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THE IMPACT OF HEATED EFFLUENTS ON

THALASSIA BEDS: A COMPARATIVE STUDY

by:

Vance P. Vicente

1877

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH,

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INTRODUCTION

Most of the existing ecological guide!

and models of

seagrass ecosystens and their response to thermal effluents or

other pollution sources criginate 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 oper:

e in temperate

latitudes (Sanders, 19683 Dobzhansky, 19503 lowe & McConnell, 1969).

?There are similarities between subtropical and tropical Thalass.

beds. However, there are some major physical and biological differ-

fences 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 sone cases below 20°C, causing kills of Thalassia leaves (Phillipe, 1960). Even extreme cold temperatures occur during winter which have caused massive kills of marine organisms on both coasts

of Florida (loner, 1977), In tropical Caribbean islands such

as Puerto Rico, marine ecosystems are never exposed to cold stress.

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There are also major differences in cone of the biological components. In Puerto Rico the seagrass Syringdoius filiforne (Kutzing) normally occurs in the shallower zone of the seagrass bed (Vicente, 19755 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 ccoaystoms exists

in the energy transfer. Intensive grazing on living seagrass by herbivorous fishes (Randall, 1965) and sea urchine (Ogden, et al.

1973; Camp, et al. 1973; Vicente and

ra Cin press)) occurs in the Caribbean Sea but apparently not significantly in other tropical or temperate regions (Kirk, et al., 1979; Brook, 1977). Intensive grazing in the Caribbean, then, may be an important nechanism in the energy transfer trom the primary producer level

to other trop!

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 te eetablich some of theve 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 hac resulted in the Possibility that by 1980, SGW (5,000M) power plants will become @ reality (Sengupta and Lee, 1975), 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

+1 19715 Mayer, 1914; Cairnes, 19565

Bieble, 19625 Bader et a3., 1971; Drost-Hanzen, 19695 Gonzflez, 1973).

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The Guayanilla electrical power plant complex has a capacity of producing 1,100MW. Tt utilizes cea water as a coolant at a rate of 2,3704°/min (Schroeder, 1975) and this water is heated 10°C above anbient. The heated effluent discharges iato an enclosed cove of approximately 23 hectares, but the warning effect is extended over an area of approximately 50 hectares. The temperature in the effluent zone in the vicinity of the dis- charge 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, 2977b5

5 Bader ve

Roessler, 1971; Thorhaug et al., 197 > 1972),

a study was conducted to determine the impact of thermal effluents

on the Thalassia beds of Guayanilla Say (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 &,

appendix). Salinity (/,,) measurements were made with a

Goldbert T/C Refractoneter 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

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Figure 1: Tholasia bed stations in Guayanilla Bay,

Southwest Coast of Puerto Rico.

East side

GUAYANILLA BAY

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were made on these componente. 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 dricd material was

weighed in @ Mettler Top Balance type K7.

In order to determine morphological variations of Thalassia

in different environments, measurenents were made of the rhizome

diameter (N= 1,150) number of leaves per shoot (i= 1,702), leaf diameter (N= 220), leaf length (N= 196), number of growing tips (iz 130), and number of new shoots (iz 130). The core samples, as well as random samples obtained at 15 seagrass bede 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 18 Thalassia beds around Puerto Rico including Jobos and Guayanilla stations to determine sexual reproduction. Fifty random samples of short choots were collected

at each of the 15 Thalassia beds. The collecting period was in

May 1976 during the sexual reproductive cycle of 7, testudinum,

In the laboratory presence or absence of sexual reproductive bodies were determined. Flowers, fruits and seeds were charac-

terized. The depth limit of 7. 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.

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Laboratory Studies

Laboratory studies were conducted to substantiate field observations. Laboratory experinents were undertaken to study the effect of temperature on the developient 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.

mak Mea 8 ange

A 39.08 23 32.5 = 39.4

3 yu sa 26.7 = 37.5

c 35.06 au.8 = 35.6

Dianbient) 29.70 awe = 32.6

The means were obtained from four readings per day with a mercury thermometer. Continuous temperature recordings were nade with a YSI Thernistor, a YST multipoint switching unit and a Honeywell Miltivolt Strip chart Recorder (Banus, personal communication).

