THE IMPACT OF HEATED EFFLUENTS ON THALASSIA BEDS: A COMPARATIVE STUDY by Vance P. Vicente 1977

INTRODUCTION

Most of the existing ecological guides 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 also major differences in some of the biological components. In Puerto Rico, the seagrass Syringodium 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 Ra Cin press) occur in the Caribbean Sea but not significantly in other tropical or temperate regions (Kirk, et al., 1979; Brook, 1977). Intensive grazing in the Caribbean 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, 1975). Power plants located close to shore utilize seawater as a coolant and return the water at temperatures higher than ambient. The impact that these heated effluents have on tropical seagrasses has been of much concern because tropical organisms live close to their upper thermal tolerance (Thorhaug et al., 1975; Mayer, 1914; Cairnes, 1956; Bieble, 1962; Bader et al., 1971; Drost-Hanzen, 1969; Gonzalez, 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 2,370°C/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 1975 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; Bader and Roessler, 1971; Thorhaug et al., 1972), 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 measurements were made with a Goldbert T/C Refractometer Model 10423. Temperature was recorded from a YSI 1/0 meter model 33 and from a mercury thermometer with an accuracy of .1°C. Secchi disc readings (2 SD) were used as an indicator of turbidity.

Figure 1: Thalassia bed stations in Guayanilla Bay, Southwest Coast of Puerto Rico. East side GUAYANILLA BAY

Measurements 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 using 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.

A total of seven hundred fifty samples were taken from 18 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

The text was observed in May 1976 during the sexual reproductive cycle of Testudinum. In the laboratory, the presence or absence of sexual reproductive bodies were determined. The characteristics of flowers, fruits, and seeds were identified. The depth limit of Testudinum was determined to use as a distribution index 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 using a line and float.

Laboratory Studies

Laboratory studies were conducted to confirm field observations. Experiments were undertaken to study the temperature's effect on the development of Thalassia seedlings, which were raised in the laboratory. Additionally, the effect of the substrate on the seedling's development was determined. Four 200-gallon fiberglass tanks were set up in the laboratory with running seawater. Ten young seedlings were conditioned and placed in each tank for a 28-day period. Mixed Halimeda shell sediment was used as a growing substrate. The tanks were adjusted to the temperatures indicated below. Values are in °C.

Mean Range
A 39.08 23 32.5 - 39.4
B 35.06 26.7 - 37.5
C 35.06 24.8 - 35.6
D (ambient) 29.70 29.4 - 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 Multivolt Strip Chart Recorder (Banus, personal communication). Laboratory substrate studies were conducted by growing seedlings in different sediments as shown below:

TANK	TYPE OF SEDIMENT	SEDIMENT SIZE
E	Halimeda-shell fragments	<1mm
F	Halimeda-shell fragments	1-2mm
G	Halimeda-shell fragments	2.5-5.0mm
H	Mangrove mud	<.63mm

Chemical analyses of Thalassia leaves were done by the Central Analytical Laboratory of the Agricultural Experimental Station in Rio Piedras. The mineral composition such as Fluorine(F), Potassium(K), Magnesium(Mg), Calcium(Ca), protein, etc were determined.

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-insoluble ash, and silica were also analyzed.

DESCRIPTIONS OF STATIONS

Suayanitia: 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 (2 SD < 1.0m), the unstable fine sediment at 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, 2, 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 + .8 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 31.79°C for station 8.

The temperatures are 31.29°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 respectively from the outlet of the heated. The Thalassia bed stations in Guayanilla are considered turbid (Vicente and Rivera, in press). SD readings at stations 8 and 1 range from 1m to 2.1m. Salinity was relatively constant (34-35%) at all the stations. The substrate at stations 2 and 4 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. The 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 stations M, IV, and X. Station 3 is in a totally undisturbed environment. The temperature fluctuations at all stations are considered ambient (see Figure 4) and salinity varies slightly (35-39%). Turbidity measurements indicate that Jobos Bay is less turbid than 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, whereas 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. In addition to the stations mentioned above, 10 additional Thalassia beds occurring in other localities around the island and 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. The mean biomass values (roots + rhizomes + 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.

+ 225 gr DW/m^2 (N=80). Statistical analysis (Student t test) indicates that the higher value for Jobos Bay is significantly different (P<.01) from Guayanilla Bay.

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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 (Wet weight).

	Feb/Apr '76	July	Oct.	Feb '77
J:	44.5	14.2	14.2	33
G:	25.9	18.8	24.3	16.1

The 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, 1975). 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<.05) from the low biomass values obtained at stations G 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<.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 0 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.

