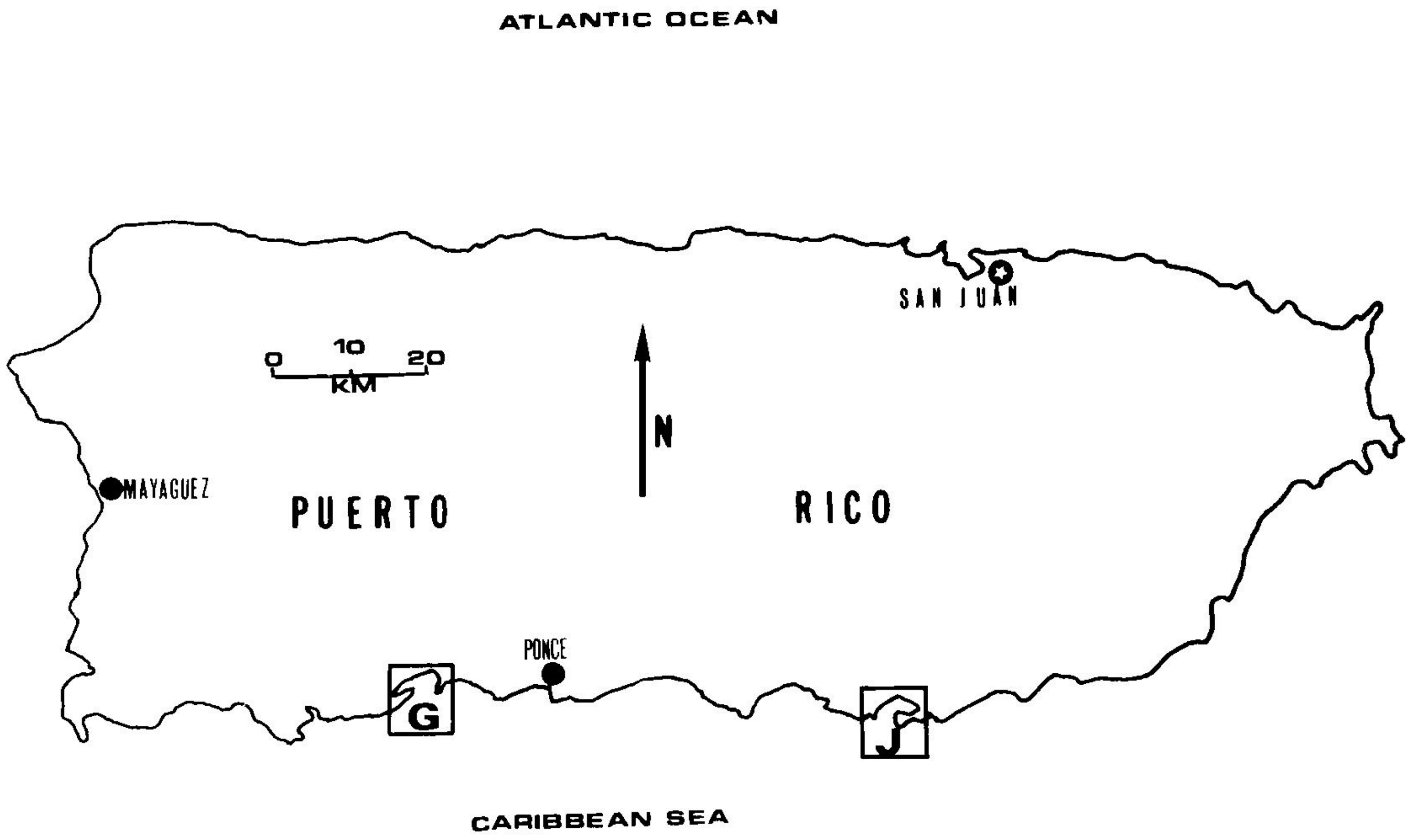

ATLANTIC OCEAN
SAN JUAN
0
10
20
KM
N
MAYAGUEZ
PUERTO
RICO
PONCE
G
J
CARIBBEAN SEA

Plate 11. The distribution of the seagrasses in Guayanilla bay: *Thalassia testudinum*, *Halophila decipiens*, *Halodule wrightii*, and *Syringodium filiforme*.

