# THE RELATIONSHIP OF TWO SEAGRASSES: *ZOSTERA MARINA* AND *RUPPIA MARITIMA* TO THE BLACK BRANT, *BRANTA BERNICLA NIGRICANS*, SAN IGNACIO LAGOON, BAJA CALIFORNIA, MEXICO

by

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A THESIS

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and the Graduate School of the University of Oregon
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APPROVED: Paul P Rudy

Paul P. Rudy

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San Ignacio Lagoon, Baja California, is a major wintering grounds for Black Brant, *Branta bernicla nigricans*, along the Pacific coast of North America. Two sources of food for Brant, *Zostera marina* and *Ruppia maritima*, occur in the lagoon. During December 1982 to April 1983 studies were made on the intertidal standing crop and production of *Zostera* and on the feeding behavior of the Brant. Bimonthly *Zostera* standing crop and production values decreased throughout the period. This seemed to be controlled by insolation. Survey data indicated that Brant favored *Ruppia* to *Zostera* as forage. The reasons for this selection appear to be nutritive value and availability of *Ruppia*. Protein analyses revealed that *Ruppia* is as good as or an even better source of protein for the birds than *Zostera*. *Ruppia* grows higher in the intertidal than *Zostera* and

hence is more frequently exposed and available as a food source.

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Special appreciation goes to my father, Bill Ward, who helped support and endure the living in Baja, Mexico. To my technical assistances, Lee Tibbitts and Janet Essley, who shared this winter adventure, I owe a great deal, and would like to share this quote by Lewis Thomas from "Lives of a Cell":

> "I don't know of any other activity in which the people engaged in it are so caught up, so totally preoccupied...... It looks like a lonely activity but it is as much the opposite of lonely as human behavior can be. There is nothing to touch the spectacle. In the midst of what seems a collective derangement of minds in total disorder, there emerges suddenly with the purity of a slow phrase of music, a single new piece of truth about nature."

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# INTRODUCTION

Harbors, estuaries and nearshore shallow coastal waters of the world comprise only 1% of the surface area of the world's oceans. Yet, these nearshore areas are inhabitated by the most highly productive ecosystems in the world (Phillips, 1978). These ecosystems are dominated by marine plants, of which the seagrasses are highly important. They are marine angiosperms which grow in shallow coastal waters of the tropical and temperate zones. The various genera of seagrasses are not closely related to each other and in fact are not true grasses (Family Poaceae). Rather, they are more closely related to the Lily family (Family Liliaceae) (Dawes, 1981).

Seagrasses perform a variety of biological and ecological functions in coastal environments. These are summarized by Wood _et_ _al_. (1969):

1) Seagrasses have a very high primary production rate (McRoy and McMillan, 1977; Dawes _et_ _al_., 1979). Production rates of 500-1000 $gC/m^2/yr.$ can be typical and even higher

rates may be reached in some areas. Approximately 50% of the carbon lost is in the form of dissolved organic carbon (Dawes, 1981).

2) The leaves support large numbers of epiphytic organisms, often with a biomass approaching that of the plants themselves.

3) Though very few oeganisms graze directly on seagrasses, many graze on associated epiphytes. Most of the food chain is based on detrital pathways.

4) Organic material in the detritus and decaying roots aid in maintaining an active sulfur cycle.

5) Essentially the grasses serve as effective sediment traps. The roots and rhyzomes bind the sediments in place, and with the protection of the leaves, inhibit erosion. The dense leaves retard currents and increase sedimentation on organic material around the plants. The seagrasses provide a preserve for the microbial flora of the sediment and sediment-water interface.

6) Seagrass communities provide an important habitat and shelter for many animals. Kikuchi (1974) found a significant decrease in the numbers of decapods and juvenile and young-adult stages of commercial fish as a result of a decrease in *Zostera marina* production.

7) Seagrasses absorb nutrients through their leaves and roots. Nitrogen and phosphorous can be returned to the water via leaching and degradation of the leaves.

There are 49 species of seagrasses classified into 3 families and 13 genera. The family Potamogetonaeceae contains 9 genera and 34 species; the family Hydrocharitaceae contains 3 genera and 11 species (Phillips, 1978); and the family Ruppiaeceae contains 1 genus and 4 species (Hutchinson, 1934, 1959).

In the family Potamogetonaeceae the genus _Zostera_ inhabits the temperate waters of the Northern Hemisphere. Two species of _Zostera_ are found along the Pacific coast of North America of which _Zostera marina L._ is the most dominant and widespread.

The genus _Ruppia_ has had a history of confused taxonomy at both the specific and familial level (Jacobs and Brock, 1982). Even in Europe where the taxonomy is more understood (Verhoevan, 1979), recent evidence suggests that new taxa should be made (Van Viersson _et al._, 1981). At present in North America there is only one marine species of the genus Ruppia, e.g. _Ruppia maritima L._. The distribution of _Ruppia maritima_ is cosmopolitan. Along the Pacific coast it is found from the Bering Sea to Mexico (Fernald, 1950).

As stated earlier one of the most important functions of seagrass communities is their high production rate, with a range of 0.2 - 7.0 gC/m$^2$/day (McRoy and McMillan, 1977), however, most organic material produced by the seagrasses is utilized through detrital food chains (Fry _et al._, 1982; McConnaughey and McRoy, 1979). Very few organisms are able to use seagrass tissus directly (Kikuchi, 1966; Kristensen, 1972). Along the Pacific coast of North America the animals that do are predominately herbivorous birds (Cottam et. al, 1944; Martin et al., 1951), invertebrates (McConnaughey and McRoy, 1979; Lawrence, 1975), green sea turtles (Felger et al. 1976) and Seri Indians (Felger and Moser, 1973).

One of the major herbivores of seagrasses is the Pacific Black Brant, Branta bernicla nigricans,(Lawrence, 1846), a relatively small goose. The importance of seagrasses especially Zostera to the brant is well documented (Moffit and cottam, 1941; Einarsen, 1965; Keller and Harris, 1966; Kramer, 1976). According to Cottam et al,1944, Zostera has made up to 85% of the birds diet.

The Pacific Black Brant is one of three races of the brant goose, Branta bernicla. According to Peters (1931) the three races and their respective distributions are as follows:

The Pacific Black Brant **breeds** along the Arctic coast of Siberia eastward to Alaska and North Canada to 100° W. longitude. They winter on the western shores of the Pacific south to Japan and northern China and on the eastern shores of the Pacific from Vancouver Island to Mexico. The Eastern American Brant, Branta bernicla horta, breeds along the eastern coast of northern Canada from 100° W. longitude to 74° N. Latitude, both shores of Greenland, Franz Josef, and on Splitzbergen. These birds winter cheifly on the Atlantic coast of the United States from New Jersey to North Carolina, while some winter along the coasts of Ireland and Great Britain. The Dark-bellied Brant, _Branta bernicla bernicla_, breeds along the coasts of northern Europe and Asia to the Taimyr peninsula. They winter along the coasts of northwestern Europe to the east coast of Great Britain.

Since 1958 the numbers of Black Brant wintering in the United States have declined from 50-60% of the total pacific population to less than 10% (U.S. Fish and Wildlife, anonymous). This decline has coincided with a corresponding increase in the numbers of Brant wintering in Baja California and mainland Mexico (Chattin, 1970; Smith and Jensen, 1970; Kramer, 1976).

San Ignacio Lagoon, Baja California (26°N latitude, 113° W longitude) is one of the major wintering areas for the Brant (U.S. Fish and Wildlife Census, 1982). In this lagoon the birds feed on _Zostera marina_ and _Ruppia maritima_.

The purpose of this study was to quantify _Zostera_ primary production and availability in San Ignacio Lagoon, and to make quantifiable observations on the feeding behavior of Brant on seagrases during the birds' wintering period.

## Study Area

San Ignacio Lagoon (Fig. 1) is a shallow water hypersaline, 35% (this study) lagoon situated 600 km south of San Diego, California. The lagoon is 140 $km^2$ with 40% not exceeding 2m deep at lowest low water. The tide flats are drained via channels leading from mangrove areas. The tides are mixed semidiurnal with an overal tidal range of 1.4m (Anonymous).

The lagoon is also the wintering grounds for the Pacific gray whale, *Eschrichtius robustus*. From January to April the gray whales use the lagoon for mating and nursing. Human activity increased during this time and human disturbance appeared to have a direct effect on the Brant's feeding behavior. The lagoon also supports commercial clamming and a resident population of 300 people.