Morphological variations of Thalassia testudinum: The morphological characteristics of 1 were compared from material collected in Jobor, unflla, and other localities around the island. The diameter of Thalassia leaves on the heated stations (0 and 1) in Guayanilla Bay was thinner than our station. However, at station 11 in Jobos Bay, a physically disturbed Thalassia bed also had thinner leaves. Stations 1 and 0 are physically stressed by the heated effluents and are biologically stressed by the grazing pressure as per Vicente and Rivera (in press). Thalassia from physically stressed stations did not have shorter leaves than from other stations. Station 11, which is under the heaviest pollution pressure, had shorter leaves and station 3, which is under 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

The depth limit and mean Secchi disc readings (ESD) obtained at each station. The maximum depth limit recorded was 5.0 m at station 1 in Jobos and the minimum depth limit (1.2 m) was obtained at stations 1 and 2 in the Guayanilla heated stations. The Spearman's rank correlation - Page Break - TABLE 5. The number of leaves per shoot of Thalassia testudinun collected from 15 seagrass beds around the island of Puerto Rico.

Station	Location	Date	S.D.
Luquillo Coast	Luqui Lio	8/22/76	8.9
Luquillo Estuarine Coast	8/22/76	3	
P. Las Marias Coast	5/22/76	10	
Punta Arenas Coast	5/27/76	307	
Las Croabas EL Coast	5/23/76	13	
Las Croabas (middle) EL Coast	5/23/76	1	
St. 10 Guay. Sin. Coast	5/14/76	6	
St. 8 Guay. SIN. Coast	5/14/76	1	
St. 7 Guay. Sin. Coast	5/18/76	9	

St. 1 Guay. Sin. Coast | 5/14/76 | 188
St. 3 Job Sin. Coast | 5/19/76 | 710
St. 2 Job Sin. Coast | 5/19/76 | 18
St. 4 Job Sin. Coast | 5/19/76 | 1
St. 5 Sin. Coast | 5/19/76 | 2
St. 10 Sin. Coast | 5/14/76 | 23
St. 8 Sin. Coast | 5/14/76 | 6
St. 5 Sin. Coast | 5/14/76 | 2
St. 7 Sin. Coast | 5/14/76 | 2
St. 7 W. Coast | 5/14/76 | 2
St. 1 Sin. Coast | 5/14/76 | 1
St. 2 Sin. Coast | 4/29/76 | 1
St. 3 Sin. Coast | 4/29/76 | 0
St. 3 Sin. Coast | 4/29/76 | 1
St. 3 Sin. Coast | 4/29/76 | 0
St. 4 Sin. Coast | 4/29/76 | 3
St. 4 S.E. Coast | 4/29/76 | 18
St. 4 Sin. Coast | 4/29/76 | 3
St. 5 Sin. Coast | 4/29/76 | 1
St. 5 Sin. Coast | 4/29/76 | 3
St. D Coast | 4/29/76 | 6

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Corrected English sentences:

His erroneous use of "as we all know," is a common error. It is often used in a manner such as this: "As we all know, square 1 is always a winner." However, it should be used correctly like this: "Square 1 is always a winner." It is also misused in the context of "As a result, success is guaranteed," when it should be "Success is guaranteed." Furthermore, "As a reminder, success is not always guaranteed," should actually be "Success is not always guaranteed."

Temperature Laboratory Study

The results of the temperature effect on the development of Thalassia seedlings are given in Table 5. There was no root development at 35°C, 37°C, and 39°C. Root growth was only evident at the temperature control tank (0). 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 38°C, the seedlings can be considered non-viable since the inhibition of root development prevents the seedlings from attaching to the substrate.

TABLE 8: The effect of elevated temperatures on the development of Thalassia seedlings under

laboratory conditions.

Tank Temp. °C	Range °C	Formation of Roots	Color of Leaves
33.0	38.5-39.4		Brown
37.0	36.7-37.5		Yellow-Green
35.0	34.8-35.6		Green
	29.7	22	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-Aguiló and Lord 1974); (Lord et al. 1974); (Arroyo-Aguiló and Evans 1975); (Arroyo-Aguiló et al. 1975). Crude protein as Kjeldhal nitrogen X6.75 was determined by the methods described by the Association of Official Analytical Chemists (1979). 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 2 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 starch. The NOS value for Thalassia, and the WS (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 (22.98) 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 ($P<.08$) higher than station 1 (less thermally stressed) and station 7 (thermal control station). Evidence has been shown that high...

ADE 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 fibers; Lig = Lignin; Ins. ash = Acid insoluble ash; Silica. Values are given as percentages.

(5) STATION 8 + STATION 1 + STATION 7

Values are as follows:

2 63.84 1.10

2 59.97 1.29
2 35.1 2.7

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"Environmental temperatures can induce a higher concentration of Lignin. The protein (17.28) 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 AguilG and Lord, 1974; Lord et al., 1974).