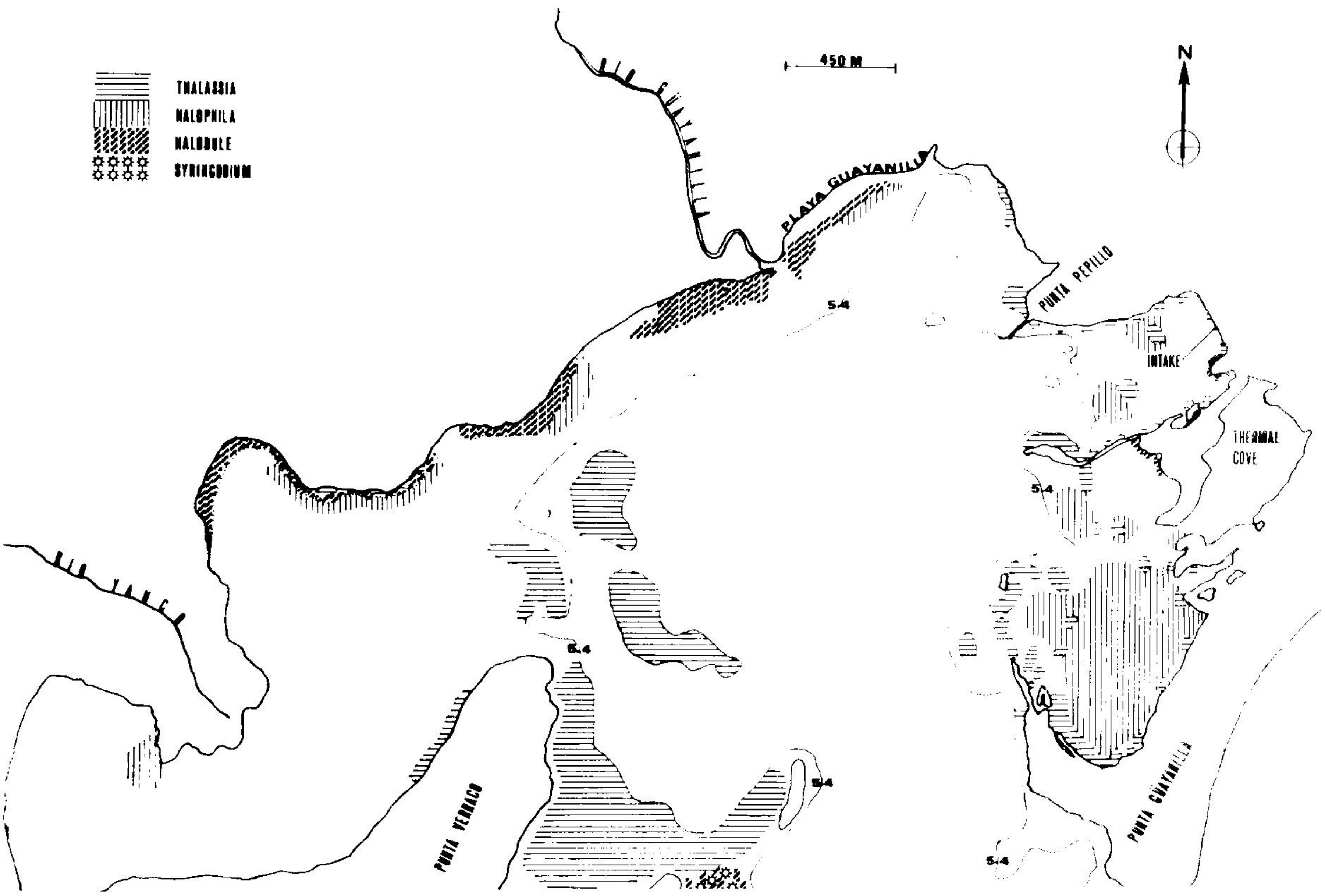

THALASSIA
HALOPHILA
HALODULE
SYRINGODIUM
450 M
N
RIO GUAYANILLA
PLAYA GUAYANILLA
PUNTA PEPILLO
INTAKE
THERMAL COVE
5.4
5.4
5.4
5.4
5.4
RIO YAUCO
PUNTA VERRACO
PUNTA GUAYANILLA

Plate 111. Turtle grass, Thalassia testudinum with a female flower.