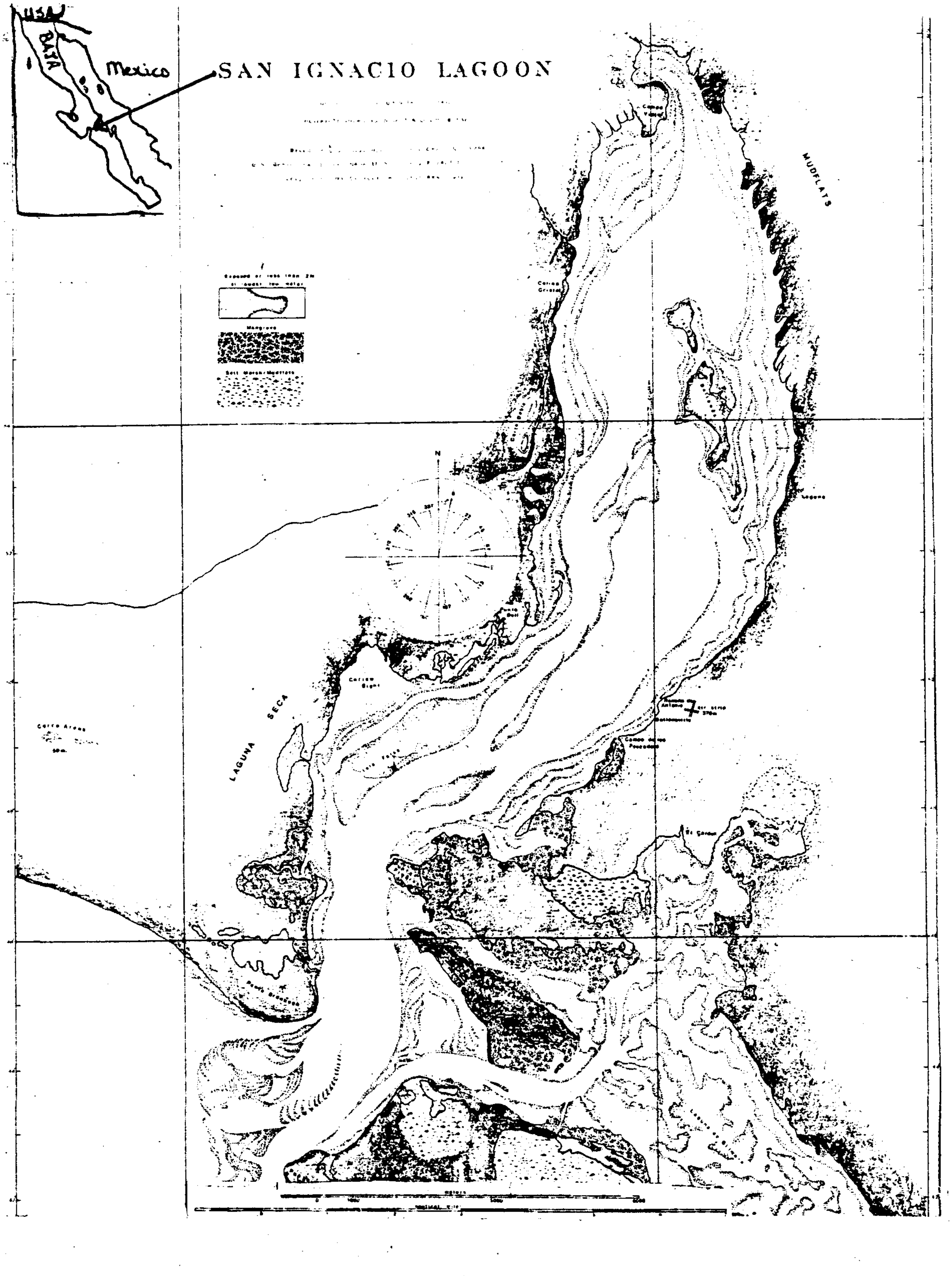


Figure 1. San Ignacio Lagoon, Baja California, Mexico

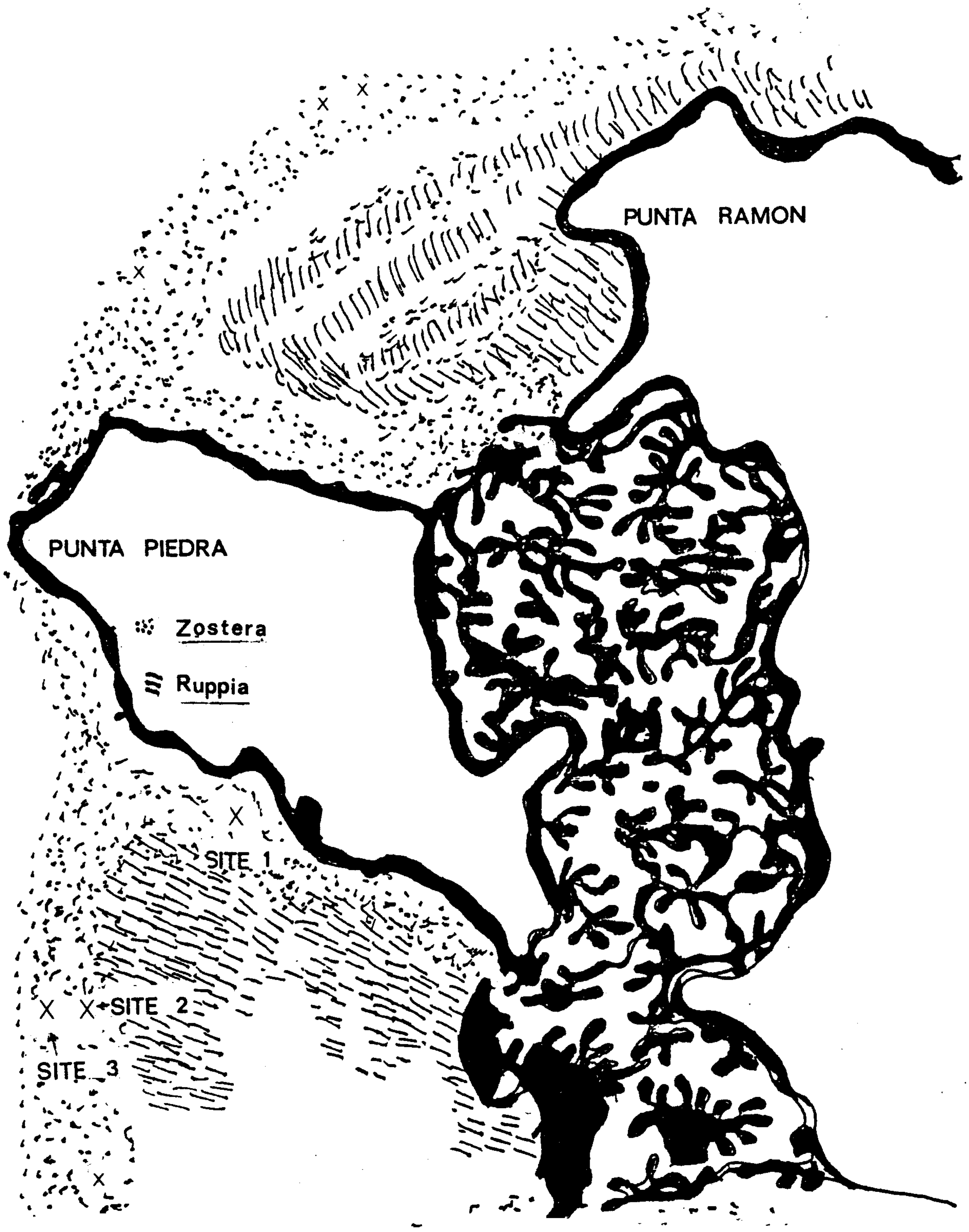


Figure 2. The three intertidal collecting sites: site 1, +0.5m, site 2, -0.5m, and site 3, -0.7m (MLLW) at Punta Piedra tide-flat. Other collecting sites are represented by X.

# MATERIAL AND METHODS

## Exclusion Cages

During February 1982 Brant grazing areas were identified. On 25 November 1982 sites were selected for placement of 10 exclusion cages each 1.0m$^2$. The cages were constructed from bamboo poles and cord. They were placed in Brant feeding areas at different tidal heights; from 0.5m to -0.7m mean lower low water (MLLW) in order to test effects of grazing. Tidal heights were measured using United States National Oceanographic and Atmospheric Administration (NOAA) tables. The study site was located 5 km south of Ballenas Bay, a site for which tidal listings can be found in the NOAA tables. All tidal heights given in the thesis are in reference to MLLW unless otherwise stated. Seven cages were placed at Punta Piedra mud-flat (Fig. 2) and three at Punta Ramon tide-flat. All cages were in place approximately one month after the main body of Brant population had arrived in the lagoon.

## Samples and Analysis

### Sampling

The area inside each exclusion cage represented ungrazed conditions. Paired, $0.1m^2$ samples were collected: one sample from within and one from outside the cage. All the $0.1m^2$ quadrats were assigned a number and sample location was determined through the use of a random numbers table. Samples were collected twice a month.

### Vegetative Parameters

Bimonthly $0.1m^2$ samples of above-ground (standing crop) were collected, washed and cleaned of epiphytes. All shoot bases within the $0.1m^2$ quadrats were also collected. Shoot densities and characteristics (leaf number, width and length) were measured. Then the samples were dried in the sun at $15-32^0$ C for 24 hours. After drying the samples were stored in plastic bags until May when they could be redried at $90^0$ C for 24 hours and weighed in the laboratory.

Ten $0.1m^2$ dried samples (5 from site 2 and 5 from site 3) were combusted at $550^0$ C for 4 hours (Dawes, 1981), and weighed to the nearest .01 g to determine ash-free dried weights. The percent organic content in Zostera was calculated by the following formula:

$$\frac{\text{Dry weight - Ash weight}}{\text{Dry weight}} \text{ X } 100 = \text{Percent Organic Content}$$

Shoot widths, lengths and number of Zostera leaves were measured from 16 representative plants in order to obtain a mean measurement for each sample. Leaf widts were taken at the sheath scar, and leaf lengths were measured from the sheath scar on the leaves with undamaged tips. Leaves were counted regardless of length, condition or age.

From the bimonthly $0.1m^2$ collection, samples taken from three tidal heights were used for comparing Zostera characteristics: site 1, +0.5m, site 2, -0.5m, site 3, -0.7m.

## Growth Rate and Production

From 2 December to 25 March a leaf marking technique (Zeiman, 1968) was used to measure leaf growth rate. Adjacent to different exclosures sites (-0.5 and -0.7m) 8 to 14 different shoots within a $1m^2$ area were marked with a 2mm punch. The holes were punched just above the base of the plants meristematic region. After 9 to 17 days the shoots were clipped and measured. The measurements were made from the bottom of the hold to the oldest leaf sheath scar. The inner leaves without holes were identified as new leaves. Growth rate was determined by addition of the leaf growth of old leaves to the growth of the new leaves and dividing by the number of days in the time period.

The average plastochrone interval, i.e. the time interval between the initiation of two successive leaves on one shoot, was calculated as

$$\text{P I} = \frac{\text{(no. of shoots marked) (observation period)}}{\text{no. of new leaves on marked shoots}}$$

Dailey growth rates were converted to net production in the following manner:

1- ($cm^2$/shoot/day) (shoot/$m^2$) = $cm^2/m^2$/day
(growth rate) (monthly density estimates)

2- ($cm^2/m^2$/day) (.002 g dry wt./$cm^2$) = g dry wt./$m^2$/day
(length:weight conversion factor)

3- (g dry wt./$m^2$/day) (0.24 C/g dry wt.) = g C/$m^2$/day
(dry wt.:carbon wt. conversion factor for net production)

The length : weight conversion factor was calculated by averaging the weights of 1cm lengths of oven dried Zostera leaves (n=20). The dry weight : carbon weight conversion factor was calculated by multipling the average carbon content of organic ash-free dry weight, 46.5% (Westlake, 1965) and by the percent organic content of Zostera, 53.4% (this study).

## Seagrass Distribution

In March seagrass distribution in the lagoon was plotted from its highest growth intertidally, +0.5m to -2.0m. This was accomplished by moving theboat along a predetermined transect and noting the presence or absence of seagrass. The reporting point was lined up with a reference point on land and then plotted on a map.

## Protein Analysis

Bimonthly samples of Zostera were collected for protein analysis. Shoots were picked at random from three different tidal heights (+0.5, -0.5, and -0.7 meters). Samples of Ruppia were collected at one tidal height (+0.5 m). The shoots were dried in the shade at temperatures less than 30° C and then stored for subsequent protein analysis back in Oregon. Previous observatins in 1981 and 1982 showed that Brant consumed only seagrass leaves. Therefore only the leaves were used for analysis.

Samples were analyzed by the Lowry-Folin copper tartrate procedure (Dawes, 1981). Individual samples (all the blades of one shoot) of 8 different shoots were taken for analysis. This allows for individual variations at each site.

The concentrations of protein are expressed in optical density and converted to percent protein by using a standard curve. The standard is developed from a series of known concentrations of protein.

$$\% \text{ Protein} = \frac{(\text{mg protein})\ (10)}{\text{mg of tissue } (10\text{mg})} \times 100$$

## Brant Dynamics

### Grazing

From 14 February to 14 March during every daylight low tide period (n=28) the number of Brant observed feeding on seagrasses was recorded. Several counts were made from a sand dune on shore approximately 4m in height which was within 500m of the birds. Before the birds started feeding the observer arrived and waited for grazing to begin. Censuses were made every 5 minutes or more frequently depending upon Brant activity. The average number of bird days was computed by multiplying the average number of birds by the average length of time the birds remained on the tidal flat. The standard metabolism (M) of the birds (kcal/day) was calculated using a formula reported by Lasiewski and Dawson (1967):

$$M = \text{Log } 78.3 + 0.723 \text{ Log } W$$

where W is the body weight of the bird in kg. The standard consumption per bird/day was calculated by multiplying the standard metabolism (M) by a factor of 3 for net food assimilation efficiency according to Jacobs (1980). Kcal are converted to g dry weight by multiplying by 0.2 (Jacobs, 1980).

The Punta Piedra study site was divided into 3 different areas in order to measure time usage on particular seagrass beds. One area contained exclusively *Ruppia*, one only *Zostera*, and a third, a mixture of the two types. Percent utilization was calculated by multiplying the average number of birds by the time the birds spent in one of three areas.

## Census

When weather permitted, bimonthly population counts were made from a boat. Counts began 1-2 hours before low tide and ended 1-2 hours after low tide. All counts started at the entrance of the lagoon, proceeded north along the east shore and returned along the west shore. All censuses were made by averaging at least 2 counts and from a distance not exceeding 800m. Whenever possible, individual bird numbers were counted, but in dense aggregations that was not possible. In such cases birds were estimated by counting representative samples and extrapolating to the whole flock.