Laboratory substrate studies were conducted by growing

ia seedlings in different sediments as shown below:

TANK TYPE OF SEDIMENT SEDINENT SIZE

E Halimeda-shell fragments ?nm

F Halimeda-shel1 fragments 12mm

6 Halimeda-shell fragments +25-. 50mm

H Mangrove mud <.63mn

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Chenical analyses of Thalassia leaves were done by the Laboratorio Central Analftico of the Agricultural Experimental Station in Rfo Piedras. Mineral composition (F, Ky Mg, Cay protein, total fiber, Lignocellulose, Lignin, ash, and Si were determined in leaves collected at the heated stations (8 and 1) and at the tenperature 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

Suayanitia

The thermal effluents from the Guayanilla Power Plant complex

discharge inside the thermal cove (see Figure 1). No station

for Thal

sia 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 uistabilized 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 nunber of Thalassia beds exposed to the thermal plune. 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.

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?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 %, 1 and 10 had temperatures above ambient throughout the year with an annual mean

AT of 3.7°C (mange + 2.4 to + 5.1) for station 8, AT of 3.2°C

(range + 1.3 to + 4.1) for station 1, and AT of + 1.8°C (range

+ .8 to + 3.5) for station 10. The air

erences in temperature

between the Guayanilia station and between seasons are illustrated

in Figure 3. July through September were found to be the warmest

months for the Guayanilia stations. Mean annual temperatures for

Guayanilla stations are 31.79¢ for station ®, 31.29C for station 1,

30.0°C for st:

ction 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

The Thalassia bed stations in Guayanilla are considered

turbid (Vicente and Rivera, in press). % SD readings at stations

8 and 1 range from «im to 2.1m. Salinity was relatively constant

(34-35°/,5) at all the stations. ?The substrate at stations @ 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.

Yodos.

Thalassia bed stations in Jobos Say were used as control

stations. However, there may be situations where natunal

conditions are altered, especially at those stations located in

the inner bay such as station M, IV, and X. Station 3 is ina

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totally undisturbed environment. The temperature fluctuations at all stations are considered ambient (see Figure 4) and salinity varies slightly (39°/,,-35°/,,). Turbidity measurements indicate ?that Jobos Bay is less turbid then eastern Guayanilla Bay. There are some differences in substrate betuean 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 Station:

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

Biomace: Thalas:

testudinuy

?The mean biomass values (roots + rhizome + leaves + stems)

of Thal

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/n? (N=80) and that for

Guayanilla was 330 + 225 gr Du/m? (N=80). Statistical analysis

(Student t test) indicates that the

igher value for Jobos Bay

is significantly different (P<.01) from Guayanilla Bay. ?The

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TABLE 2, Total biomass (rhizomes, roots, stems and leaves) of Thalassia

kestudinun in Jobos (3) and Guayanilla (G) ays. Bach number

Fepresents the mean value (We5:_31/DH/.02n').

?starzow Peb/apr. "76 uly oct. Peo. 77

wa at 44.5 14.2 14.2

33 25.9 ana 18.8 24.3

xo 16.1 12.2 16.9

na wat 16.7 15.4

76 9.2 144 8.0 9.3

we 42 15.8 9.6 7.8

16 3.9 a a3 48

ac uw? 2.0 2a 23

18

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maximum value for Jobos was 2,225 gr Di/m? and for Guayanilla 725 gr DW/m?. Both maximum values were obtained in July 1977.

?The maximum value of biomass ever obtained in Jotos was $,800 ar Di/n? (Vicente, 1975D).

The differences in biomass values between stations and the Seasonal variations are illustrated in Figure $. 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 @ and 1 in Guayaniiia, which are closest to the outlet of the heated cove. The higher biomass values in the month of July are significantly different (Px.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 seasona? 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 @ 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 rhizones, roots, tens and leaves for

Guayanilla are lower than the Jobos Bay Thalassia beds.