The development of Thalassia seedlings grown in different sediment size substrates was studied. This research aimed to compare the development of young Thalassia seedlings grown in various 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 were 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 Halida calcareous sediment size was in the range of 2-5 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.

The following characteristics of Thalassia studinum 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), and d) their shallow depth."

Limit and Inhibition of Sexual Reproduction
(Section 6 is unreadable and may need re-typing.)

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 (p = +83).

b) Laboratory studies indicated that temperatures equal to, greater than, or somewhat lower than 36°C inhibit root development and growth in Thalassia seedlings.

c) The higher lignin content of Thalassia at 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 a 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 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 the absence of Lytechinus at these beds. It is known that they, as well as most tropical marine organisms, live only a few degrees from their upper thermal limit. Regardless of 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 and biotic potential of the plant in the system.
b) The reduction of roots and rhizomes will destabilize the sediments and enhance turbidity.
c) A 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 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 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 ecosystem's stability.

The depth distribution of Thalassia (Vicente, in press) indicates changes in coastal morphology during both the construction and operational phases in Guayanilla Bay. These changes have had a detrimental impact, directly or indirectly, on the marine environment. For instance, nearly all the vegetation surrounding the construction sites has been removed, destabilizing the soil. This soil can enter the marine environment due to wind or rain erosion, subsequently increasing the turbidity in the near shore. Evidence of this has been observed in aerial photographs of Guayanilla Bay.

The transportation of tugboats, periods of high wave energy, and dredging activities resuspend bottom sediments, partly accounting for an increase in turbidity. Based on this model, recommendations have been made to the local industries of the Guayanilla site to take action. Actions may include reducing the temperature of power plant effluents and decreasing the site's turbidity. The heat from thermal effluents can be reduced by implementing cooling towers or cooling ponds, provided that secondary effects are considered. High turbidity in Guayanilla Bay could be reduced by reforestation of mangroves and other land vegetation, including Thalassia.

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The text should read:

Florida is in the subtropics; Guayanilla Bay, P.R. is in the tropics. The text pertains to Waste Management and Utilization, edited by Samuel S. Lee and Subrata Sengupta. In the section XI-B-13i, Thorhaug, A., Moore, and H. Albertson (1971) discuss laboratory thermal tolerances in an ecological study of South Biscayne Bay. The study is conducted at the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Florida. The manuscript is from pages 1-33.

Toner, M. (1877) reports a lasting freeze that kills fish and imperils coral reefs in The Miami Herald, Friday, Jan. 21.

Vicente, V.P. (1975a) discusses seagrass bed communities of Jobos Bay in Aguirre Environmental Studies, Jobos Bay, Puerto Rico. This is the Final Report, Vol. I. PRNC 198: 27-45.

Vicente, V.P. (1975b) continues the discussion in Aguirre Environmental Studies, Jobos Bay, Puerto Rico. This is the Final Report, Vol. II. Tables: pages 27-131.

Vicente, V.P. (1977a) examines the effect of an industrially disturbed environment on the ecology of Thalassia beds in the South Coast of Puerto Rico. This can be found in the Proceedings A-T.M.L.C. 12: 17 Curacao, March 1977.

Vicente, V.P. (1977b) discusses the impact of heated effluents from a power plant on seagrass beds. This paper was presented at the 13th Meeting of the Association of Island Marine

Laboratories of the Caribbean, A.T.M.L.C., in October.

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

Zieman, J.C. (1970) discusses the effect of a thermal effluent stress on the seagrasses and macroalgae in the vicinity of Turkey Point, Biscayne Bay, Florida. This is from his Ph.D. dissertation at the University of Miami, Coral Gables, Fla.

Zieman, J.C. (1975) discusses quantitative and dynamic aspects of the ecology of turtle grass, Thalassia testudinum, on pages $41- $62 in L.R. Cronin, ed. Estuarine Research, Academic Press, New York.

The appendix includes a table of temperature, salinity, and visibility at Station #8, Guayanilla Bay, Puerto Rico - 1976/1977.

20. 33.0 9 Feb. 29.3 and 7 March 29.0 34.2 7 April 20.6 35.0 6 May 32.6 1.0 June 22.3 - July 342 32.0 6 Aug. 342 3.0 Sept. 35.3 35.0 and Oct. 22.0 32.0 2 Nov. 27 35.0 and Dec. 27 as “6 Jan. 29.7 and 42 Feb. 29.9 35.5 10 2

TABLE 2. Temperature (°C), Salinity(%), Visibility (Secchi) at Station #1, Guayanilla Bay, Puerto Rico 1975/1977

DATE TEM. (°C) SALINITY(%) SECCHI (m)