## Statistical Procedures

Statistical differences of the sample means were determined from a "t" test from Snedecor and Cochran (1967):

$$t = \frac{X_1 - X_2}{\sqrt{\frac{1}{N} + \frac{1}{N} \quad \frac{(N_1-1)\ (S_1^2) + (N_2-1)\ (S_2^2)}{N_1 + N_2^{-2}}}}$$

A relationship between sample coefficients of correlation and regression was used from Snedecor and Cochran (1967) to determine significant figures between sampling dates within sites:

$$t = r\sqrt{\frac{N-2}{1-r^2}}$$

# RESULTS

## Exclusion Cages

During the four months of this study, differences in standing crop between grazed and ungrazed samples were minimal (Table 1). The total difference between all cages was only 1 g dry wt./$m^2$. Individual differences ranged from -16 g dry wt./$m^2$ to 28 g dry wt./$m^2$. Because of the very low differences in grazed and ungrazed samples both ungrazed and grazed samples (4 replicates) were used to determine standing crop trends.

## Seagrass Dynamics

### Vegetative Parameters

Different *Zostera* populations were represented in the study sites. Site 1, +0.5m, contained patchy *Zostera* beds whose shoots were comparatively small: $\overline{X}$ leaf length was 15.2cm and leaf width was 0.33cm. The site was located near mangrove drainage channels. Site 2, -0.5m, was located lower in the intertidal and represented a more homogenous bed of Zostera. The shoots were longer ($\overline{X}$=22.1cm) and wider ($\overline{X}$=0.45cm) than those found in site 1. Site 3, -0.7m, was located directly in front of site 2 and contained still longer ($\overline{X}$=36.5cm) and wider ($\overline{X}$=0.55cm) leaves than site 2 (Table 2).

In comparing mean densities of shoots between sites a highly significant ($P < 0.005$) difference was found between site 1 and site 2 and a significant ($P < 0.05$) difference between site 2 and site 3. However, there was not a significant difference in bimonthly mean estimates of shoot density within each site (Table 2). Site 1 throughout the study lacks the first month's data.

The range of mean leaf lengths at all three sites was between 9.1cm and 57.2cm. There was a significant ($P < 0.001$) difference in bimonthly mean leaf lengths within each site (Fig. 3). The significant difference between the individual sites was a $P < 0.1$.

The mean leaf width decreased during the study period (Fig. 4). At site 1 there was no significant difference in bimonthly estimates. However at both site 2 and site 3 significant differences ($P < 0.001$) were recorded. There was a significant ($P < 0.001$) difference in mean leaf widths between individual sites.

Standing crop increased with increasing depth (Table 2) but this was only found to be a significant ($P < 0.1$) difference between site 1 and site 3. At site 1 the mean range of standing crop was 49-87 g dry wt./$m^2$, at site 2 this was found to be 75-147 g dry wt./$m^2$ and at site 3 the mean range was 87-317 g dry wt./$m^2$. All three sites showed a highly significant ($P < 0.001$) difference in bimonthly standing crop estimates (Fig. 5).

If the standing crops of Zostera are combined and averaged at all three sites the overall standing crop decreased an average of 2g dry wt./$m^2$/day. The largest drop occured at site 3 where 72% of the original (Dec. 3) standing crop was lost by the end of the study period.

Both standing crop and leaf length increased with increasing intertidal depth. From this relationship the standing crop per meter squared of Zostera was found to be a function of leaf length (Fig. 6). The regression line $y = .26X + 258.2$ $r - 0.94$ is highly significant ($P < 0.001$).

There was no significant bimonthly variation in percent organic ash-free dry wt. of Zostera from sites 2 and 3 (Appendix). The organic content throughout the study period averaging 53.4% organic content figure was used along with Westlake's (1965) 46.5% carbon content figure to obtain a conversion factor for net production estimates.

| | | DATE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12-3 | 12-14 | 12-26 | 1-13 | 2-8 | 2-25 | 3-25 | X | s | TOTAL DIFF. |
| | G | - | - | 11.5 | 11.4 | 6.7 | 5.4 | 5.1 | 8.0 | 3.2 | +2.8 |
| SITE 1 | UG | - | - | 8.2 | 8.6 | 9.8 | 5.3 | 5.4 | 7.5 | 2.0 | |
| SITE | G | - | - | 7.4 | 6.8 | 6.6 | 6.0 | 4.4 | 6.2 | 1.1 | -0.7 |
| 1A | UG | - | - | 7.5 | 6.1 | 5.9 | 7.6 | 4.8 | 5.0 | 2.2 | |
| SITE | G | 16.0 | 15.0 | 12.8 | 11.4 | 9.4 | 7.2 | 8.0 | 11.4 | 3.4 | |
| 2 | UG | 16.8 | 14.7 | 11.1 | 12.2 | 9.9 | 7.6 | 9.1 | 9.5 | 4.1 | -1.6 |
| SITE | G | 13.4 | 9.8 | 10.1 | 7.7 | 8.6 | 9.6 | 6.7 | 9.4 | 2.1 | |
| 2A | UG | 12.6 | 13.7 | 8.2 | 9.8 | 7.7 | 8.0 | 6.2 | 9.5 | 2.8 | -0.3 |
| SITE | G | 33.5 | 22.1 | 17.4 | 15.1 | 10.6 | 10.1 | 9.0 | 16.8 | 8.7 | -0.2 |
| 3 | UG | 32.1 | 22.2 | 18.5 | 13.3 | 12.5 | 9.8 | 9.6 | 16.9 | 8.1 | |
| SITE | G | 31.2 | 21.8 | 13.6 | 12.1 | 10.3 | 8.7 | 8.0 | 15.1 | 8.6 | +1.1 |
| 3A | UG | 29.8 | 19.9 | 15.3 | 11.5 | 10.1 | 9.9 | 8.1 | 14.9 | 7.7 | |
| P.P. | G | - | 9.5 | 6.5 | 4.2 | 4.1 | 2.5 | 2.2 | 4.8 | 2.8 | +1.4 |
| | UG | - | 8.0 | 7.4 | 3.6 | 4.6 | 2.6 | 1.3 | 4.5 | 2.7 | |
| P.R. | G | - | - | 18.6 | 9.5 | 11.3 | 11.4 | 8.1 | 11.8 | 4.1 | +1.0 |
| | UG | - | - | 18.5 | 11.7 | 12.4 | 10.0 | 9.3 | 12.3 | 3.6 | |
| P.R. | G | - | 17.0 | 15 | 9.5 | 8.1 | 7.7 | 4.3 | 10.2 | 4.8 | -1.3 |
| | UG | - | 19.5 | 10.0 | 10 | 8.3 | 7.6 | 7.5 | 10.5 | 4.6 | |
| P.R. | G | - | - | 15.9 | - | 13.3 | 12.1 | 10.2 | 6.2 | 1.1 | -2.3 |
| | UG | - | - | 17.3 | - | 14.0 | 13.5 | 9.1 | 6.4 | 1.2 | |

-0.1

Table 1. Differences in standing crop between 10 grazed (G) and ungrazed (UG) quadrats. Staning crop is measured in g dry wt./0.1m$^2$. P.P. represents Punta Piedra as wells as sites 1, 2 and 3. P.R. reprsents Punta Ramon. See figure 2.

Table 2. A comparison of mean standing crop (n=4), mean shoot density (n=4), mean leaf length (n=64), and mean leaf width (n=64) of Zostera at three intertidal heights: site 1, +0.5m, site 2, -0.5m and site 3, -0.7m (MLLW). s= standard deviations.

| DATE | STANDING CROP (g dry wt./$m^2$) | | | LENGTHS (cm) | | | WIDTHS (cm) | | | DENSITY ($m^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-1 | S-2 | S-3 | S-1 | S-2 | S-3 | S-1 | S-2 | S-3 | S-1 | S-2 | S-3 |
| 12-3 | - | 147 | 317 | - | 34.3 | 57.2 | - | .48 | .60 | - | 810 | 500 |
| 12-14 | - | 133 | 215 | - | 29.5 | 49.2 | - | .46 | .58 | - | 790 | 480 |
| 12-29 | 87 | 106 | 162 | 20.6 | 24.4 | 39.8 | .33 | .47 | .55 | 1310 | 910 | 620 |
| 1-14 | 80 | 103 | 126 | 18.6 | 21.1 | 39.0 | .34 | .45 | .57 | 1140 | 770 | 470 |
| 2-8 | 73 | 89 | 109 | 15.8 | 18.3 | 28.1 | .35 | .45 | .55 | 960 | 670 | 570 |
| 2-25 | 61 | 81 | 100 | 12.1 | 15.0 | 24.2 | .34 | .42 | .51 | 1360 | 860 | 820 |
| 3-25 | 49 | 75 | 87 | 9.1 | 12.1 | 18.6 | .31 | .41 | .48 | 1350 | 1050 | 640 |
| $\bar{X}$ | 70 | 105 | 160 | 15.2 | 22.1 | 36.5 | .33 | .45 | .55 | 1225 | 835 | 610 |
| s | 15 | 27 | 82 | 4.7 | .79 | 13.8 | .02 | .03 | .04 | 172 | 120 | 123 |
| Range | 49 - 317 | | | 9.1 - 57.2 | | | .31 - .60 | | | 470 - 1360 | | |

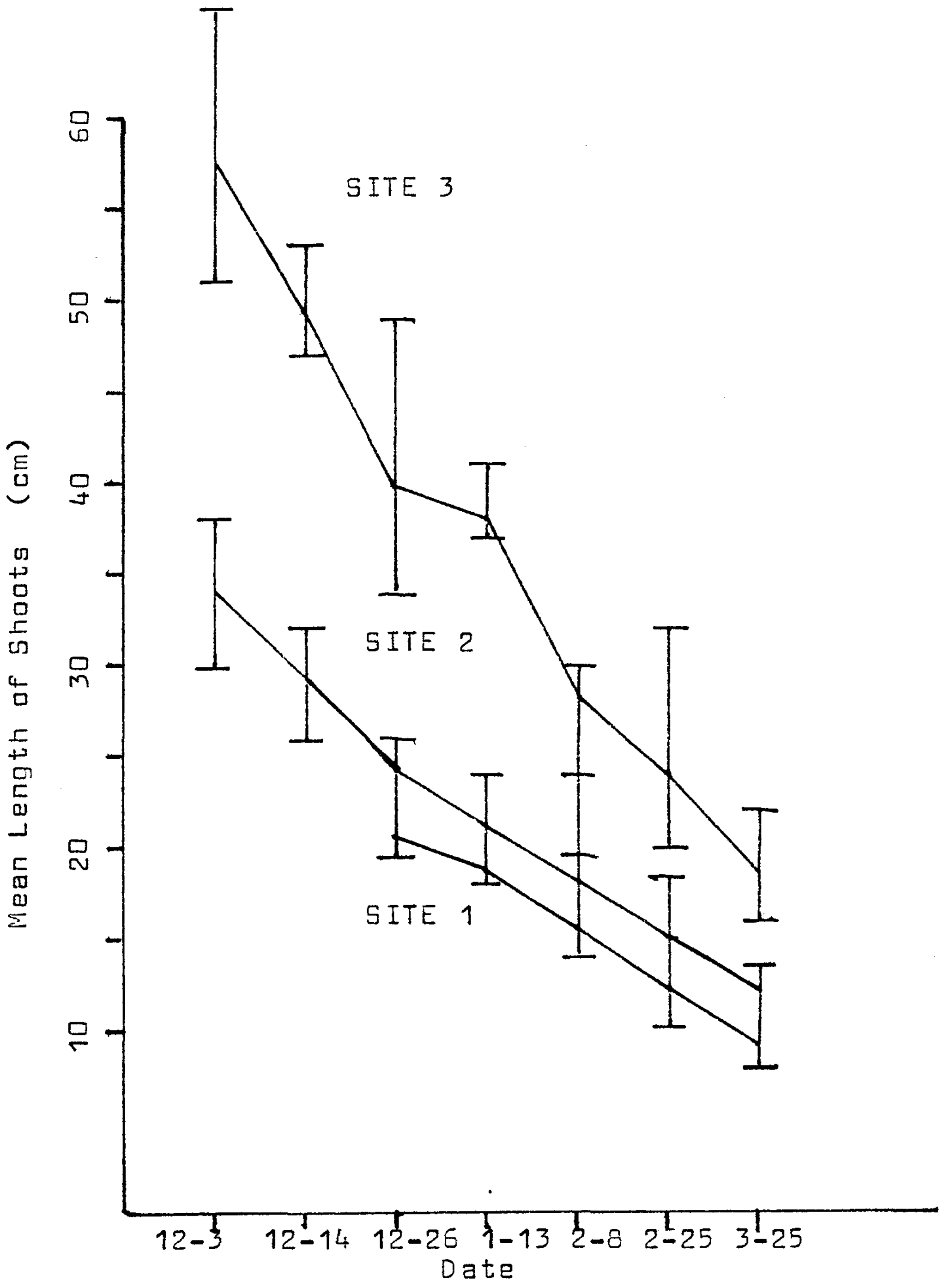


Figure 3. Comparison of bimonthly shoot lengths from site 1 +0.5m, site 2, -0.5m, and site 3, -0.7m (MLLW). Vertical bars represent range (n=64) for each bimonthly estimate.