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Morphological variations of Thalassia testudinun

?The morphological characteristics of 1

were compared from material collected in Jobor, % + unflla, and

other localities around the island (Tables © en

The dianeter of Thalassia leaves on the nowt tions

(@ and 1) in Guayanilla Bay was thinner thn nur stati

However, at station 11 in Jobos Bay, a physion '/ swasiurbed

Thalassia bed also had thinner leaves. Stations = suc 1 ape

physically stressed by the heated effluents iv nat is

biologically stressed by the grazing pressus: re anvid Lamum

(Vicente and Rivera, in press). Thalassia from ?wrnsily stressed

stations dic not have shorter leaves than

fren other

stations. Station 1iwnich is under heaviest poy. oy pressine

had shorter leaves and station 3 which is under

grazing

pressure had the longest leaves. The number of » per shoot

(Table 5) seems to be a constant morphological churasteristic

for Thalassia testudinum irreepective of where t)./ ovcur. The mean rhizone diameter, number of growing tips an? renter of now

shoots have lower values in station 8 which is the warmeut station.

Depth limite of Thalassia testudinum

?The depth limits of Thalassia testudinum vere cotermined in 12 stations. Table 6 presents the depth limir an¢ mean Sacchi disc readings (ESD) obtained at each station. "b= maximum depth Limit recorded was 5.0 mat station @ in Jobos anc the minimum

depth limit (1.2 m) was obtained at stations & an¢ 2 -n the

Guayanilla heated stations. ?The Spearman's kins coneeiation

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TABLE 5. The number of leaves per shoot of Thalassia testudinun

collected fron 15 seagrass beds around the island of

Puerto Rico.

Station Location Date S.D.

Luqui Lio Coast 8/22/76 8.9

Luquillo Estuarine Coast 8/22/76 3 10

P. Las Marias Coast 5/22/76 Mo

Punta Arenas Coast 5/27/76 307

Las Croabas EL Coast 5723/76 13 lo

Las Croabas (middle) EL Coast 5/23/76 1 fs

St. 10 Guay. Sin. Coast 5/14/76 6 le

St. 8 Guay. SIN. Coast 5/14/76 fo 1?

Stl 7 Guay: SiW. Coast 5/18/76, 9 19

St. 1 Guay! SIW. Coast 5/14/76 188

St. 3 JOB SIE, Coast 5/19/76 710

St. = JOB SIE. Coast 5/19/76 18

St. M JOB SIE, Coast 5/19/76 fo ts

St. IV Jos SIE! Coast, 5/29/76 fo ls

stl it SIE! Coust 5/19/76 218

St. 10 Siw. Coast 5/34/78, 318

St. 10 S.W. Coast 5/14/76 23

St. 10 Siw. Coast 5/14/76, ee

Stl 8 owl Coast 5/14/76 6 fy

stl § Siw. Coast s/1a/76 218

Stl o8 Si. Coast 5/14/76, 2 8

stl 7 SIW. Coast 5/14/76 218

st Siw. Coast S/1A/76 6 vo

stl 7 W. Coast snas76 2 le

stot SIN: Coast 5/14/76 ny an

Stir SIN. Coast 5/14/76 ee)

stot SIN! Coast 5714/70 a i8

Stl oz SIE. Coast 4729/75, hott

Stl SIED Coast 4/29/76 1 18

stl SIE. Coast 4729/76 300007

stl 3 SIE! Coast 4729/76 tls

Stl 3 SIE. Coast 4729/76 018

Stl 3 SIE. Coast 4729/76 M13

stow SIE. Coast 4729/76 316

st oM S.E. Coast 4729/76 1819

Stow SIE! Coast 4729/76 310

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corfficient between mean Secchi depth (FSD) readings and the lower

Limit of T. testudinum was r= + .?2 and significant at the 18 level,

However, at station 11 the depth limit of Thalassia was recorded at

1.0m where the FSD was 4,2 meters which suggects that come other

factor cuch as grazing, (Vicente and Rivera, in press) is regulating

the depth limit of Thalassia at this station. Tigure 6 illustrates

the correlation between % SD and depth limit of Thalassia. From

this figure it can be sean 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 48 Thal

\3sia beds around Puerto Rico, including Jobos

and Guayani.

stations, are given in Table 7. Inhibition of

sexual structures occurs at the heated stations (@ and 1) and at

the temperature control station (7) in Guayanilla Bay. Even where

sexual bodies were found in Guayanilla (Station 10), only #8 of

?the shoots were found to be fertile. Jebos Bay stations were

proliferous when compared to Suayanilla Bay, At Punta Las Mari

on the north coast of Puerto Rico

reproductive bodies were found.

