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AN INVENTORY OF BIVALVES AND THEIR FOOD SUPPLY IN THE INDIAN RIVER, BREVARD COUNTY, FLORIDA

Final Report Submitted to the
Brevard County Water Resources Department
and the
Brevard County Board of County Commissioners

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EXECUTIVE SUMMARY

1. An extensive literature review covering the years between 1973-81 revealed a lower population of hard clams (*Mercenaria mercenaria*) and higher bivalve diversity than what was found in this investigation.

2. Ninety-eight percent of the bivalves collected, sorted, identified, and measured from 110 stations along 12 transects in the Indian River lagoon between April and July 1985 were *Mulinia lateralis* (coot clam). The next most abundant bivalve was *Mercenaria mercenaria*, comprising one percent of the total number. However, because of its small size (<0.5 in., shell length), the coot clam contributed only 36 percent of the weight to the bivalve community; the hard clam's contribution was 64 percent. Overall, only nine species of bivalves were collected.

3. Recruitment of juvenile hard clams in the Grant area was 31 individuals/m^2. Low recruitment at Melbourne and Merritt Island locations (1.0-3.4 individuals/m^2) suggests that those areas will not provide large numbers of harvestable clams.

4. The population of harvestable clams (>1.75 in. in length) at Grant (5.5 individuals/m^2) is considerably lower than the juveniles, probably because of commercial harvesting; slightly lower numbers of legal sized harvestable clams were found at Melbourne (4 individuals/m^2). The waters of Merritt Island contained only 1.9 legal sized clams per m^2.

5. The number of individual coot clams (*Mulinia lateralis*) were large for the Melbourne and Merritt Island areas (2,484 and 3,165 individuals per m^2) where comparably sized "seed" hard clams were low.

6. Dry weight meat biomass, obtained from shell length-dry meat weight regression relationships of subsamples of coot and hard clams, was significantly different among the three collection areas for either coot or hard clams. However, when the biomass of all species were summed at each sampling site, there were no significant differences between the sampling sites in total bivalve biomass, which ranged from 8.8 to 13.7 g dry meat wt. per m^2.

7. Chlorophyll *a* concentrations and primary productivity rates indicated food production in the estuary was less than the amounts necessary to sustain the bivalve community based on maximum filtration rates, indicating food may be a limiting resource.

8. Based on a bi-monthly sampling schedule from October 1984 through October 1985, phytoplankton standing stock was approximately 30% lower at Grant than at Melbourne. Likewise, primary productivity (monthly measurements) was 40% lower at Grant than at Melbourne. For both chlorophyll *a* and primary productivity average values, the differences between Grant and Melbourne were statistically significant. Annual chlorophyll *a* averages from 1980-1984 collected by Brevard

County were not significantly different between stations at Grant and Melbourne (except 1982); nor was the average for 1984 statistically higher than the 1980 average at either site. This indicates chlorophyll a concentrations in the river did not increase during this period. Both chlorophyll a concentration and primary productivity in the Indian River estuary are extremely high when compared to other estuarine systems.

ACKNOWLEDGMENTS

We would like to thank Conrad White and Bob Day of the Brevard County Environmental Services Division for supplying benthic, chlorophyll a, and salinity data for areas of the estuary which were not sampled during this research. Paul Jensen instructed in the ^{14}C analysis. Mark Castro and Larry Pollack assisted in the field work; Simone Triantafyllidis helped in sorting shellfish. R. Tucker Abbot contributed his expert taxonomic skills to some of the more problematic bivalves. Stimulating conversations with Mark Berrigan of the Florida Department of Natural Resources on shellfish biology and ecology provided the impetus for the design of the bivalve field census. The administrative skills of Steve Kintner of the Brevard County Water Resources Department allowed the co-principal investigators to focus more on the research effort. John Schneider, Chief of the Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources, provided an invaluable service by excluding the sites at Melbourne and Merritt Island from relaying for the duration of the study. Finally, Betty Fink contributed to the typing and word processing of this final report.

Preparation of this Final Report was primarily supported by a grant from the U.S. Office of Ocean and Coastal Resource Management, National Oceanographic and Atmospheric Administration, and Florida Department of Environmental Regulation, Office of Coastal Zone Management, through the Coastal Zone Management Act of 1972 as amended.

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INTRODUCTION

The Indian River is a barrier island lagoon which extends 150 miles along the east coast of Florida. This lagoon supports dense populations of shellfish: hard clam (*Mercenaria mercenaria*) landings from the Brevard County section of the estuary were reported by the National Marine Fisheries Service to be over 90% of the total harvest for the state in 1984, which was 1.7 million pounds of clam meats valued at $6.1 million (dockside value of $3.59 per pound of meat). Since Florida harvests 13% of the nation's total, clamming is clearly an economically important industry to Brevard County. Several other species of bivalves, although not utilized commercially, reportedly occur in even greater numbers.

In 1978, clam mortality rates increased because of unknown reasons, resulting in poor commercial harvests until the summer of 1982, when an explosion in the hard clam population occurred. With the decline in the oyster and blue crab industries, along with the steady growth in the numbers of commercial shellfishermen, competition for the remaining commercially important shellfish, the hard clam, has occurred. In a Brevard County Clam Industry Workshop held on September 7, 1985 and sponsored by the Brevard County Sea Grant Extension Program, concern of the attendees focused on the problems affecting the future of the clamming industry. These problems include a lack of information concerning the biology and ecology of clams, the effects of pollution and increased fishing pressure on the resource, and enforcement of current laws relating to harvesting and certification of shellfish dealers. Partial results of this research dealing with the clam population were presented at that workshop. In 1984 the Marine Fisheries

Commission, which is composed of Governor-appointed representatives from commercial and sport fisheries, the scientific community, and conservation groups, and whose task is to formulate policy on marine resources, set 7/8" across the hinge as the minimum size limitation on harvested clams.

With the accelerating interest in the management of the clam fishery in the Indian River, a scientific basis for formulating policy is needed. The answers to fundamental questions, such as what types and numbers of shellfish presently occupy the river bottom, are unknown or exist in a diverse array of fragmented and unpublished literature. Another, more germane (from the standpoint of formulating a sound management program) question is: does competition for food by non-commercial shellfish influence the production of commercial shellfish?

The primary purpose of this research was to provide data that will lead to a better understanding of the biology and ecology of the hard clam in the Indian River. This information is essential in the formulation of a management plan for the shellfish industry in Brevard County, and could be used by responsible policy-formulating parties such as the Marine Fisheries Commission. The end product of the project is an inventory according to numbers, sizes and densities of the dominant commercial and non-commercial bivalve shellfish in the Indian River in southern and central Brevard County. In addition, a thorough search of relevant unpublished reports, theses, or population censuses was completed. Because the food source of shellfish is of paramount importance in determining the capacity of the estuary to support the maximum number of hard clams, phytoplankton standing crop and primary productivity was routinely assayed at bi-weekly and monthly intervals, respectively.