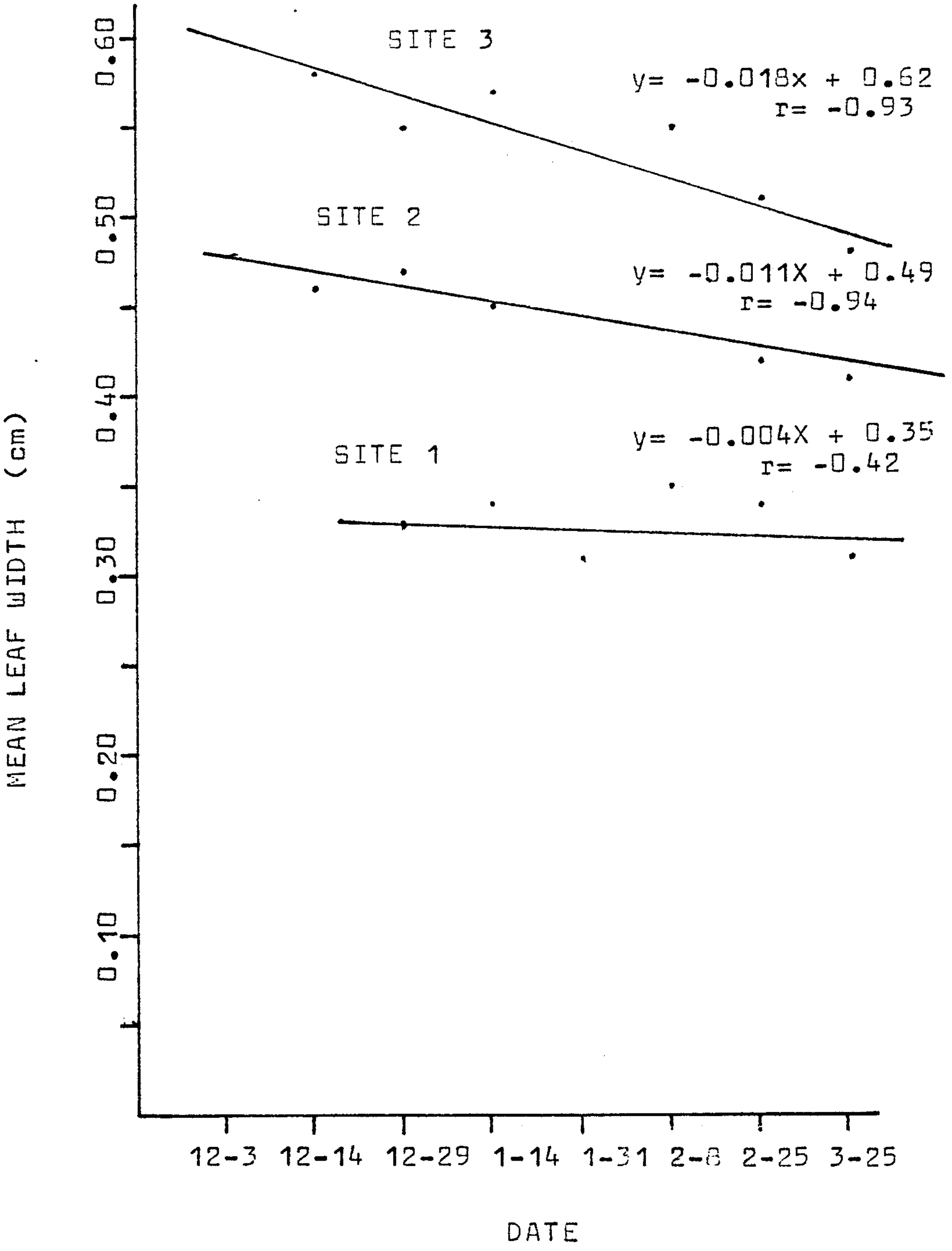


Figure 4. Linear regrssion of bimonthly mean leaf widths of *Zostera* from site 1, +0.5m, site 2, -0.5m site 3 -0.7m (MLLW). Bars represent the range (n=64) for each bimonthly estimate.

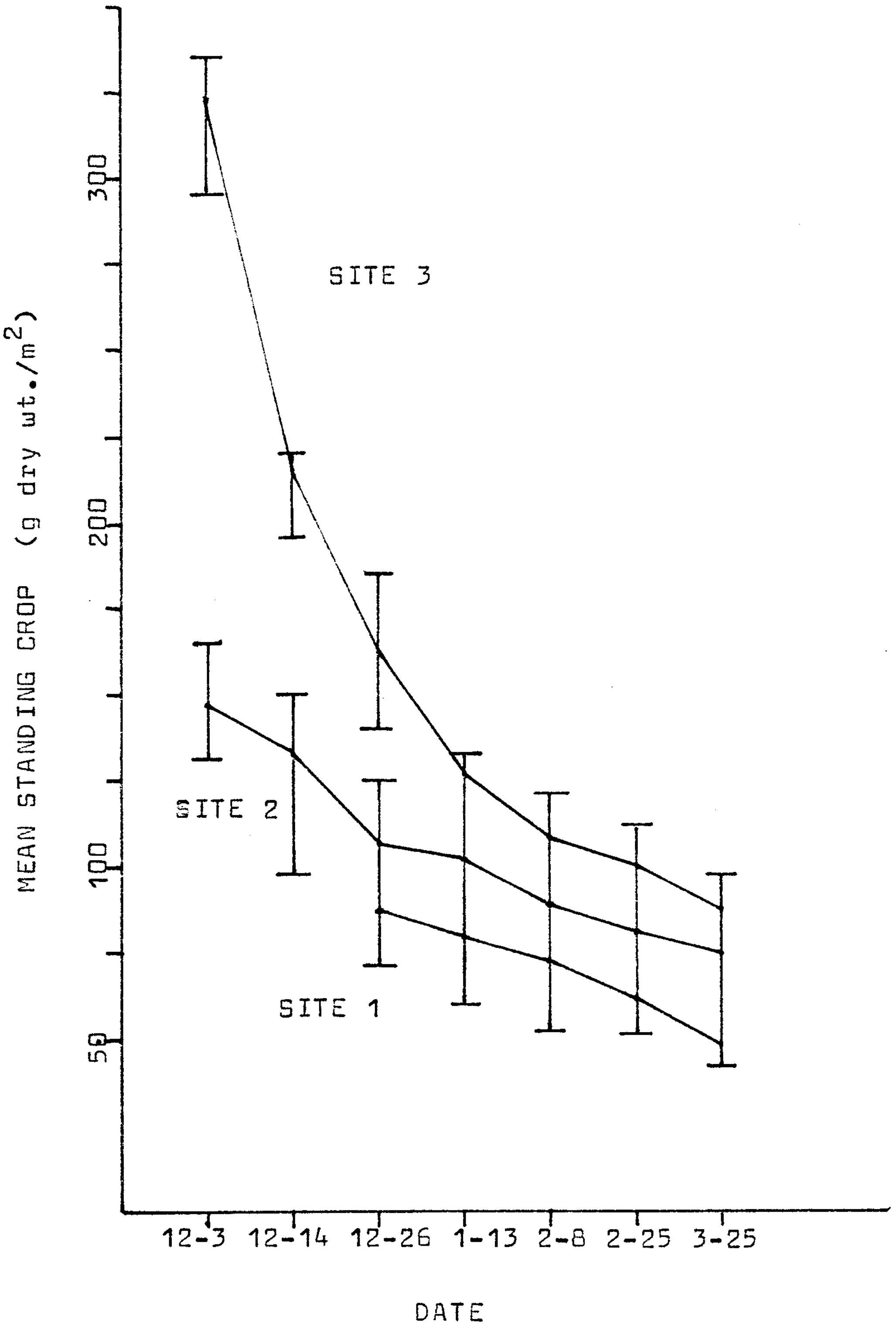


Figure 5. Comparison of mean bimonthly standing crop of Zostera from site 1, +0.5m, site 2, -0.5m, and site 3, -0.7m (MLLW). Bars represent range (n=4) for each bimonthly estimate.