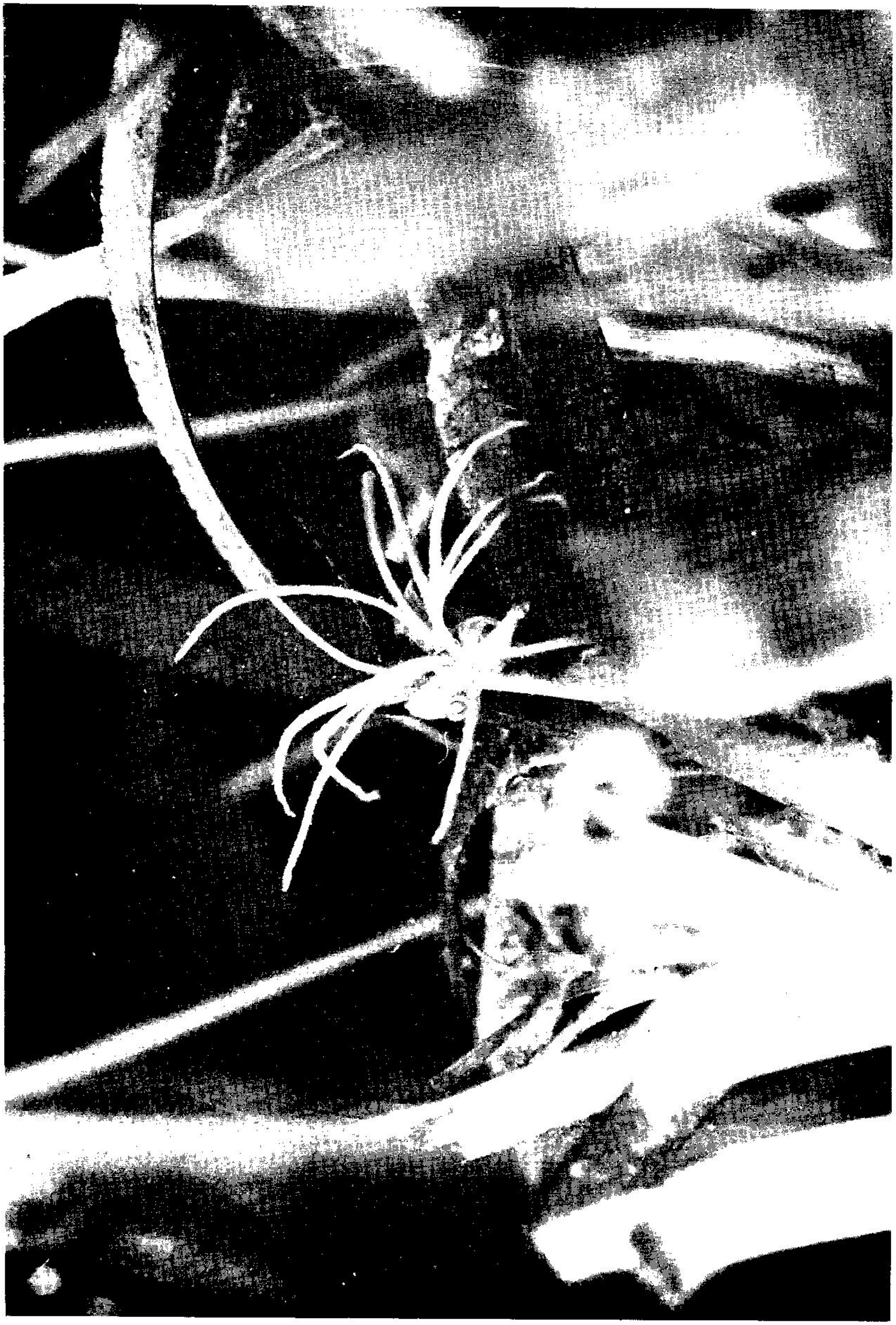


Plate V. A section of a turtle grass meadow with shoalgrass, *Halodule wrightii*.