METHOLOGY

Shellfish Populations

Sixteen benthic transects across the lagoon were established in the sites adjacent to Grant, Melbourne and Merritt Island (Fig. 1). The Grant site represented a conditionally approved area with a history of heavy clam harvesting; the Melbourne location was in closed (restricted) waters and had some relaying associated with it; the third section in closed waters with little harvesting activity was located between Channel Markers 99 and 100 south of the Pineda Causeway. Initially, only the Grant and Melbourne sites were to be sampled, with the Melbourne site serving as a control (unharvested) area for comparison with shellfish populations from heavily harvested Grant area. However, relaying activity by commercial fishermen from the closed waters at the Melbourne site became prevalent beginning in December, 1984, violating our conditions of a non-harvested site. After petitioning the Department of Natural Resources, Bureau of Marine Resource Regulation and Development, for two exclusion zones (one at the Melbourne site and the other near the Pineda Causeway), the Department excluded the two areas from all future relay permits beginning February 20, 1985.

Four transects were sampled at stations of 200 m intervals at each site, producing 8 to 11 sampling stations along each transect. Transects were sampled on a fixed rotating basis: Transect A was sampled first at all sites beginning with the Grant site and ending with the Merritt Island site, then Transect B, etc. Shellfish sampling commenced on April and ended July, 1985.

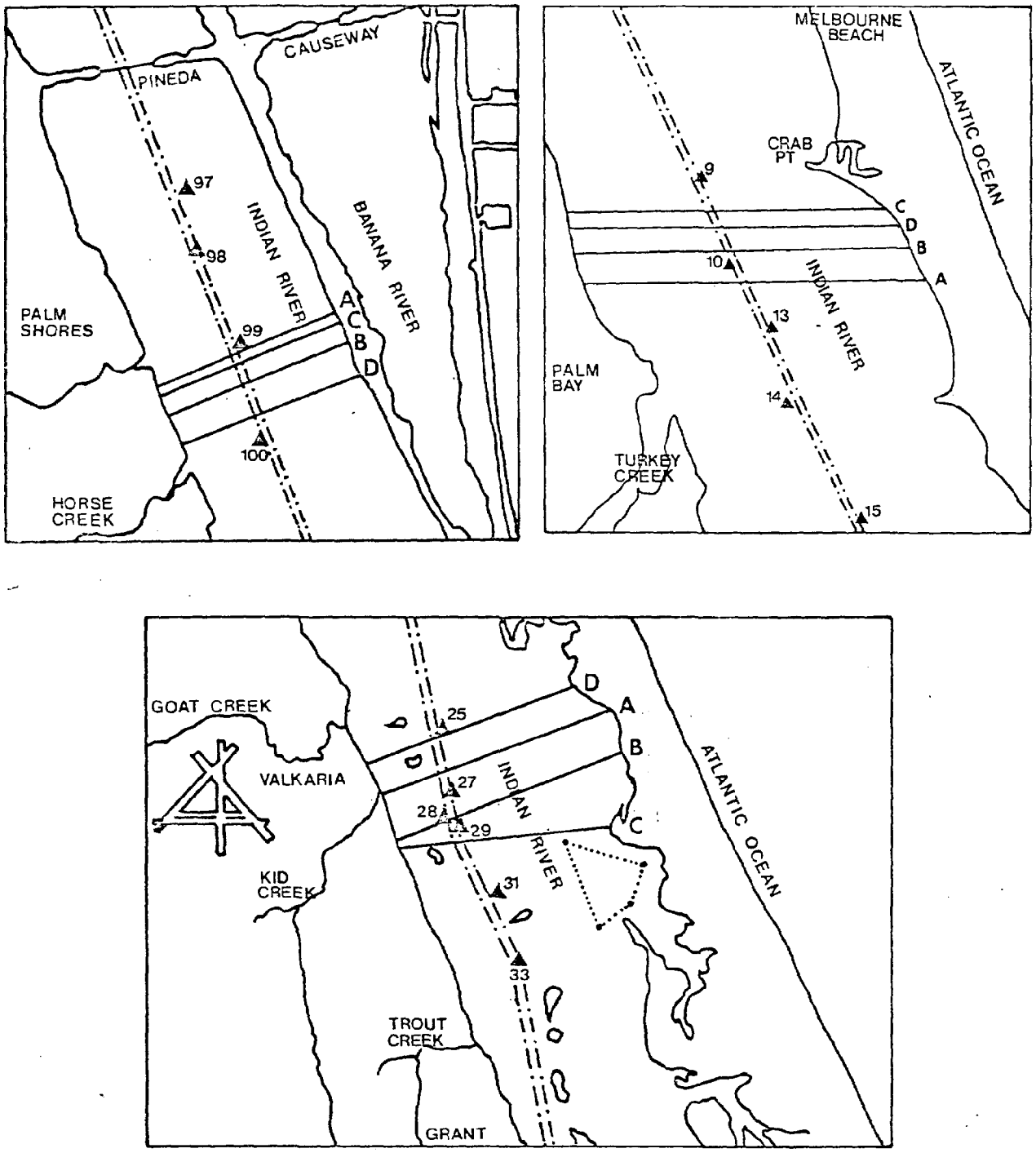

Figure 1. Location of the four bivalve sampling transects (A, B, C and D) at each of the three areas in the Indian River: Merritt Island (upper left), Melbourne (upper right), and Grant (bottom).

A 1/4 m^2 open-ended drum with a 10 cm wide fluorescent strip and a bevelled edge was pushed to a depth of 10 cm into the sediment. Bottom substrate along with shellfish were collected with an airlift (suction) dredge (Fig. 2) with the assistance of SCUBA equipped divers. The hydraulic suction dredge operates by a Briggs and Stratton 5 h.p. gasoline engine attached to a pump which generated a water flow through the intake. The outflow passes through a long hose leading to a suction control valve which regulates the force of water transmitted to a reduction nozzle in the suction head, which according to the Venturi principle, the flow of the water is accelerated and the pressure below the nozzle falls creating suction on the suction hose. Consequently, a sample is airlifted through the hose and collected into a 2 mm mesh bag. This technique has been reported to be nearly 100% efficient and was not size selective for Mercenaria mercenaria >5 mm long (Peterson et al. 1983). All samples were stored frozen prior to analysis. Sorting of the benthos samples was done by sieving them through a 2.8 mm screen sieve (U.S. Standard No. 7) and collecting the bivalves from the shell fragments and debris. The screen size above was chosen as appropriate considering the number and size of the samples, but still allowed a realistic sieving time.