Jan. 27.0 30 2 Feb. 2.4 24.0 9 March 23.0 34.2 1 April 30.9 34.5 May 31.7 and 8 June and 34.0 - July 33.9 32.0 6 Aug. 33.5 34.0 Sept. and 35.0 and Oct. 33 32.0 2 Nov. and as 18 Dec. 36 and 1.0 Jan. 29.5 34 1.0 Feb. 29.6 35.5 1.0

TABLE 2. Temperature (°C), Salinity(%), Visibility (Secchi(m) at Station 10, Guayanilla Bay, Puerto Rico 1976/1977

DATE Temp (°C) SALINITY(%) SECCHI(m)

Feb. 29.5 wo March 26.4 as 18 April 29.4 a5 3.1 May 29.2 38.0 12 June 30.9 34.0 16 July 32 24.0 Aug. and 34.0 12 Sept. and 34.0 8 Oct. 32 34.0 Nov. at 32.0 18 Dec. 0.2 and 12 Jan. 27.3 and a Feb. 27.9 35.0 1.0 March - and 15

TABLE 4, Temperature(°C), Salinity(%), Visibility (Secchi (m) at Station #7, Guayanilla Bay, Puerto Rico 1995/1977

DATE TEMP. (°C) SALINITY (%) SECCHI (m)

Jan. 25.7 34.2 16 Feb. 26.0 and 14 March 25.6 38.5 18 April 27.4 35.0 13 May 28.1 36.1 13 June 20.7 24.0 te July 2.9 34.0 12 Aug. 29.8 34.2 1.0 Sept. 30.4 35.0 2a Oct. 30.0 32.0 18 Nov. 29.2 34 and Dec. 21.7 34.5 15 Jan. 26.7 and 1 Feb. 27.4 25.0 15

TABLE 5. Temperature(°C), Salinity(%), Visibility (Secchi(m) at Station M, Jobot Bay, Puerto Rico 1976/1977,

DATE TEMP. (°C) SALINITY (%) SECCHI (m)

Jan. 25.0 28.5 26.5 Feb. 20.5 29.0 26.5 March 20.4 20.8 27.8 April 27.6 26.9 26.9 May 38.5 35 33.5 June 33.5. 35.0 and July 38.0 34 35 Aug. and and and Sept. and and and Oct. and and and Nov. and and and Dec. and and and

TABLE 6. Temperature (°C), Salinity(%), Visibility (Secchi(m) at Station IV, Jobos Bay, Puerto Rico, 1976/1977,

DATE TEMP. (°C) SALINITY (%) SECCHI (m)

Jan. 25.5 No No Feb. 25.0 No No March 22.0 No No April 20.0 No No May 30.8 No No

June 20.2 No 29.5 35.0 Aug. 22.0 34.0 26 Sept. 20.4 34.0 27 Oct. 20 23.0 27 Dec. 28.5 35.0 2.5 Jan. 27.0 25 3.0 Feb. 28.7 35.0 2.0

TABLE 7. Temperature(*C), Salinity(*/,,), Visibility(Secchi(n) at Station X, Jobos Bay, Puerto Rico - 1976/1977.

DATE Temp. (*c) SALINITY(*/,.) Secchi (n)

Jan. 24.0 No No Feb. 24.5 No No March 28.0 No No April 24.0 No No May 20.5 No No June 28.6 No No July 29.0 34.5 No Aug. 20.3 34.0 22 Sept. 27 35.0 3.2 Oct. 28 33.0 27 Nov. - - - Dec. 27.8 35.0 28 Jan. 27.2 25 25 Feb. 27.5 35.0 2.0 March 27.4 - 2.8

TABLE 8. Temperature(*c), Salinity(*/,.,), Visibility (Secchi la), at Station 3, Jobos Bay, Puerto Rico - 1976/1977

Date Temp. SALINITY (*/,.) Secchi (la)

Jan. 26.2 No No Feb. 26.0 No No March 29.0 No No April 30.2 No 23.0 May 27.5 No No July 28.0 No No Aug. 30.7 25 3.0 Sept. - - - Oct. 20.2 34.0 3.6 Dec. 26.3 35.0 5.0 Jan. 27.8 25.0 5.0 Feb. 26.3 36.0 25 March 26.0 - 35 49

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

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

Plate III. 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 VII. Two ecophenotypes of Thalassia testudinum: gigantism in enclosed, or protected mangrove lagoons, and dwarfism caused by heavy grazing pressure. Scale: 30cm.

Plate VIII. The widgeon grass Ruppia maritima with young fruits.

Plate IX. The manatee grass.

Syringodium filiforme with inflorescence.
Plate X. The seagrass Halophila decipiens with flowers, young and adult fruits.
Plate XL. Fruits and seeds of the seagrass Halophila decipiens.
Plate XLI. 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.