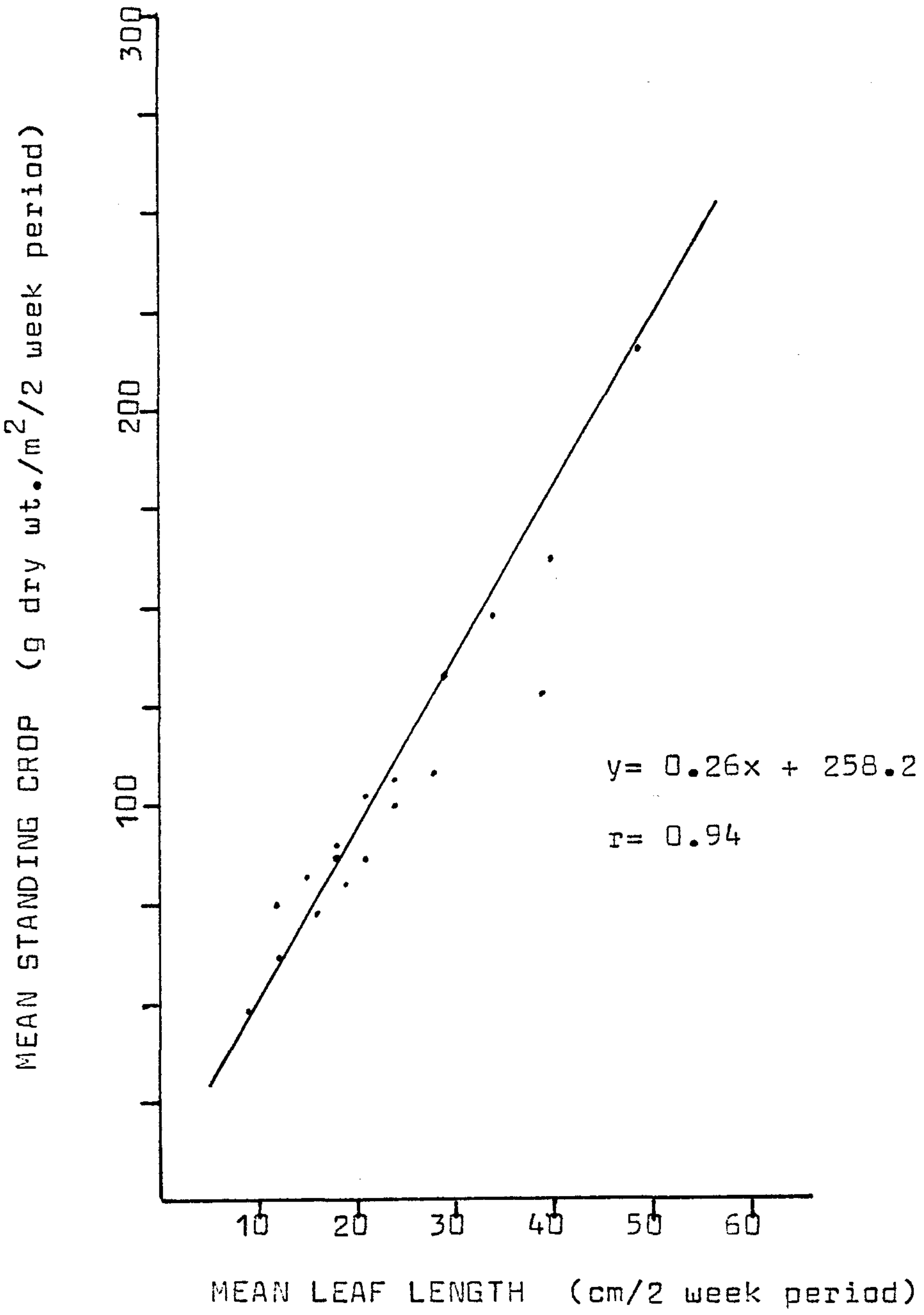


Figure 6. Linear regression of bimonthly mean standing crop and leaf length of Zostera at three sites, 1,2,and 3.

## Production

Shoots that had been hole-punched for production showed no significant decrease in leaf growth as a result of mechanical damage to the leaf. A sample of shoots (n=10) marked with a small sewing needle showed no significant difference from hole-punched shoots in production estimates (Appendice A).

The mean daily growth rate from 3 December 1982 to 23 March 1983 for site 2 was 2.7cm$^2$/shoot and for site 3 was 3.1cm$^2$/shoot (Table 3). There was no significant difference between the two sites. However the bimonthly growth rate decreased significantly ($P < 0.001$) throughout the study period. Only at site 2 from 3 December to 14 December was there an increase in growth rate. The growth rate increased from 2.8cm$^2$/shoot to 3.2cm$^2$/shoot. This was a highly significant ($P < 0.001$) difference. The new leaves that were formed in this period were thinner than the existing leaves by as much as 0.15cm. This could possibly account for the increase in growth despite a decrease in standing crop, leaf length and leaf width.

The daily in situ net production was calculated using the leaf growth information, a length : weight conversion factor (Appendix), and a dry weight : carbon weight conversion factor (Appendix). Daily net production ranged from 1.37 g C/m$^2$ to 0.91 g C/m$^2$ with a mean net production rate of 1.08 g C/m$^2$ (Table 4). The bimonthly mean net production estimates from sites 2 and 3 are shown in figure 7.

At site 2 a mean of 2.2 new leaves was produced every two weeks and at site 3 a mean of 2.3 new leaves every two weeks (Table 3). A range of 1.8 leaves/two weeks to 2.5 leaves/two weeks was formed at site 2 and at site 3 a range of 1.8 leaves/two weeks to 2.6 leaves/two weeks was formed. Total number of leaves remained relatively constant throughout the study. The average number of leaves per shoot was 4.3 at site 2 and at site 3 it was 4.5. Because new leaves were produced continuously, the variation in the number per shoot was probably caused by a greater breakage of old leaves. The average plastochrone interval (PI) was 7.5 days at site 2 and 7.1 days at site 3. Assuming that the older outer leaves are sloughed at the same rate new leaves are formed, the average turnover rate for a typical leaf at both sites is 27 - 36 days (Table 3). A high turnover rate is evident by the fact that very vew epiphytic animals or plants were found on the plants.

In spite of the general pattern of leaf growth (Table 3) there existed a variation in individual P I . The course of the P I showed a reverse correlation with insolation (Fig. 8). Note the insolation figures are for San Diego, California, 500 km north of San Ignacio lagoon. Water temperature seemed of smaller importance: it rose gradually from 19$^0$ C early in December to a maximum of 22$^0$ C in late March. At low tide, on warm sunny days air temperture played a more prominent role heating tidal pools (to 30$^{o}$C) and Zostera beds without water coverage.

The overall changes in P I are very similar to changes in insolation. The variations are probably due to a difference in insolation between San Diego and San Ignacio Lagoon.

The increasing insolation of late December to a peak in early January resulted in a decrease in P I from a peak high in late December, 9.6 days, to a low in mid-January, 6.9 days. The lowest P I was reached on February 25, 5.5 days; this was just after there was an increased insolation reading.

## Seagrass Distribution

Ruppia beds were found to be the more extensive species above two meters within San Ignacio Lagoon. Total square area of seagrasses in the lagoon was calculated to be 52.8 km$^2$: Ruppia beds comprised 36.6 km$^2$ and Zostera beds comprised 26.2 km$^2$. The study area at Punta Piedra was calculated to be 2.1 km$^2$ of which Ruppia covered 700m$^2$ and Zostera covered 1200 m$^2$. The remainder of the study area was sand and lacked seagrass.

| MARKING DATE | LEAF GROWTH ($cm^2$) | | NO. NEW LVS. PER 2 WEEKS | | NO. LVS./ SHOOT | | TIME LEAF ATTACHED (days) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 12-3-<br>12-14 | 2.8 | - | 2.2(11) | - | 4.2 | - | 31.5 | - |
| 12-14-<br>12-29 | 3.2 | 3.89 | 1.8(11) | 1.8(11) | 3.8 | 3.7 | 28.5 | 26.3 |
| 12-29-<br>1-14 | 3.06 | 3.34 | 2.2(11) | 2.4(8) | 4.3 | 4.3 | 32.2 | 30.5 |
| 1-14-<br>1-31 | 2.95 | - | 2.0(8) | - | 4.1 | - | 30.7 | - |
| 2-9-<br>2-25 | 2.64 | 3.30 | 2.2(8) | 2.4(8) | 4.5 | 5.0 | 29.2 | 35.5 |
| 2-25-<br>3-11 | 2.29 | 2.76 | 2.5(14) | 2.6(14) | 4.3 | 4.1 | 32.2 | 29.1 |
| 3-11-<br>3-25 | 2.05 | 2.26 | 2.3(9) | 2.4(14) | 4.6 | 5.6 | 34.5 | 39.8 |
| X | 2.71 | 3.10 | 2.2(10) | 2.3(11) | 4.3 | 4.5 | - | - |
| Range | 2.05-3.2 | 2.26-3.89 | 1.8-2.5 | 1.8-2.6 | 4.1-4.6 | 3.7-5.6 | 29.2-34 | 26-40 |

Table 3. Means of production, new leaf emegence, leaves per shoot and leaf attachment time of Zostera from site 2 and site 3. Leaf attachment time is calculated as the no. leaves/shoot X 7 (site 3) and 7.5 (site 2). Number of shoots measured during each marking period in parenthesis.

| DATE | SHOOT DENSITY no./m$^2$ | LEAF GROWTH cm$^2$/shoot | NET PRODUCTION g dry wt/m$^2$ | g C/m$^2$ |
|---|---|---|---|---|
| *12-3 to 12-14 | 810 | 2.8 | 4.54 | 1.14 |
| 12-14 to 12-29 | 635 | 3.55 | 5.51 | 1.37 |
| 12-29 to 1-14 | 765 | 3.20 | 4.90 | 1.23 |
| *1-14 to 1-31 | 770 | 2.95 | 4.54 | 1.14 |
| 2-9 to 2-25 | 620 | 2.97 | 3.68 | 0.92 |
| 2-25 to 3-11 | 840 | 2.53 | 4.25 | 1.06 |
| 3-11 to 3-25 | 845 | 2.16 | 3.65 | 0.91 |
| $\overline{X}$ | 755 | 2.88 | 4.30 | 1.08 |

Table 4. Daily in situ net production of *Zostera* from the means of sites 2&3. The leaf growth is multiplied by .002 (conversion factor for cm$^2$ to g dry wt.) and 0.25 (conversion factor for g dry wt. to carbon) for conversion to net production. Conversion factors are discussed in material and methods section.
* - values from site 2 only.