All live shellfish retained by the 2.8 mm mesh sieve were identified using Abbott (1974), Lindner (1975), and The Audubon Society (1981). They were then enumerated and measured along the longest anteroposterior axis to the nearest 0.05 mm using vernier

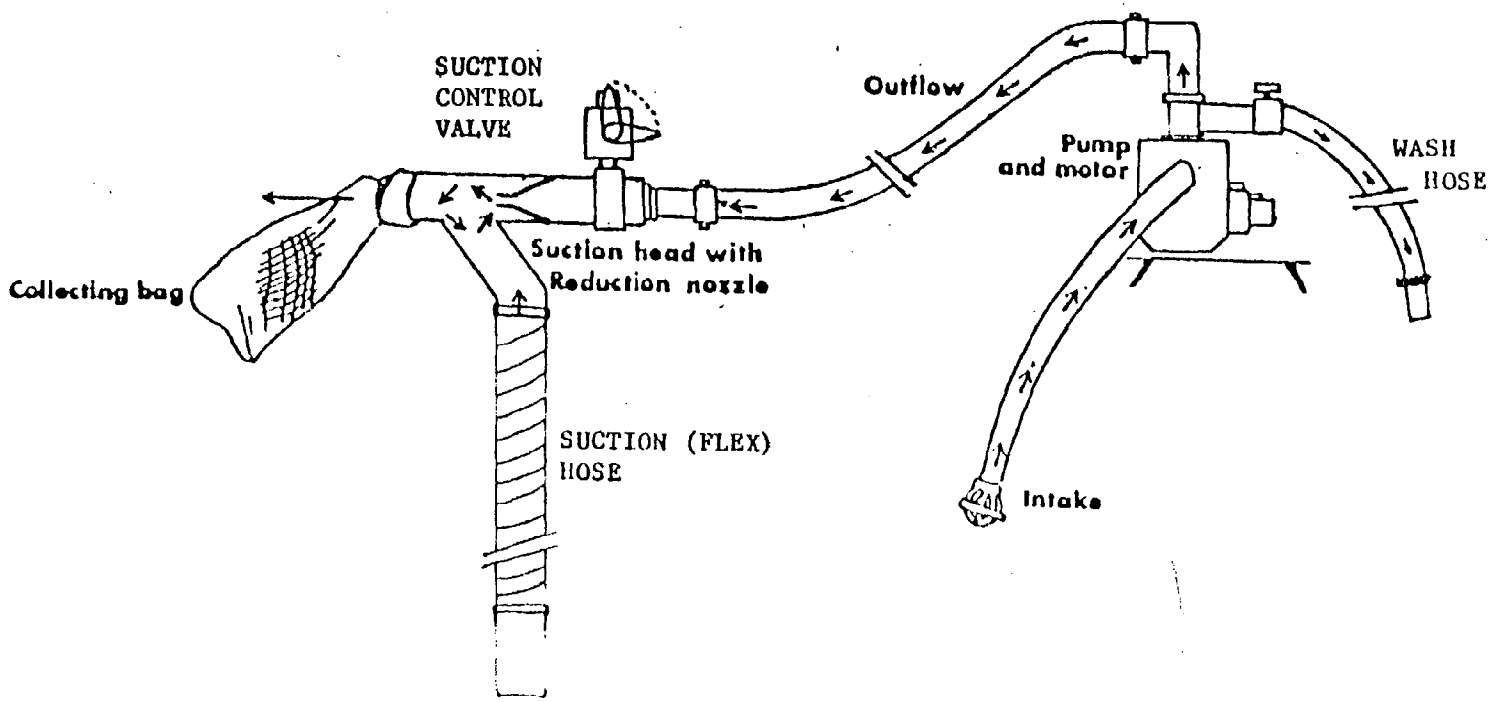

Figure 2. Airlift suction dredge.

calipers. The total wet weight of subsets of approximately five Mercenaria and 20 Mulinia clams from each 10 mm incremented size range (10 and two size classes for Mercenaria and Mulinia, respectively) were determined prior to drying the meat at 80°C to determine shell length-dry weight relationships. The total dry meat weight for each size class was determined from the total individuals and median length of each size class as predicted by the regression equations of the log transformed data from the measured subset. Non-linear regression and one-way ANOVA analyses were performed on a PRIME computer using a MINITAB program.

Chlorophyll a

Phytoplankton sampling was initiated in the Indian River lagoon along two east-west transects, one in open water, the other in waters closed to shellfishing. The "open water" transect was adjacent to Channel Marker 28, between the towns of Grant and Valkaria. The transect in closed water is approximately 1500 m south of the Melbourne Beach municipal pier at the Melbourne site. Water samples were collected semi-monthly from the eastern, center, and western sections of each transect. Two hundred and fifty ml of water were filtered through a 0.45 μm cellulose nitrate filter. Two drops of a saturated $MgCO_3$ solution was added during filtering to inhibit chlorophyll degradation. The filter plus retentate was placed in a vial containing 10 mL of 90% acetone, and held in the dark at 0°C for 12-18 hr. The vials were then centrifuged, the supernatant collected and adjusted to a volume of 10 mL, and fluorescence measured on a Turner fluorometer. Each reading was corrected for phaeophytin concentration.

Salinity and Water Temperature

Water temperature and salinity were measured at the six stations in the lagoon at the time of each chlorophyll a water sampling.

Phytoplankton Species

Unconcentrated phytoplankton from the center station at each transect was preserved with buffered formalin at a 4% final concentration. The samples, collected semi-monthly are archived so that identifications can be made if additional monies or assistance become available.

Primary Productivity

Monthly measurements of phytoplankton productivity were conducted beginning in November. Water samples from the central stations along each transect were collected from two depths (0.25 m and 0.25 m) at Grant and three depths at Melbourne (0.4 m, 1.4 m, and 2.5 m). The 2.5 m depth for Melbourne was not included until after the March sampling trip. These waters were placed in triplicate (surface waters) or duplicate (subsurface waters) light and dark glass bottles (300 ml), inoculated with 2.5 μcurie $NaH^{14}CO_3$, and incubated for 2-4 hours at their respective depths (0.25 and 1.4 m). At the end of the incubation period, the sample bottles were placed in a dark cooler on ice. A 250 ml aliquot of water from each bottle was filtered through a 0.45 m filter within one hour. The filters were transported to the laboratory, fumed over concentrated HCl to remove unincorporated $NaHCO_3$, and placed in vials containing 10 ml of Amersham scintillation cocktail. Samples were counted with a Searle

Mark III LSC at a counting efficiency >80%. Available inorganic carbon in the water at each site was estimated from total alkalinity, pH, salinity and temperature measurements (Strickland and Parsons 1972).

Phytoplankton productivity was calculated using the expression:

$$\text{mg C m}^{-3}\ \text{h}^{-1} = (R)(W)(1.05)/(R)(N) \qquad (1)$$

where R = dpm's counted (dark blank subtracted)

W = total available inorganic C per m^{-3}.

1.05 = preferential uptake factor $^{12}C:^{14}C$.

R = dpm's added as inoculum.

N = incubation time in hours.

Total solar insolation at the water's surface was estimated using an Epply pyroheliometer located at the HBF laboratory, which is 50 km south of the experimental site.

Morning and afternoon productivity incubations (ca 3-4 hr each) were conducted on each sampling date in order to provide a direct measurement of carbon fixation during the bulk of the daylight hours. The coefficient of variation for 84 separate primary productivity incubations (each incubation in either duplicate or triplicate) ranged from 0 to 64.4% with an average of 13.9%. A ratio of incident solar radiation during the incubations (I_{exp}) to total daily insolation (I_{tot}) was calculated from an intergrated record of incident solar radiation measured with an Epply pyroheliometer.

pyroheliometer. Daily productivity was obtained by multiplying the ratio I_{tot}/I_{exp} by the quantity of carbon fixed during the experimental period, assuming a linear relationship between incident solar radiation and carbon uptake by phytoplankton in the water.