This Thalassia bed occurs under extreme heavy wave action and

sand abrasion.

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?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. sesides, since roots did not

develop at 38°C, the seedlings can be considered non-viable since

the inhibition of root devetopnent prevents the seedlings from

attachment to the sub:

TABLE 8. The effect of elevated temperatures on the developnent of Thalassia

seedlings under laboratory conditions

aor Joboratony conditions

Formation color of

Tank Tomp. °c * Range *c of Roots eaves

a 33.0 23 38,5-39.4 ° Brown

8 37.0 17 36.7-97.5 ° Yellow-creen

e 35.0 116 34.8-35.6 ° creen

> 29.7 22 + creen

Chemical Analysis of Thalassia Leaves

Chemical analyses of the crude fiber fraction of Thalassia

jeaves in the past have beon done by proximate analysis. Sone

Gata indicate that the crude fiber fraction is more digestible

?than the nitrogen-free extract which demonstrates that this method

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fails to separate the carbohydrates into soluble and insoluble,

digestible or indigestible fractions. This is the main eriticiem

against the use of proximate analysic scheme (Kayongo-Male, et al.

1976). A more refined method of determining the fibrous carbohydrate

fractions as described by Goering and Van Soest (1370) was utilized.

?This method has been used for tropical forage grasses analysis

(Kayongo-Male, et al. 1976); (Arroyo-Aguil6 and Lord 1974);(Lord et al.

1974) ;(Arpoyo-AguilG and Evans 1975); (Aeroyo-Aguilu et al. 1975).

Crude protein as Kjeldhal nitrogen X6.75 was determined by

the methods described by the Association of Official Analytical

Cheniste (1979). Mineral composition alse followed standaré methods.

Thalassia leaves were collected tron

?ations @ and 1 exposed to

?the thermal e*Fluents and at et:

?on 7, the temperature control

station. The results of the analyeis are prescnted in Tables ?

and 10. The NDF (neutral detergent fiber) is a measune of the

total fiber fraction, The neutral detergent solubles (NDS) is

the difference between 100 and the NDF value

ich, roughly, is

equivalent to 408 in Thal

sia leaves. The NDS represents the

neutral detergent solubles such as proteins, lipids, soluble

carbohydrates and ach. The NOS value for Thalassia, and the WS (Acid

detergent fiber) which represents the lignocellulose Fraction, are

comparable with tropical forage grasses (Lord ¢

als, 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

a

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ADE 9,

Te chemical composition of Thalassia leaves at the themal stations {8 and 1) and at the texperature control station (7). Cerbohyanaee {4brous Fraction: NOF - Neutral detergent fiber; AOP'= Acid detersent fibers Lig = Lignin; Ins. ash = Aciainsolwlessh; Sim Stiica

Watues are given as percontages_ (5)

STATION + STATION @ ?StagrON 7

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nor 3 38.84.86 34180 Le 2 40.590 1.6

Lis. 1 2a27 = 2 28.20 + 2 22.28

ne. Ash 1 oan 1 ee 1 oe =

si 1 6 6 1 0 6 1 0 6

Protein 2 17.82.09 217.56 a0 2 16.06.44

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environnental temperatures can induce higher concentration of

Lignin. ?The protein (17.28) and minerals such as P, Ky 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

?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 cetermined 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 Hali

da calcareous sediment size was in the

range of 25.

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 6.

DISCUSSION

?The following characteristics of Thalassia

studinun occurring

within the thermal plume (Sta. 8 and 1) suggest that these sea-

grass bede 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), a) their shallow depth Limit and

) inhibition of sexual reproduction.

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Although it is believed that there are various disturbing

factors operating simultancously, the following evidence suggests

?shat temperature is an important source of stress to Thalassia:

4) there is a negative correlation between temperature and

+83), b) laboratory studies indicated

Thalassia biomass (p =

?that temperatures of equal, greater, or somewhat lower than 36°C

inhibit root development and growth in Thalassia seedlings, and

©) 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

Hhatassia rhizomes and roots may be a result of sediment erosion

due So @ decrease in the biomass of these components as a result

of high temperature and high turbidity.