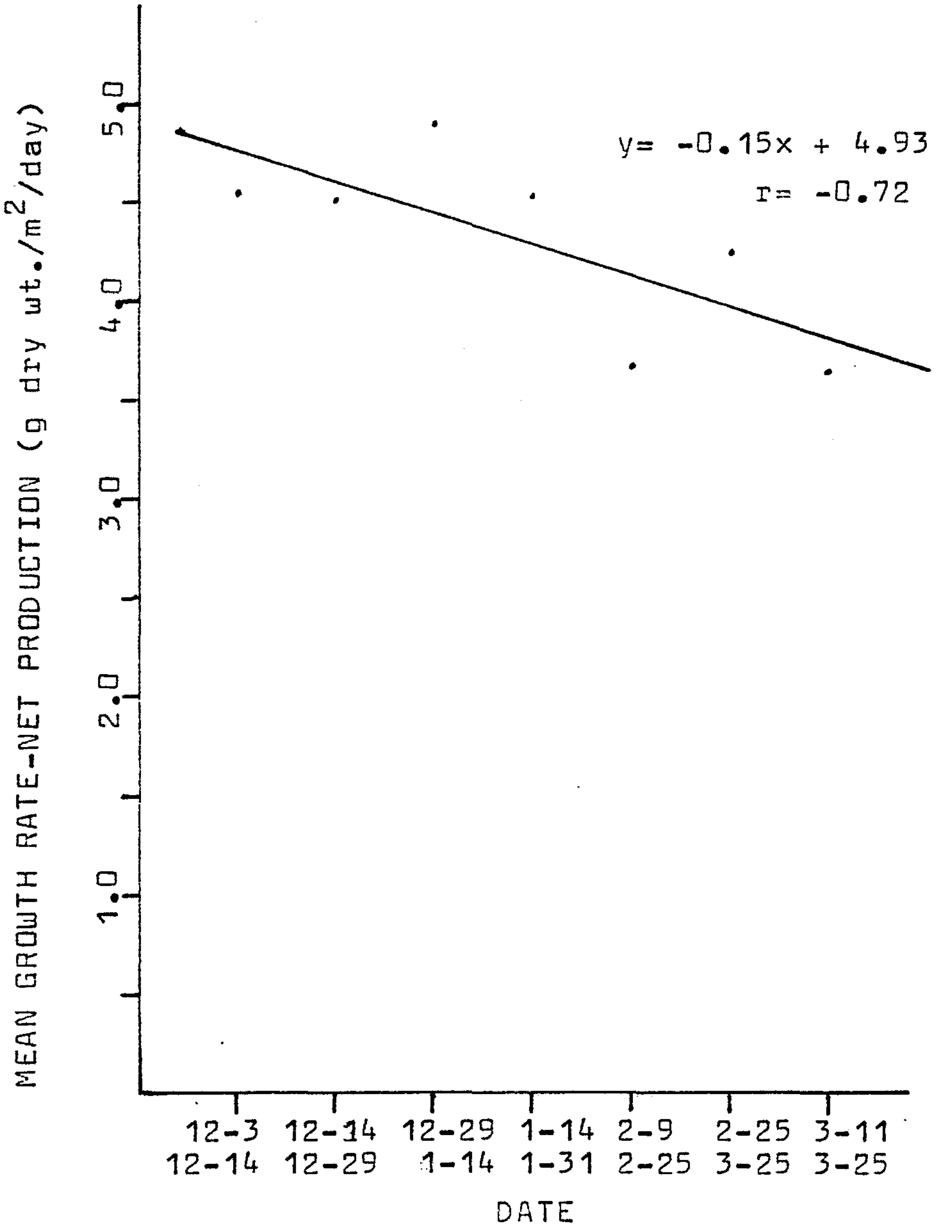
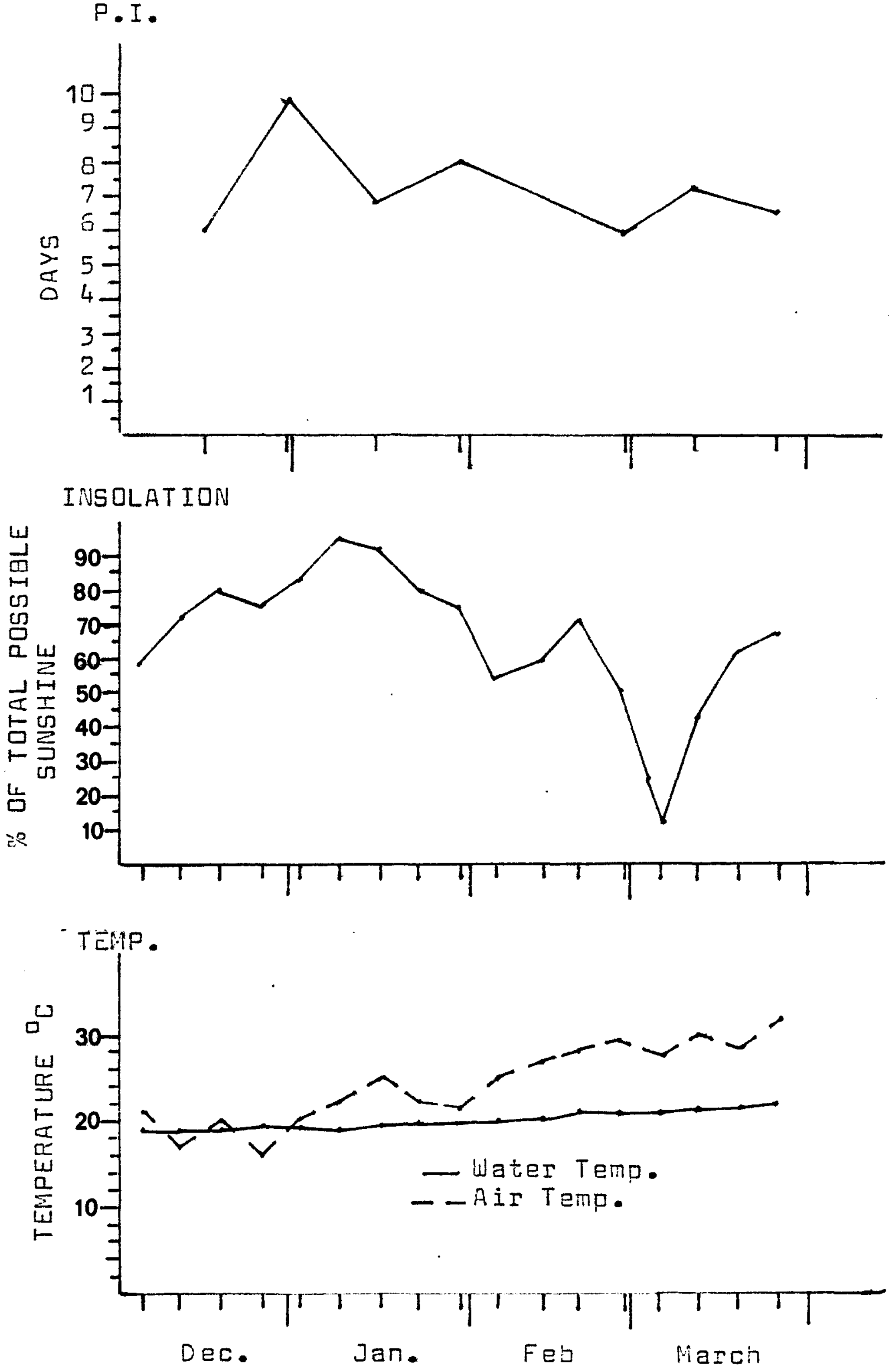


Figure 7. Linear regression of bimonthly *in situ* net *Zostera* production from the combined means of site 2 and site 3.

Figure 8. Seasonal changes in plastochrone interval (P.I.) of *Zostera* at San Ignacio Lagoon (mean P.I. of sites 2 and 3), compared with insolation and temperature. All values given are means for a 2 week period. The insolation figures are from N.O.A.A. for San Diego, California.


P.I.
DAYS
10
9
8
7
6
5
4
3
2
1
INSOLATION
% OF TOTAL POSSIBLE SUNSHINE
90
80
70
60
50
40
30
20
10
TEMP.
TEMPERATURE °C
30
20
10
Water Temp.
Air Temp.
Dec.
Jan.
Feb
March

## Protein Analysis

Protein analysis was done on the bimonthly Zostera samples from three different sites: site 1, 0.5, site 2, -0.5, and site 3, -0.7m. Ruppia was collected at only two different times, 23 February and 23 March at just one location, +0.5m.

The 23 Feb. protein content of Ruppia was compared to that of Zostera at all three sites (Table 5). Ruppia was found to contain more protein than Zostera but was only significantly higher ($P < 0.05$) than Zostera at just site 1, +0.5m.

The 23 March protein content of Zostera at site 3 was slightly higher than the protein content of Ruppia. However Ruppia again was significantly ($P < 0.01$) higher in protein than Zostera at site 1.

At each tidal height there was no apparent trend toward higher or lower protein content during the study period. Ruppia and Zostera varied only 1 - 2% in protein. There was however a significantly ($P < 0.01$) higher amount of protein in Zostera at site 3 than at site 1. Also there was a significantly ($P < 0.001$) higher amount of protein in Zostera at site 2 than at site 1. This indicates a possible variation in protein content with intertidal depth (table 5).

| | Zostera | | | Ruppia |
|---|---|---|---|---|
| | site 1 (+0.5m) | site 2 (-0.5m) | site 3 (-0.7m) | (+0.5m) |
| Dec. 3 | - | 10% | 9.5% | - |
| Dec. 28 | 8.5% | 9% | 9.2% | - |
| Feb. 1 | 9.2% | 10% | 9% | - |
| Feb. 23 | 7.3% | 10.5% | 10.3% | 11.2% |
| March 23 | 6.7% | 9.9% | 10.5% | 10.1% |

Table 5. Percent Protein Content of _Zostera_ and _Ruppia_ at one intertidal height at Punta Piedra tide-flat. *Standard curve and individual shoot concentrations are given in Appendix.

## Brant Dynamics

### Grazing

From 15 Feb. to 14 March Brant were observed feeding at Punta Piedra tide-flat (Fig. 2). Of the time the birds spent on the mudflat, 67% was spent grazing on _Ruppia_, 27% was spent grazing on _Zostera_ beds, and the remaining 6% was spent on an area of mixed _Zostera_ and _Ruppia_. During high tide Brant aggregated around drifting "rafts" of _Zostera_ and were observed feeding on sloughed leaves floating on the water's surface. _Ruppia_ was not found floating in any substantial amounts.

Thirty to sixty minutes before the seagrass beds were exposed, the Brant arrived on high sand bars to rest and preen. Foraging for food began as soon as the seagrasses could be reached by bobbing and continued for 3 hours 40 minutes on average. The number of birds varied greatly between different low tide periods and even during one tidal period. The area of study was highly suseptible to human disturbance coming from airplanes carrying whale watchers and from commercial clam diggers.

The range of birds on the mudflat varied from 0 to 990 birds and time spent from 0 to 8 hours and 25 minutes. The average number of birds and time spent was 340 birds and 3 hours 40 minutes per day. Using the data and figures for standard metabolism the total amount of seagrass consumed was calculated as 136kg dry wt. per study period (28 days) (Table 6).

| DATE | BIRD WT.* (kg) | STANDARD METABOLISM** (kJ/day) | BIRD DAYS | SEAGRASS CONSUMED | |
|---|---|---|---|---|---|
| | | | | kJ x $10^6$ | kg dry wt. |
| 2-15 to 2-14 | 1.4 | 419 | 1500 | 3.2 | 136 |

*Jacobs <u>et</u> <u>al</u> (1981)
**Lasiewski and Dawson

Table 6. Zostera consumption by Brant between 15 February and 14 March 1983 on the tide-flats at Punta Piedra in San Ignacio Lagoon.

Assuming that the Brant feed uniformly over the entire tidal flat, consumption quantities of Ruppia and Zostera can be evaluated. In the 28 day period the birds were known to consume 136 kg dry wt. of seagrass (Table 6). Then if the Brant use Ruppia beds 67% of their feeding time and Zostera beds 27% of the time, the Brant consumed 91.1 kg dry wt./$m^2$ of Ruppia and 36.7 kg dry wt./$m^2$ of Zostera. The 36.7 kg dry wt./$m^2$ of Zostera is 31% of the maximum standing crop for that period, or 26% of the production.

## Census

During the study period four Brant population counts were made (Fig. 8). The birds arrived approximately the second week of October. On 2 Dec. the population was calculated to be 6850 birds and rose to a peak of 10,400 birds in late February. Kramer (1976) observed a peak spring migration in mid March at San Quintin Bay. Overall the Brant population had decreased from the 1982 winter season (Anonymous). U.S. Fish and Wildlife Service documented a similar trend in their January 1983 waterfowl surveys of Baja in San Ignacio Lagoon.

From the four different counts and personal observations it was noted that the Brant favored certain areas of the lagoon. The heavily used area of the lagoon was the more northerly end; approximately 60% of the total number