Measurements of carbon fixed per unit volume of water were converted to integrated water column (areal) rates as follows. At Grant, the 1.5 m deep water column was partitioned into two equal sections, 0.75 m in depth. Carbon fixation (P_s) measured at a depth of 0.25 m was chosen to represent average productivity in the top section of the water column, while carbon fixation (P_b) measured at a depth of 1.4 m was used to represent average productivity of the bottom of the water column. Areal fixation (i.e., mg C m^{-2} hr^{-1}) was thus calculated as (P_s + P_b) (0.75 m), with P_s and P_b expressed in mg C m^{-2} hr^{-1}. At the deeper (3 m) Melbourne site, the water column was partitioned into three sections: 0-1 m, 1-2 m, and 2-3 m (for April to October). Average carbon fixation in the surface section was estimated with bottles incubated at 0.25 m (P_s); carbon fixation in the middle section was estimated with bottles incubated at 1.4 m (P_m), and carbon fixation in the bottom section was estimated with bottles incubated at 2.5 m (P_b). The integrated water column rates at Melbourne were thus calculated by the expression (P_s + P_m + P_b) (1 m).

QUALITY ASSURANCE

This section presents the results of seven separate plankton experiments designed to test extraction efficiency, spatial and temporal variability, instrument calibration, and primary productivity methodology.

Filter Pore Size and the Effects of Grinding on the Efficiency of the Chlorophyll a Analysis

Two short-term experiments were conducted to determine whether improvements on the filtration and extraction techniques for phytoplankton could be made. In the first experiment, a grinding step was added to the procedure in order to determine whether we were obtaining "complete" chlorophyll a removal from the phytoplankton. Triplicate one liter samples were collected from two stations in the river. Separate 250 ml aliquots from each bottle were filtered. One set of filters was ground for two minutes (in 90% acetone) using a hand operated glass tissue homogenizer. The companion set of filters was not ground. Both sets of filters were placed in the dark for 12 hours for further extraction. Fluorescence of the extracts was determined as described above. Grinding neither increased chlorophyll a yields, nor improved the precision of the method (Table 1). Although grinding is typically recommended for chlorophyll a analyses when short (ca. 1 hr) extraction times are utilized, it does not appear necessary with the 12-18 hr extraction period as used in this study.

Table 1. Effect of phytoplankton grinding on chlorophyll a extraction. Six aliquots were taken from each sample; three were ground following filtration.

SAMPLE	GROUND	NOT GROUND
	.....chlorophyll a, (mg m^{-3}), X (s.d.), n=3.....	
I	72.3 (8.4)	73.2 (8.0)
II	81.7 (3.6)	77.6 (4.1)

A second experiment was conducted to determine whether small phytoplankton, in the size range 0.45 to 0.1 um, contribute substantially to total chlorophyll a concentrations in the lagoon, and are not part of the retentate trapped on the 0.45 um filter routinely used in this study. Four 250 ml aliquots of river water were filtered first through a 0.45 um filter, and then through a 0.1 um cellulose nitrate filter. Chlorophyll a was extracted from filters using 90% acetone, and fluorescence was measured as described above. Phytoplankton larger than 0.45 um were found to comprise the bulk of the microalgal standing crop in the water column at both sites in the Indian River lagoon (Table 2). Phytoplankton in the size class of 0.45 um were responsible for only 0.3 - 0.5% of the total chlorophyll a concentration in these waters.

Table 2. Standing crop (chlorophyll a concentrations) of Indian River lagoon phytoplankton of two size classes: greater than 0.45 um and 0.45 to 0.1 um.

SAMPLE	> 0.45 um	0.45 -0.1 um
	.....chlorophyll a (mg m^{-3}).....	
Ia	19.5	0.06
b	30.3	0.08
IIa	7.2	0.04
b	6.4	0.03

Surface vs. Deep Water Chlorophyll a Concentrations

On eight occasions between November 1984 and March 1985, shallow (0.1 m) and deep (1.4 m) water samples were collected from the central station of either the Palm Bay or Grant transects. Chlorophyll a concentrations were determined by fluorometry, and differences in shallow water and deep water pigment concentrations were evaluated using a t-test of paired comparisons.

No difference ($P = 0.20$) was found between chlorophyll a concentrations of shallow (0.1 m) and deep (1.4 m) waters at individual sampling sites during this study (Table 3). Because similar pigment concentrations were found with depth under a range of wind conditions, and at both high and low pigment concentrations, we conclude that the Indian River lagoon at these sites is vertically well mixed during the fall and winter months.

Table 3. Chlorophyll a concentrations of shallow (0.1 m) and deep (1.4 m) waters at individual sampling sites in the Indian River lagoon. Samples were collected between 14 November 1984 and 12 March 1985 at both Grant and Melbourne sites.

DEPTH	
0.1 m	1.4 m
.....chlorophyll a (mg m^{-3}).....	
17.3	18.7
7.8	6.6
67.9	66.6
25.4	28.1
15.6	15.0
19.7	10.7
15.5	15.1
18.8	10.7

Sediment Pigment Concentration and Sediment Density

Sediments at Grant and Melbourne were compared with respect to pigment concentrations and densities. On 28 February 1985, seven sediment cores (3.8 cm diamter X 20 cm deep) were collected from the central station of each transect, placed on ice, and transported to the laboratory. Each core was extruded and the top 1 cm removed with a knife. For three of the cores from each site, this fraction was dried (48 h at 70° C) and weighed for the determination of sediment bulk density. Each of the remaining four core fractions was ground for one minute in a mortar containing 10

ml of 90% acetone and two drops saturated $MgCO_3$ solution. The sediment-acetone slurries were poured into wide mouth plastic tubes, which were then held in the dark at 0° C for 18 hours. The fluorescence of a 5.0 ml aliquot from each tube was measured on a Turner fluorometer. Chlorophyll a and pheophytin concentrations were calculated according to Strickland and Parsons (1972).

Grant and Melboune lagoon bottom sediments differed markedly in physical and chemical characteristics. Melbourne sediments were unconsolidated and silty (0.7 ± 0.5 g cm^{-3} bulk density), whereas the sediment at Grant consisted primarily of sand particles (1.8 ± 0.2 g cm^{-3}). Chlorophyll a and pigment degradation product (pheopigment) concentrations in the sediment were seven times higher at Grant than at Melbourne (Table 4). The sediment at the shallower Grant site is well within the euphotic zone (bottom light intensity is ca. 10% of surface light intensity), so it is possible that benthic microalgae account for a portion of the high sediment pigment levels at this site. Benthic diatoms, for example, commonly occur in sandy sediments in temperate estuaries (Tietjen, 1968). However, the live chlorophyll a to total pigment ratio in the Grant sediments was quite low, and did not differ from that at the Melbourne site (Table 4).

Unlike the sediments, the bulk of the photosynthetic pigments in the water column consisted of "live" chlorophyll a (Table 4). The higher water column chlorophyll levels at Melbourne, expressed both in concentration (wt/vol) units and as per unit area of river

Table 4. Photosynthetic pigment concentrations in the sediment (wt/wt) and water (wt/vol) at two locations in the Indian River lagoon on 28 February 1985.