Tt ie difficult to define which disturbing factor io

Tesponsible for the dete:

ration of seagrass beds in the high

?hemmal zone in eastern Guayanilla Say. There are many factors

operating simultaneously at this locality, both natural and

induetrial. & model has been prepared which tries to explain

?the mechanisms by which seagrass beds can be disturbed or de-

teriorated 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

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of urchin, gastropod and foraminiferan fauna within these sea-

grass beds. Although chemicals were not taken into consideration in? this part of the study they are included in the model (there- fore, 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, ae 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 ?themmal effluent stations my be responsible for reducing the

biomass of Thalassia. A reduc?

lon of Thalassia biomass to low

levels has serious consequences for the whole system as illus-

trated in the diagran: a) it will reduce the growth on biotic

potential of the plant in the system; 8) the reduction of roots

and rhizones will destabilize the sediments and enhance turbiditys

© reduction in lear production witi 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

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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.

is destabilizes the soil which will enter the marine environment either by wind or rain erosion which in tum 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. Pased on this model, recommendations are made to the local industries of the Guayanilla site to take sone action to reduce the temperature of power plant effluents, as well as action to Feduce the turbidity of the site. Heat from the thermal effluents ean be reduced by implementing cooling towers or cooling ponds, Provided that secondary effects of these are taken into consideration. Turbidity, which ic high in Guayanilia Bay,could be reduced by reforestation of mangroves and other land vegetation, as well

as of Thalassia,

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APPENDIX

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TABLE }. Tomperaturo(*c), Salinity(J..), Visibility (Secchila) at

Station #8, Guayanilla Bay, Puerto Rico - 1976/1977

SE Ea Pre Bice = 1976/1977

Dane Te. (0) SALINITY (*/02) SECCHY fp)

Jan. 20. 33.0 9

Feb. 29.3 an6 7

March 29.0 34.2 7

april 20.6 35.0 6

may 32.6 1.0

June 22.3 -

saly 342 32.0 6

aug. 342 3.0

sept. 35.3 35.0 aa

oct. 22.0 32.0 2

Noy. a7 35.0 a

dec. M7 as ?6

gan. 29.7 ans. 42

Feb. 29.9 35.5 10

2

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TABLE 2. Temperature (°C), Salinity(*/,,), VisSbility (Secchile)) at

Station #1, Guayanilla Bay, Pusrte Rico 1975/1977

DATE TEM. (°C) SALINITY(*/, SBCCHE (=)

van. 27.0 30 2

Feb. 2.4 24.0 9

march 23.0 34.2 1a

porit 30.9 345 °

may 317 aes 8

June ans. 34.0 -

guly 33.9 32.0 6

aug. 33.5 34.0

Sept. as 35.0 wt

oct. 33 32.0 2

Nov. ane as 18

pee. 36 aa. 1.0

Jan. 29.5 34s 1.0

Feb. 29.6 35.5 1.0

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?TABLE 2. Temperature (%), Salinity(*/,,), Visibility (Secchifm) at

Station 10, Guayanilla Bay, Puerto Rico = 1976/1977

DATE Temp (°C) SALINITY(*/,,)___ SECCHT(m)

Feb. 29.5 wo

march 26.4 as 18

peri 29.4 a5" 3.1

may 29.2 38.0 12

une 30.9 34.0 16

saly a32 24.0 °

ug. ans 34.0 12

Sept. ane 34.0 8

oct. 32 34.0

Nov. at 32.0 18

Doc. 0.2 aes. 12

san. 27.3 ms a

Feb. 27.9 35.0 1.0

March - es 1s

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TABLE 4, Tomperature(°C), Salinity(*/,,), Visibility (Secchi (n) at

Station #7, Guayanilla Bay, Puerto Rico 1995/1977

EE Savana Bay Puerto; Rico 1978/1977

DATE TEMP. (*C) SALINITY (*/,4) SECCH fy

gan. 25.7 34.2 16

Feb. 26.0 aa. 14

March 25.6 38.5 18

april 274 35.0 13

may 28.1 36.1 13

Bune 20.7 a4.0 te

saly 2.9 34.0 12

ug. 29.8 34.2 1.0

Sept. 30.4 35.0 2a

cee: 30.0 32.0 18

ov. 29.2 34s as

Bec. 21.7 34.5 1s

Jan. 26.7 aa 1

Feb. 274 25.0 1s

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TABLE 5. Tenperature(*c), Salinity(*/,,), Visibility (Secchi ln) at

Station M, Jobot Bay, Puerto? Rico ~ 1976/1977,

gan.