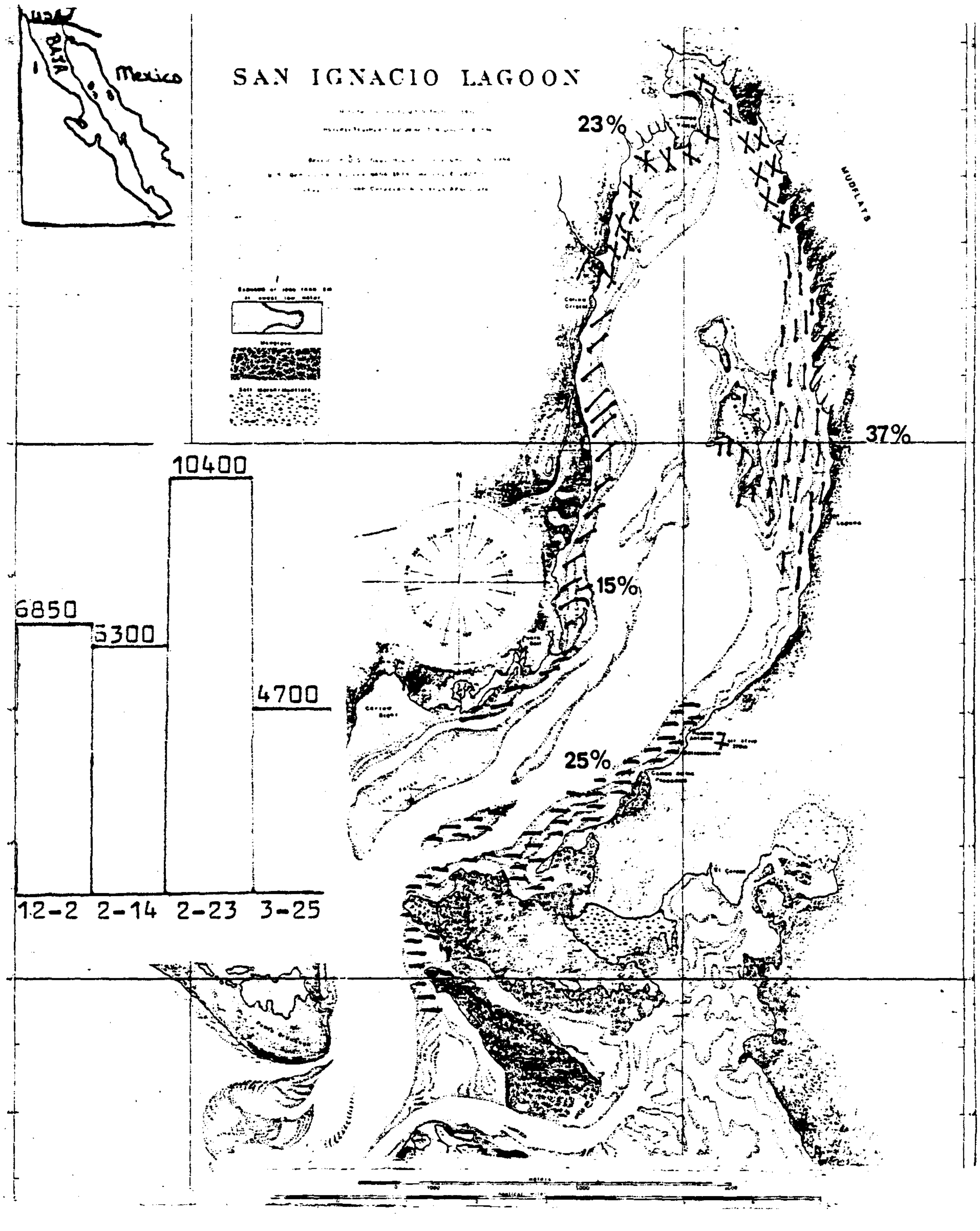


Figure 8. The four Brant censuses in San Ignacio Lagoon are represented: first, the bar graph, as the total number of Brant on four different dates and second, the hatching, as the four different grazing areas and the percent utilization of these areas by the Brant.

of Brant observed used this area. This was also where the largest beds of Ruppia were found; Zostera was found subtidally there. Another consideration for the Brant's usage of the northern end was the fact that this area had the least amount of human disturbance. Kramer (1976) found in San Quintin Bay that the Brant were very suseptible to human disturbance,

Another area the Brant used to feed was Gilmore Lagoon located near the southern portion of San Ignacio Lagoon (Fig. 1). This area contained 85 $km^2$. On 2 Dec. a population census of both lagoons revealed Gilmore Lagoon had 7300 birds and San Ignacio Lagoon had 6850 birds. It appears that Gilmore Lagoon is as important a feeding area as the main lagoon. Possibly this also relates to the fact that very little commercial activity takes place in this lagoon. Other counts in Gilmore Lagoon were not taken due to inclement weather, lack of time, and difficulty of maneuvering in the shallows of the lagoon.

The study site at Punta Piedra was heavily utilized foraging area for the Brant (Fig. 1 and 2). It is situated 3 km from the mouth of the lagoon and is the first major stand of seagrass the birds meet upon entering San Ignacio Lagoon. Because Brant are known to fly only over water to reach certain locations they make considerable detours around land masses (Einarsen, 1965). Brant from San Ignacio Lagoon enter or leave Gilmore Lagoon via two entrances. Punta Piedra is located at one of the two entrances to Gilmore Lagoon. During low tide Brant arrived from both lagoons to forage at Punta Piedra.

# CONCLUSION

## *Zostera* Dynamics

Though the distribution of *Zostera* and *Ruppia* beds in San Ignacio Lagoon overlap intertidally, *Ruppia* is found primarily higher in the intertidal (+0.7m to +0.3m) and *Zostera* occurs lower in the intertidal (+0.5m to -0.9m), though *Zostera* continues to grow subtidally to a depth of about -5.0m.

The lower spatial limits of *Zostera* growth is most likely defined by the intensity of irradiance but tidal currents could also have a strong influence. Neinhius and deBree (1977) stated that after the closure of the Grevelingen estuary *Zostera* beds extended deeper as a result of increased irradiance. In California at a light transmittance of 20% or less, some of the *Zostera* eventualy died in shading experiments while adjacent plants receiving higher irradiance lived (Bachman and Barilotti, 1976). *Zostera* grows to a depth of about 5m in San Ignacio Lagoon. Below this level scattered patches of Zostera occur.

The upper spatial limits of Zostera in the intertidal is influenced by the duration of submergence in tidewaters and period of desiccation at low tide (Keller and Harris, 1966; Jacobs, 1979). In the intertidal the upper limits of Zostera in San Ignacio Lagoon was confined to areas near mangrove channels or areas where tide pools formed at low tide. Keller and Harris (1966) found at Humboldt Bay, California ($41^{0}$N latitude, $124^{0}$W longitude) Zostera required a minimum tidal coverage for survival of 85%, whereas optimal growth occured where the plant experienced 95-100% coverage. In the tide pools photosynthesis is not suppressed by hydration but rather by hypersalinity and extreme water temperatures (McRoy and Biebl, 1971).

Tidal range within the lagoon is sizeable, 1.4m (NOAA tables, 1983). During changes in tides the tidal rip is very strong and over the years has caused many relocations of drainage channels. It also would seem probable that this affects the distribution of Zostera.

Keller and Harris (1966) found an increasing biomass of Zostera with increased intertidal depth to a maximum between +0.3 to -0.5m. This is similar to what Backman and Barilotti (1976) discovered in Zostera beds for a southern lagoon. At San Ignacio Lagoon leaf length and leaf width and standing crop increased as a function of depth to -0.7m. Below this level no measurements were taken. From the information gathered on Zostera distribution it can be seen that the majority of the Zostera beds extended below -0.7m. Optimal growth for Zostera is lower in the intertidal in San Ignacio Lagoon than in more northerly Zostera communities.

As a result of this investigation at San Ignacio Lagoon the following conclusions can be drawn about Zostera growth in relation to depth.

1) Leaf length ($P < 0.1$), leaf width ($P < 0.001$) and standing crop ($P < 0.1$) increase with increased depth;
2) Density decreases with an increased depth ($P < 0.05$);
3) A linear relationship exists between standing crop and leaf length (Fig. 6). As leaf length increases so does the total standing crop. The correlation for the relationship is 0.94.

Many investigators (Harrison and Mann, 1975) agree with Setchell (1929) that temperature is fundamentally important in controlling the seasonal growth cycle of Zostera. Setchell stated that vegetative growth occured between 10-15° C and stopped below 10° C or above 20° C. However in 1971, Beibl and Mann showed experimental evidence that the photosynthetic ratio of Zostera from Alaska in-

increases with temperature up to 30-35° C. From figure 8 and table 4 it is evident that vegatative growth continues above 20° C: it is primarily controlled by insolation and not by temperature, as also shown by Sand-Jensen (1975). At San Ignacio Lagoon the relative changes in PI showed a reverse correlation of insolation. Thus it is very probable that insolation controls vegetative growth in relation with depth. This is also reported by Bachman and Barilotti (1976), Nienhius and deBree (1977) and Jacobs (1979).

Estimates of Zostera production are usually based on short term changes in biomass data. Only a few people have used radioactive carbon to determine production rates (McRoy, 1974). Sand-Jensen (1975; Denmark) and Jacobs (1979; France) estimated production of Zostera using a modified Zeiman technique. A comparison of the techniques is difficult because the plastochrone interval technique can be applied *in situ* during longer periods while the inorganic $^{14}C$ uptake techniques require short incubation times under controlled conditions.

During the four month study in San Ignacio Lagoon Zostera production decreased. The mean net production rate was 4.3 g dry wt./$m^2$/day or 1.08 g C/$m^2$/day. The overall net production of Zostera above 2.0m depth was 12,500 kg dry wt./$m^2$/111days. The maximum standing crop of Zostera was 4,190 kg dry wt./$m^2$/111 days or 1/3 of the total net production. Because the optimal growth of Zostera occurs lower in the intertidal than the areas sampled, these production rates underestimate overall Zostera production in San Ignacio Lagoon.

At San Ignacio Lagoon the plastochrone interval (PI) and turnover rate are higher than more northerly communities. In this study the PI was 7.3 days. This leaf production is higher than that obtained at Humboldt Bay. There the peak summer PI was 9 days (Bixler, 1982). Jensen (1975) found an average summer PI of 14 days for Zostera in Denmark. At this lagoon a given leaf remained attached 28 to 36 days on average. This was twice as long as found by Bixler (1982) and Jensen (1975) in their studies.

## Brant Dynamics

Few studies have considered seasonal or individual variations in organic composition of seagrasses or the importance of various parts of the plants as a food source (Dawes, 1981). Einarsen (1965) analyzed Zostera from sites in Alaska, Washington, and Oregon and found protein content ranges from 7-15% dry wt.. Burholder and Doheny (1968) found 6-11% dry wt. for Zostera from Long Island Sound. At San Ignacio Lagoon the protein content of Zostera ranges from 7 to 10% dry wt. which is very similar to the range of protein found further north. There was a change in protein content of *Zostera* with intertidal height (Table 5). This suggests that the variability of protein content may be a result of differences in intertidal height or a difference in experimental technique tha in latitudinal variation. This is also reported by McRoy (1978).

According to the literature, brant are some of the most specialized of waterfowl in regards to their feeding habits (Cottam *et al* (1944). When the "wasting disease" caused a disappearance of *Zostera marina* in the North Atlantic Coastal areas (Ogilive and Mathews, 1969; Charman, 1977), the Dark-bellied Brant population declined in Europe to 25% of its pre-1930's level.

Recent evidence suggests that the brant consume *Ulva spp*. (Einarsen, 1965), and *Enteramorpha spp*. (Charman, 1978) along with *Zostera* a their primary foods. When the primary foods are not available the birds will feed upon other plants i.e. *Phyllospadix spp*. (Cottam *et al*, 1944) and marsh plants (Ranwell and Downing, 1959; Charman, 1978).

When brant are feeding on *Zostera* they are known to feed on all parts of the plant. However in this study only leaf blades were observed being consumed. At Coos Bay, Oregon in the spring of 1983 Brant were observed feeding on only the meristematic region of the shoot (Hodder, personal communication). It appears that the Brant are selective in feeding upon particular species of plants as well as upon particular parts of the plants.

At San Ignacio Lagoon during Dec. to April the Brant were observed grazing on Ruppia beds 67% of their time as compared to only 27% of the time on the Zostera beds. Cottam et al (1944) discovered that before the "wasting disease" of Zostera in the North Atlantic, the Eastern American Brant fed on Zostera 85% of their time. In North Carolina, the end of the range of Zostera along the Atlantic coast of North America, Ruppia became prominent in the diet of the birds, averaging 12% of their food during migration and wintering periods. When considering the results of protein analysis in San Ignacio Lagoon, Ruppia is as good or better a source of protein to the Brant than Zostera is.

When evaluating any source of food, accessibility to the animals is an important aspect of foraging efficiency. Throughout San Ignacio Lagoon Ruppia was found higher intertidally than Zostera. In fact in the northern portion of the lagoon Ruppia was more abundant and even dominated the intertidal area, thus making it more accessible to the Brant. Large "rafts" of Zostera were seen floating in the water and during high tide when the seagrasses were submerged, they provide a food source. These "rafts" consisted mainly of older and dead leaves. Harrison and Mann (1975) stated that there was a nutritive loss in older or dead Zostera; the leaves were found to contain less protein than normal in situ leaves.