	SEDIMENT[1]		WATER[2]	
	Grant	Melbourne	Grant	Melbourne
	...pigment (ug/g)...		...pigment (ug/l)...	
Chlorophyll a	0.27 (0.07)	0.04 (0.03)	5.2 (1.3)	20.7 (3.6)
Pheophytin	2.63 (0.81)	0.34 (0.10)	2.0 (0.5)	6.5 (1.8)
Total Pigment	2.90 (0.85)	0.38 (0.12)	7.2 (1.8)	27.1 (5.4)
	----------%----------		---------%----------	
Chl a/Total Pigment	9.4 (2.4)	8.4 (5.6)	72.8 (0.2)	76.3 (1.8)
	---pigment (mg/m^2)---		---pigment (mg/m^2)---	
Chlorophyll a	4.9	0.3	7.3	62.1
Total Pigment	52.2	2.6	10.1	81.3

[1] x, (s.d.), n = 4

[2] x, (s.d.), n = 2

surface (wt/area)(Table 4), suggests that phytoplankton (and hence, pigment) deposition at this site is greater than at Grant. The resulting lower sediment pigment levels at Melbourne indicates that the deposited material decomposes at this location more rapidly.

The Effect of Incubation Time on ^{14}C Uptake Rates

Phytoplankton productivity estimates by the ^{14}C technique are typically conducted with waters incubated in small glass or polycarbonate bottles for a period of time ranging from 1 to 24 hours. Long incubation times (e.g., sunrise to sunset) have the advantage of permitting direct measurement of daily phytoplankton production (Williams et al. 1983). However, many investigators have observed that the enclosure of algae in small static volumes for long time periods does not provide a true measure of in situ C fixation, since interference from pH drift, carbon depletion, bacterial proliferation on the bottle walls, and even changes in algal species composition can occur.

On 20 December 1984, a study was conducted to determine whether the 4 hour ^{14}C incubations, as utilized in this study, were subject to "bottle effects". Carbon fixation rates of phytoplankton in lagoon waters over a 4 hr period were measured using a 4 hr incubation period and two lesser timed incubation periods, which when added, each totaled 4 hrs of incubation. One set of three 300 ml glass bottles was filled with Indian River water, inoculated with 2.5 µcurie $NaH^{14}CO_3$, and placed at a depth of 0.25 m in a concrete tank containing 700 L of lagoon water. These bottles were incubated from 1100 to 1500 h. The same 4 hr incubation was accomplished with lagoon water contained in another two sets of bottles (3 per set) incubated 2 hr each, from 1100-1300 h and 1300-1500 h. An additional four sets of bottles (3 per set) were

incubated over the same 4 hr period, at one set per hour. The contents of all bottles were filtered immediately upon removal from the water. Light bottle carbon fixation rates, alkalinity and chlorophyll a of the river water was measured by methods previously described. Corrections for dark bottle carbon uptake were not made, but were assumed from prior experience to be slight (ca. 5% of total C fixed). Differences in total quantity of carbon fixed over the 4 hr period using the three incubation times were tested for statistical significance using a one-way ANOVA.

Carbon fixation over a 4 hour period was found to be slightly higher with one, 4 hour and two, 2 hour incubation times than with four, 1 hr incubations (Table 5). These differences, however, were not significant ($P = 0.15$). Hence, the 3 - 4 hour long morning and afternoon ^{14}C incubations in the present study are probably not subject to deleterious "bottle effects".

Table 5. Phytoplankton production over a 4 hour period in 300 ml glass bottles as measured using one hour (1 + 1 + 1 + 1), two hour (2 + 2) and four hour (4) incubation times.

Incubation time (hr.)	Incubations/4 hr.	Carbon fixed/4 hr period[1] ---------mg C/m^3 ---------
1	4	23.7 (1.2)
2	2	25.1 (0.6)
4	1	25.2 (0.7)

[1] x, (s.d.) n = 3

Comparison of ^{14}C Uptake and O_2 Evolution Techniques in Measuring Primary Productivity

An experiment was conducted to compare phytoplankton productivity measured by the ^{14}C technique with net and gross productivity as measured by the O_2 evolution technique. Coincident with the morning ^{14}C incubations on 8 January and 30 July 1985, oxygen changes in duplicate bottles containing Grant and Melbourne waters were measured using the Winkler method (APHA, 1971). Net primary production (as mg O_2 m^{-3} hr^{-1}) was calculated from the change in oxygen concentration in the light bottles during the incubation period. Respiratory oxygen consumption (measured in dark bottles) was added to light bottle oxygen changes to provide a measure of gross primary production. Oxygen evolution rates were converted to carbon uptake rates by multiplying by the factor 0.3 ug C fixed/1.0 ug O_2 evolved (Ryther 1956), which accounts for the difference in atomic (molecular) weights of C and O_2, and assumes a photosynthetic quotient of 1.25.

The comparison between productivity measured by the O_2 evolution and ^{14}C uptake techniques in this study showed that the latter method more closely approximates "net" than "gross" productivity (Table 6), a finding in agreement with most previous studies (Ryther 1956).

Table 6. A comparison of primary productivity by Indian River phytoplankton as measured by the ^{14}C uptake and the O_2 evolution techniques.

DATE	LOCATION	^{14}C METHOD	O_2 METHOD	
			Net	Gross
		-----Productivity (mg C m^{-3} hr^{-1})----		
01/08/85	Grant	79.6 ± 9.2	105 ± 10	111 ± 3
	Melbourne	67.6 ± 14	60	81
07/30/85	Grant	181 ± 14	195 ± 22	234 ± 29
	Melbourne	230 ± 19	103 ± 11	114 ± 13

The O_2 evolution technique should not be use in either ultra-oligotrophic waters, because of the method's low sensitivity [3 mg C m^{-3} hr^{-1}] (Riley and Chester 1971), or in grossly eutrophic waters, because of interference from high bacterial respiration. With the exception of Melbourne on 30 July 1985, Indian River phytoplankton productivity appears to be in a range which can be accurately measured by the simpler and less expensive O_2 evolution technique.

EPA Quality Control Samples
For Fluorometric Analyses of Chlorophyll a

Reference samples for chlorophyll a obtained from EPA were used for instrument calibration and verification of the calibration. The "check solution" containing 16.7 ug/L of chlorophyll a and -0.1 ug/L pheophytin a measured 17.1 ug chlorophyll a and 0.5 ug pheophytin a per L, well within the confidence limits stated by EPA; agreement was within 98% for the chlorophyll a solution.

Bivalve Taxa

Bivalves whose appropriate taxonomic position was uncertain were identified with the help of R. Tucker Abbott, a noted malacologist.