Plate VI. The effect of natural high wave energy periods on seagrass meadows. The stack of leaves are composed principally of manatee grass and turtle grass.

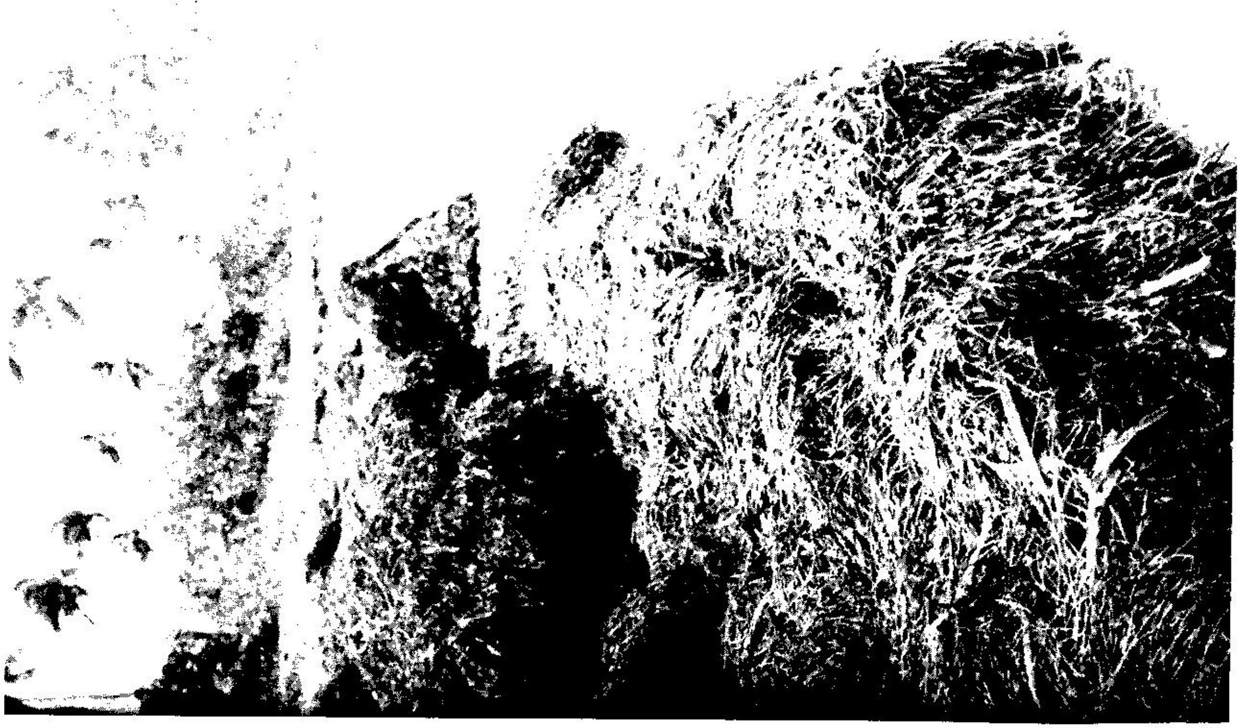


Plate V11. Two ecophenotypes of <u>Thalassia</u> <u>testudinum</u>: gigantism in enclosed, or protected mangrove lagoons, and dwarfism caused by heavy grazing pressure.Scale: 30cm.

Plate Vlll. The widgeon grass _Ruppia_ _maritima_ with young fruits.

Plate 1X. The mannatee grass <u>Syringodium</u> <u>filiforme</u> with inHoresence.

Plate X. The seagrass Halophila decipiens with flowers,young and adult fruits.

Plate X1. Fruits and seeds of the seagrass *Halophila decipiens*.

Plate XII. The shoal grass, Halodule wrightii with fruits attached to the rhizomes.

Plate IV. Stages in the life history of the seagrass _Thalassia testudinum_: A, female bud, B, female flower, C, young fruit D, seeds, and E, seedlings.


A
B
D
C
E