Another important aspect of food value is its carbohydrate levels. Direct analysis of carbohydrate content of Zostera or Ruppis from San Ignacio Lagoon was not taken. Drew (1980) found carbohydrate levels, i.e. sucrose levels, of Zostera leaves and rhizomes varied with geographic location. Plants from 40° - 50°N latitude averaged 10% extracted dry wt. of sucrose whereas plants from 20° - 30° N latitude contained only 1-2% extracted dry wt. of sucrose. Thus these results indicate that carbohydrate levels in Zostera will be low in San Ignacio Lagoon.

There also exists the possibility that the Brant are feeding on epiphytic animals or plants associated with the grasses. In San Ignacio Lagoon neither Zostera nor Ruppia contained significant quantities of epiphytic algae or encrusting organisms. However, there were invertebrates living in the seagrasses, particularily in the Zostera beds. Cottam et al (1944) reported that more invertebrates occurid in stomach analyses of the Eastern American Brant in times of Zostera scarcity, and to a lesser degree when the birds began to migrate to nesting areas.

Only a small portion of the Zostera is consumed by the Brant. In the 28 day study period (Table 6) Brant consumed only 26% of the production and 31% of the maximum standing crop. The *Zostera* production is only leaf production and doesn't take into account underground growth which can be significant (Jacobs, 1979). Because optimal growth of *Zostera* occurs lower in the intertidal than the sites for *Zostera* production at San Ignacio Lagoon, the production values are also considered low. It is apparent in San Ignacio Laggon the Brant are not consuming significant quantities of *Zostera* to make an impact on the community.

It is evident at San Ignacio Lagoon *Ruppia* is a primary food source for the Brant. The reasons behind Brant selection of *Ruppia* are not completely understood but it is suggested that nutritive value and accessibility of *Ruppia* are major factors. Further more detailed studies of Brant food selection are necessary.

# APPENDIX

## Tables and Figures

| | DRY WT. (grams) | ASH WT. (grams) | ASH-FREE WT. (grams) |
|---|---|---|---|
| | 15.0 | 7.4 | 7.6 |
| | 18.5 | 8.9 | 9.6 |
| | 10.1 | 4.2 | 5.9 |
| | 15.3 | 7.6 | 7.7 |
| | 9.4 | 4.1 | 5.3 |
| | 9.6 | 4.6 | 5.0 |
| | 13.6 | 6.3 | 7.3 |
| | 7.6 | 3.0 | 4.6 |
| | 21.8 | 10.2 | 11.6 |
| | 6.2 | 2.9 | 3.3 |
| Percent | - | 46.6 | 53.4 |
| $\bar{X}$ | 12.7 | 5.9 | 7.0 |
| s | 4.9 | 2.3 | 2.6 |
| Range | 21.8-<br>4.9 | 10.2-<br>2.9 | 11.6-<br>3.3 |

Table 1A. Ash content of 10 0.1m$^2$ dry weight samples. Five samples taken from site 2 and five samples from site 3. Combustion was done at 550$^\circ$ C for 4 hours. Mean, $\bar{x}$, standard deviation,s, and range are also given.

| NO. OF SHOOTS COLLECTED | HOLE PUNCHED (grams) | NEEDLE (grams) |
|---|---|---|
| 1 | 59.2 | 54.2 |
| 2 | 59.9 | 48.8 |
| 3 | 48.5 | 50.9 |
| 4 | 36.0 | 65.2 |
| 5 | 48.5 | 50.4 |
| 6 | 59.5 | 58.4 |
| 7 | 58.0 | 49.2 |
| 8 | 55.2 | 53.7 |
| 9 | - | 57.7 |
| 10 | - | 62.3 |
| Total | 424.6 | 550.9 |
| $\overline{X}$ | 53.1 | 55.1 |
| s | 7.9 | 5.6 |

Table 2A. A comparison of holes in Zostera shoots as a measure of production with a 2mm punch and a sewing needle on 14 Jan. 1983. Mean, $\bar{x}$, and standard deviation are also given.

| | DRY WT. (g/10cm) | ASH WT. (g/10cm) | ASH-FREE WT. (g/10cm) |
|---|---|---|---|
| | .021 | .006 | .015 |
| | .020 | .006 | .014 |
| | .040 | .017 | .023 |
| | .020 | .004 | .016 |
| | .029 | .009 | .020 |
| | .024 | .007 | .017 |
| | .020 | .004 | .016 |
| | .015 | .004 | .011 |
| | .029 | .007 | .022 |
| | .026 | .008 | .018 |
| | .014 | .004 | .010 |
| | .017 | .004 | .013 |
| | .018 | .004 | .014 |
| | .027 | .008 | .019 |
| | .025 | .008 | .017 |
| | .021 | .007 | .014 |
| | .022 | .007 | .015 |
| | .015 | .004 | .014 |
| | .025 | .010 | .015 |
| | .020 | .006 | .014 |
| $\bar{X}$ | .023 | .007 | .016 |
| s | .006 | .003 | .004 |
| Range | .014- | .004- | .010- |
| | .040 | .017 | .023 |

Table 3A. Ash content of 20, 10cm segments of *Zostera* leaves: as used as a conversion factor for length to weight. Mean, $\bar{x}$, standard deviation, s, and range also given.

| SITE | | | | SHOOTS | (optical density) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (date) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | $\bar{X}$ | s |
| #2<br>12-3 | .115 | .112 | .098 | .114 | .120 | .105 | .108 | .108 | .110 | .006 |
| #2<br>12-28 | .098 | .123 | .113 | .105 | .078 | .095 | .110 | .100 | .103 | .013 |
| #2<br>2-1 | .125 | .122 | .096 | .112 | .109 | .097 | .109 | .110 | .110 | .010 |
| #2<br>2-23 | .103 | .115 | .110 | .118 | .114 | .111 | .112 | .114 | .112 | .004 |
| #2<br>3-25 | .108 | .107 | .101 | .114 | .113 | .120 | .099 | .106 | .109 | .007 |
| #3<br>12-3 | .115 | .112 | .095 | .102 | .100 | .112 | .118 | .094 | .106 | .009 |
| #3<br>12-28 | .096 | .100 | .102 | .108 | .092 | .111 | .111 | .110 | .104 | .008 |
| #3<br>2-1 | .081 | .085 | .105 | .093 | .126 | .091 | .080 | .095 | .103 | .015 |
| #3<br>2-23 | .112 | .111 | .118 | .114 | .090 | .117 | .114 | .110 | .111 | .009 |
| #3<br>3-23 | .123 | .115 | .109 | .105 | .111 | .115 | .109 | .109 | .112 | .006 |
| #1<br>12-29 | .096 | .098 | .110 | .104 | .109 | .093 | .097 | .101 | .101 | .006 |
| #1<br>2-1 | .086 | .104 | .106 | .092 | .098 | .110 | .101 | .102 | .100 | .007 |
| #1<br>2-23 | .070 | .072 | .152 | .090 | .089 | .113 | .085 | .088 | .095 | .027 |
| #1<br>3-23 | .086 | .105 | .089 | .090 | .100 | .094 | .085 | .089 | .092 | .007 |
| Ruppia | .124 | .128 | .105 | .134 | .095 | .112 | .110 | .120 | .116 | .012 |
| Ruppia | .104 | .101 | .111 | .115 | .119 | .120 | .104 | .106 | .110 | .007 |

Table 4A. Concentrations of protein as expressed in optical density of *Zostera* leaves at site1,0.5m, site 2, -0.5m, and site3,-0.7m, and *Ruppia* leaves at one site, 0.5m (M11W). Mean,$\bar{X}$, and standard deviation also given.

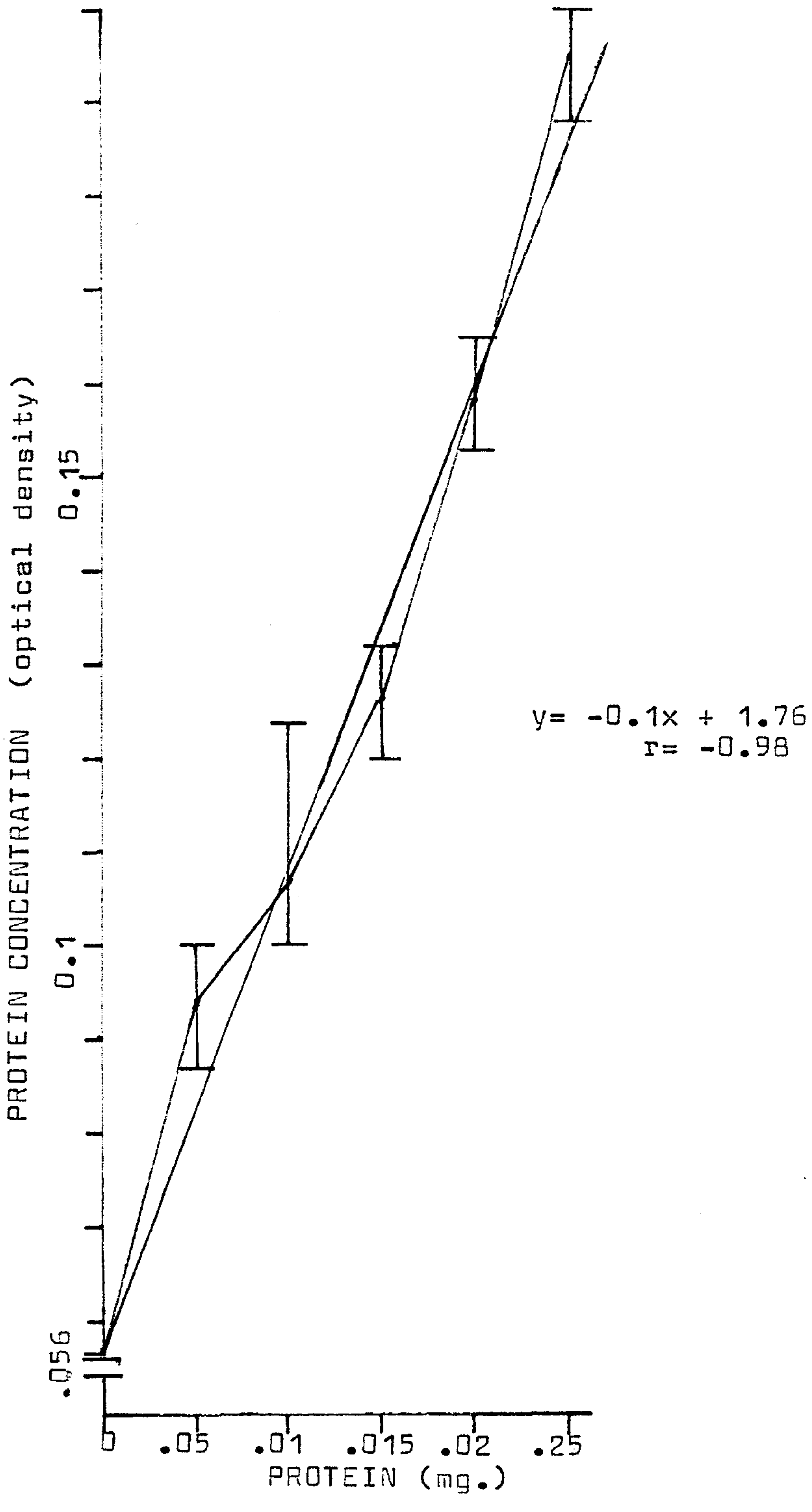


Figure 1A. Linear regression for a protein standard curve. The curve represents known quantities of bovine serum albumin (96-97% reagent grade).

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