RESULTS AND DISCUSSION

Salinity and Temperature

Salinities at Grant were greater than at Melbourne (Table 7) because of the closer proximity of Grant to an ocean inlet and the more numerous freshwater inputs in the Melbourne area. At Grant, salinities ranged from 15°/oo (immediately after the Thanksgiving Day storm) to 36°/oo with a mean of 25.8°/oo (s.d. ± 6.2°/oo); the range was 13°/oo to 28°/oo at Melbourne and a mean of 22.3% (s.d. ± 4.3). Unlike salinity, water temperature did not differ between the two sampling areas (Table 8). The minimum water temperature was 11°C on 11 January 1985; the highest was 32.5°C on 30 July 1985.

Chlorophyll a

The annual average chlorophyll a concentration (± 1 s.d.) was roughly 30% lower at the Grant site (21.1 ± 21.7 mg m^{-3}) than at Melbourne (29.4 ± 20.0 mg m^{-3}); the difference was significant ($p<0.05$). Chlorophyll a concentrations of the water at the Melbourne site ranged from 6.7 to 108 mg m^{-3}, whereas chlorophyll a concentrations at the Grant site exhibited a slightly narrower range (4.3 to 99 mg m^{-3}) (Table 9). Wide variation among the east and west edge and one center sampling station within each site occurred on some sampling occasions (Table 9). However, over the entire study year, there were no statistically significant differences among sampling sites within each transect.

The Environmental Resources Division of Brevard County has collected monthly chlorophyll a data at numerous stations in the Indian River lagoon since 1980. Two of these stations, one at Channel Marker 14 (near Turkey Creek, in Melbourne) and the other at Channel Marker 32 (near Grant), are close

Table 7. Salinity along two transects in the Indian River. W, C, and E designate the west, central, and east stations, respectively.

DATE	GRANT			MELBOURNE		
	W	C	E	W	C	E
	.....Salinity (ppt).....					
10/18/84	23	23	23	20	20	19
10/31/84	26	26	26	20	20	20
11/14/84	18.5	18.5	17.5	17	18	17
11/28/84	15	15	16	14	14	13
12/11/84	18.5	18.5	18.5	20	20	20
12/27/84	22	21	21	17	18	17
01/08/85	22	22.5	22	21.5	20	20
01/24/85	20	19.5	19.5	19	19	19
02/14/85	22	20	20	17	17	21
02/28/85	25	23	-	21	23	22
03/12/85	34	34	35	27	26	27
03/28/85	35	34	35	27	26	27
04/18/85	25	24	24	17	25	24
05/02/85	35	35	27	35	24	25
05/16/85	36	34	36	27	28	26
06/06/85	30	30	30	24	24	24
06/20/85	30	29	29	27	26	24
07/02/85	33	34	33	26	26	26
07/30/85	30	29	30	28	29	28
08/16/85	32	31	32	27	26	27
09/03/85	25	26	26	22	21	24
09/24/85	15	22	23	22	21	20
10/15/85	-	21	-	-	19	-

Table 8. Water temperature along two transects in the Indian River. W, C, and E designate the west, central, and east stations, respectively.

DATE	GRANT			MELBOURNE		
	W	C	E	W	C	E
	.....Temperature °C.....					
10/18/84	27	27	27	27	27	27
10/31/84	25	25	25	25	25	25
11/14/84	19	19	19	19	19	19
11/28/84	22	22	22	22	22	22
12/11/84	17.5	17.5	18	17	17	17
12/27/84	23	23	23	23	22	22
01/08/85	16.5	16	16	16	16	16
01/24/85	11	11	11	11	11	11
02/14/85	13	12.5	12.5	13	13	12
02/28/85	22	22	22	22	21.5	21.5
03/12/85	23.5	23	23	23.5	23	23
03/28/85	20.5	21	21	20.5	20	20
04/18/85	24	23	24	24	23	23
05/02/85	25	25	25	25	24	25
05/16/85	28	28	28	28	28	29
06/06/85	29	29	29	29	29	29
06/20/85	30	30.5	30.5	30.5	30.5	30
07/02/85	30	29.5	30	29.5	29.5	29.5
07/30/85	31.5	32.5	32	32	31.5	32
08/16/85	30	29.5	30	29.5	30	29.5
09/03/85	30	29	29	29	29	29
09/24/85	28	28	28	28	27.5	27
10/15/85	-	27	-	-	28	-

Table 9. Chlorophyll a concentrations along two transects in the Indian River, Florida. W, C, and E designate the west, central, and east stations, respectively.

DATE	GRANT			MELBOURNE		
	W	C	E	W	C	E
	.....chlorophyll a, mg m^{-3}.....					
10/18/84	11.1	12.0	10.9	30.3	24.2	27.0
10/31/84	22.4	20.9	26.9	48.7	50.9	63.9
11/14/84	19.8	25.4	24.3	37.4	67.9	35.8
11/28/84	99.2	73.2	89.2	67.2	77.6	70.4
12/11/84	6.4	7.8	7.1	13.6	17.3	10.2
12/27/84	8.6	6.8	5.9	31.4	24.9	16.1
01/08/85	14.7	15.3	13.5	15.6	16.1	10.4
01/24/85	34.0	46.4	64.5	72.4	56.0	60.0
02/14/85	7.7	13.4	13.6	13.5	16.0	9.5
02/28/85	6.1	4.3	8.1	18.1	23.2	-
03/12/85	20.2	15.5	15.5	18.1	15.6	35.6
03/28/85	14.9	13.1	12.6	17.6	5.4	16.6
04/18/85	9.6	13.4	8.3	29.2	32.5	30.5
05/02/85	6.3	11.2	6.7	14.9	11.2	11.2
05/16/85	11.0	14.4	13.9	32.7	18.3	26.0
06/06/85	15.5	16.1	19.8	19.3	12.8	19.8
06/20/85	55.4	79.6	55.4	79.4	108.3	62.6
07/02/85	17.1	18.2	15.0	17.1	19.3	12.8
07/30/85	20.3	19.0	20.1	14.4	12.3	19.5
08/16/85	17.7	17.7	16.1	20.3	9.1	6.7
09/03/85	17.4	17.4	18.5	40.6	23.0	23.8
09/24/85	9.1	18.7	15.0	18.5	23.0	19.8
10/15/85	-	9.9	-	-	20.3	-

to the transects selected for phytoplankton and bivalve inventories in this study. Their data for these sites show seasonal variations in chlorophyll a, with maxima occurring between June and December (Fig. 3). These trends are similar to those found to date in the present study (except for January). Mahoney and Gibson (1983) attributed such pulses in chlorophyll a in the Indian River lagoon to heavy rainfall events, and the associated release of nutrient-laden fresh waters to the lagoon from nearby agricultural operations and urban areas. While this may be the causative reason for some of the phytoplankton maxima observed in our study, it does not explain all of the phytoplankton peaks. The maxima associated with the 28 November 1984 and 20 June 1985 sampling dates (Fig. 4) were preceded by 5.64 and 3.31 inches of rain, respectively, eight days before sampling (F. Doehring, pers. commun.; rainfall data collected at the Port Malabar sewage treatment plant, which is approximately mid-way between the two transects). However, the chlorophyll a peak on 24 January 1985 was not associated with any major rainfall events, nor did the heavy rain (6.2 inches from 18 to 21 September 1985) produce high chlorophyll a concentrations preceding 24 September 1985 sampling date.