Feb.

march

25.0

28.5

26.5

20.5

29.0

26.5

20.4

20.8

27.8

27.6

26.9

26.9

SALINITY (*

wo

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wo

wo

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38.5

a5

33.5

33.5.

35.0

aes.

38.0

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wo

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TABLE 6. Temperature (*C), Salinity(*/,,). Vietbilitw (Secchi: f) at

Station IV. Jebos Bav. Puert3? Rico. 1976/1977,

ane	TEMP. (*c)	SALINITY (*/,.)	SECCHY (a)
gan.	25.5	No	wo
Feb.	25.0	No	wo
March	22.0	nyo	wo
peril	20.0	no	No
may	30.8	No	No
Sune	20.2	No	ao
saly	29.5	35.0	wo
aug.	22.0	34.0	26
Sept.	20.4	34.0	27
oct.	a0	23.0	27
Bee.	28.5	35.0	2.5
Jan.	27.0	aes	3.0
Feb.	28.7	35.0	2.0

0

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TABLE 7. Temperature(*C), Salinity(*/,,), Visibility(Secchi(n) at

Station X, Jobos Bay, Puerto Rico - 1976/1977.

DATE	TeWe. (*c)	SALINETY(*/,.)	SBCCHT 63)
san.	24.0	wo	wo
Feb.	24.5	wo	nyo
March	28.0	"0	wo
dorit	2.4	No	wo
may	20.5	no	nyo
une	28.6	no	No.
galy	29.0	34.5	w/o
ag.	20.3	34.0	22
sept.	2.7	35.0	3.2
oct.	ae	33.0	27
Nov.	-	-	-
ee.	27.8	35.0	aa
Jan.	27.2	aa.	25
Feo.	27.5	35.0	2.0
March	27.4	-	28

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TABLE 8. Tenperature(*c), Salinity(*/,,), Visibility (Secchi la), at

Station 3, Jobos Bay, Puarto Rico - 1976/1977

Dae re. SALINITY (*/, secon

van. 26.2 wo w/o

Feb. 26.0 No No

March 29.0 w/o wo

dori 30.2

nay 23.0

owe 27.5

saly 28.0

avg. 30.7 aes: 3.0

Sept. - - as

wt. 20.2 34.0 3.6

Dee. 26.3 35.0 5.0

Jan. 278 25.0 5.0

Feb. 26.3 36.0 25

march 26.0 - 35

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Plate 1. The location of Jobos and Guayanilla bays on the ca-

ibbean coast of Puerto Rico.

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Plate 11, The distribution of the seagrasses in Guayanilla bay:

?Thalassia testudinum, Halophila decipiens, Halodule

Wrightii, and Syringodium £i1i forme.

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Plate 111, Turtle grass, Thalassia testudinum with a female

flower.

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

Halodule wrightii.

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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.

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Plate VIL. Two ecophenotypes of Thalassia testudinum: gigantisn

in enclosed, or protected mangrove lagoons, and dvarfism

?caused by heavy grazing pressure.Scale: 30cm.

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Plate VLI1. The widgeon grass Ruppia maritima with young fruits.

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Plate 1X, The mannatee grass Syringodium filiforme with

infloresence.

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Plate X. The seagrass Halophila docipiens with flovers,young

and adult fruits.

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Plate XL. Fruits and seeds of the seagrass Halophila decipiens.

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Plate XL1. The shoal grass, Halodule wrightii with fruits

attached to the rhizomes.

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Plate 1V, Stages in the Life history of the seagrass Thalassia

testudinum: A, fenale bud,B, female flower,C,young fruit

D, seeds, and E,seedl ings

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