Relative to previous studies in the Indian River region, the average chlorophyll a concentrations of 21 to 29 mg m^{-3} found in the present study are high. Mahoney and Gibson (1983) reported average chlorophyll a concentrations in the Vero Beach area of 4.0 mg m^{-3} during the months October through December. Mean annual chlorophyll a concentrations reported in the Brevard County study ranged from 9 to 26 mg m^{-3} (Table 10), and the statistically insignificant between-site differences (except for 1982) for annual chlorophyll

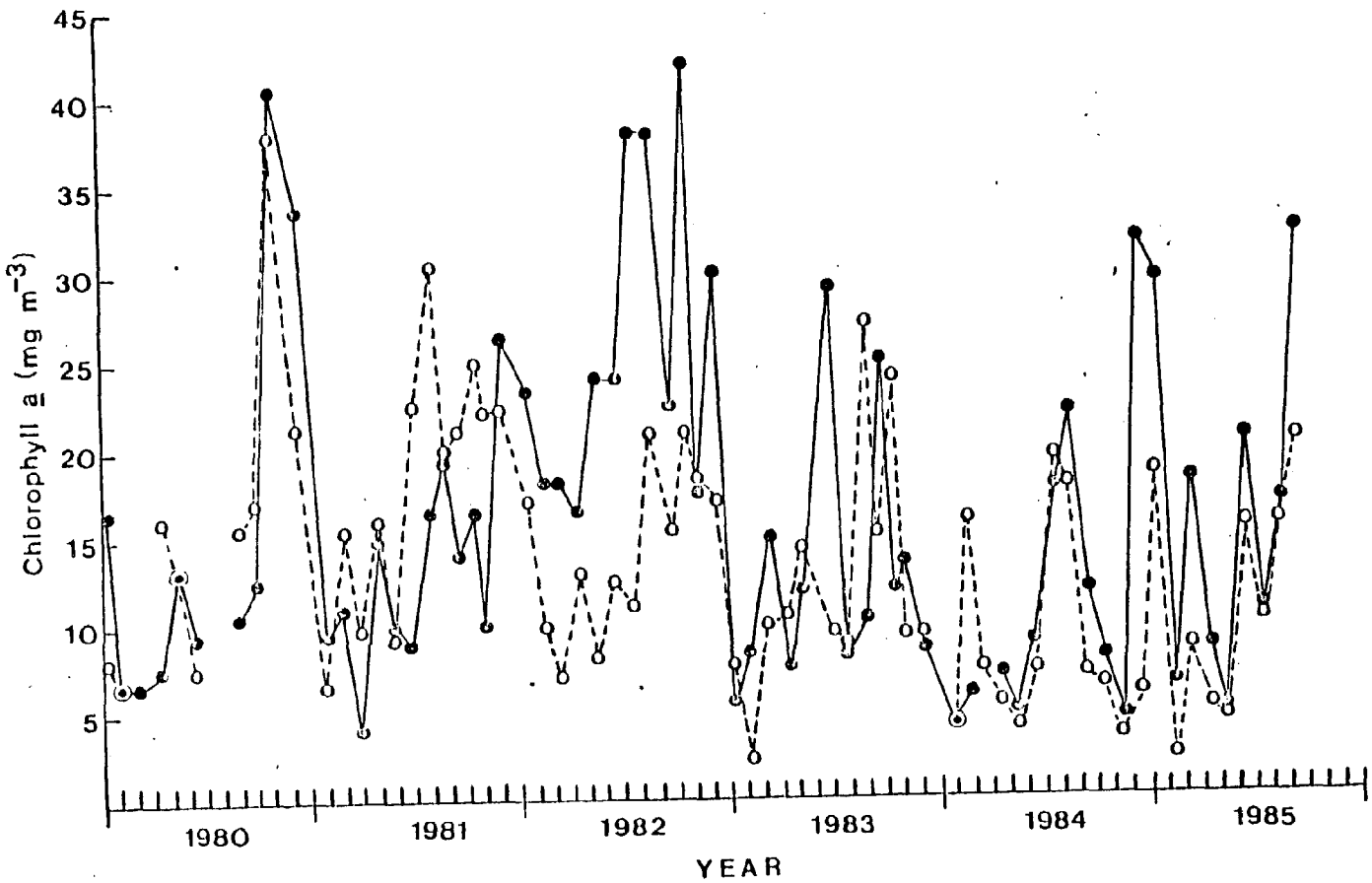

Figure 3. Monthly concentrations of chlorophyll a in the Indian River lagoon at Melbourne (closed circles) and Grant (open circles) between 1980 and 1985 (data provided by Conrad White and Bob Day of Brevard County Water Resources Dept.

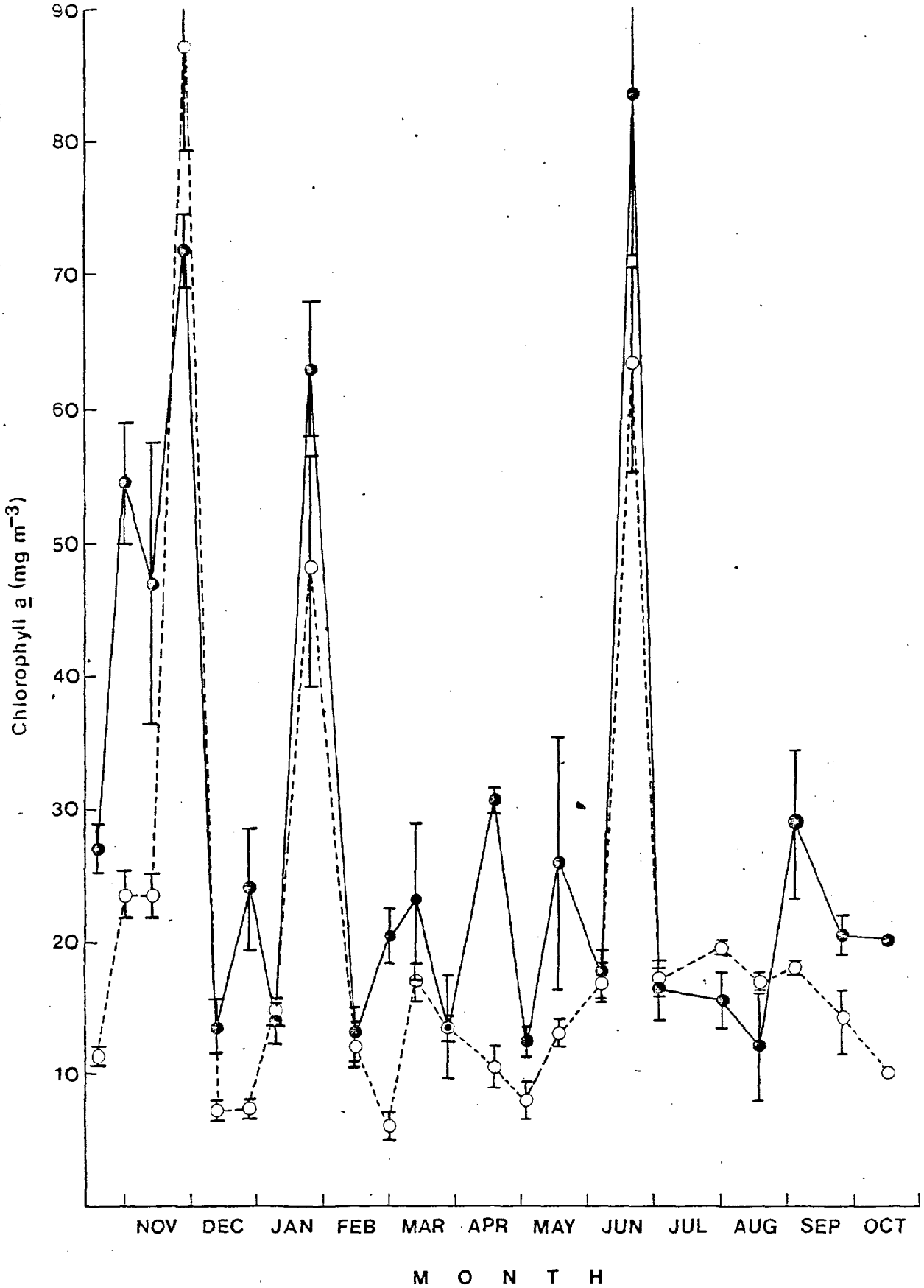

Figure 4. Mean chlorophyll a concentrations (mg m^{-3}) ± 1 S.E. along transects at Melbourne (closed circles) and Grant (open circles).

Table 10. Annual mean (± 1 s.d.) chlorophyll a concentrations for Station I 10 at Melbourne and Station I 11 at Grant from 1980 to 1985. Data provided by Conrad White and Bob Day of the Brevard County Water Resources Division.

	1980	1981	1982	1983	1984
Melbourne	16 ± 2	14 ± 6	26 ± 9	13 ± 7	12 ± 9
	n = 10	n = 12	n = 12	n = 12	n = 11
Grant	16 ± 10	18 ± 7	14 ± 5	12 ± 7	0 ± 6
	n = 9	n = 12	n = 12	n = 12	n = 12

a concentrations in the Brevard County study is contrary to the significant differences of our 1985 data. Higher chlorophyll a concentrations would be expected in Melbourne because of its proximity to several sewage treatment outfalls and urban runoff.

There is no trend of increasing chlorophyll a concentrations in the lagoon from 1980 to 1984 since there was not a significant difference between chlorophyll a levels between those two years at the Melbourne station. At Grant the chlorophyll a concentration was actually significantly lower in 1984 than 1980.

Boynton et al (1982) reported that annual mean chlorophyll a concentrations in 39 estuaries ranged from near zero to 24 mg m^{-3}, with the majority (34 out of 39 estuaries) 15 mg m^{-3} or less. Based on our data, chlorophyll a concentrations in the Indian River lagoon are thus high compared to other estuarine systems.

Primary Productivity

Morning incubations usually yielded higher primary productivity rates than did afternoon incubations at both sites (Table 11), probably due to the morning incubation period being closer to mid-day than the afternoon incubation. Based on the volumetric primary productivity rates presented in Table 12, surface (0.25 m) and subsurface (1.4 m) waters from Melbourne had significantly higher rates than at Grant for 18 of the 40 incubations; only two of the 40 incubations produced higher productivity rates at Grant than Melbourne. The productivity rates for the bottom (2.5 m) waters at Melbourne (data not shown) were low (4.7 to 48 mg C m^{-3} h^{-1}), as expected due to light limitation.

Not only was Melbourne productivity higher on a volume (m^{-3}) basis (Table 12), but the greater depth of the water at this site further increased the difference between Melbourne and Grant productivity on an areal basis (e.g.,

Table 11. Depth integrated phytoplankton productivity at two sites in the Indian River. Both morning and afternoon incubations were conducted at each site, except on 15 October 1985 when one-six hour incubation elapsed both morning and afternoon times.

DATE	MELBOURNE		GRANT	
	a.m.	p.m.	a.m.	p.m.
	---------Productivity (mg C m^{-2} hr^{-1})--------			
11/14/84	186.0	-	88.7	-
12/11/84	77.8	92.9	21.6	16.9
01/08/85	133.4	122.9	97.7	90.4
02/14/85	193.6	165.2	67.6	116.0
03/12/85	137.0	112.2	91.8	51.1
04/18/85	207.4	161.4	71.3	48.4
05/16/85	91.8	74.3	29.7	28.8
06/20/85	371.8	121.5	348.7	96.0
07/30/85	374.2	147.5	212.3	27.9
09/03/85	230.0	433.6	258.5	312.0
10/15/85	419.6		215.3	

Table 12. Phytoplankton productivity at two sites in the Indian River lagoon. Values represent average carbon uptake (mg C $m^{-3}h^{-1}$) ± 1 s.d. in a 3 hr in situ incubation during morning and afternoon incubations for surface (0.25 m depth) and subsurface (1.4 m depth) waters.

	Melbourne Surface		Melbourne Subsurface		Grant Surface		Grant Subsurface	
Date	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
11/ 4/84	118.3 ± 27.3	---	46.3 ± 26.3	---	85.7 ± 19.6	---	32.5 ± 0.0	---
12/11/84	44.0 ± 1.4	52.0 ± 1.7	25.8 ± 3.4	31.5 ± 0.4	15.9 ± 1.5	13.9 ± 0.3	13.0 ± 1.1	8.7 ± 0.1
01/08/85	67.6 ± 2.4	63.4 ± 9.4	53.4 ± 2.1	48.0 ± 1.1	79.6 ± 9.2	55.5 ± 2.5	50.6 ± 7.8	27.5 ± 3.6
02/14/85	108.3 ± 22.3	88.5 ± 14.9	65.7 ± 35.6	60.7 ± 2.5	56.4 ± 8.4	95.6 ± 14.0	33.7 ± 10.8	59.1 ± 8.7
03/12/85	77.7 ± 11.5	71.9 ± 5.9	45.2 ± 1.4	13.0 ± 2.2	93.5 ± 9.7	52.0 ± 6.4	28.9 ± 4.5	16.1 ± 2.3
04/18/85	140.4 ± 17.6	100.4 ± 1.9	70.1 ± 33.5	32.9 ± 18.6	69.8 ± 5.3	29.8 ± 2.3	45.2 ± 1.1	14.7 ± 1.8
05/16/85	61.2 ± 4.9	43.7 ± 4.2	30.9 ± 1.1	20.9 ± 1.2	22.0 ± 5.6	20.8 ± 2.3	24.7 ± 0.8	10.7 ± 1.2
06/20/85	132.0 ± 0.9	108.1 ± 0.9	204.1 ± 0.4	12.0 ± 0.4	302.3 ± 42.8	117.2 ± 41.0	162.6 ± 10.2	---
07/30/85	229.8 ± 18.6	139.3 ± 1.8	111.5 ± 3.3	2.9 ± 1.3	181.2 ± 13.8	31.3 ± 3.1	101.9 ± 12.6	5.9 ± 3.8
09/03/85	120.9 ± 3.5	302.8 ± 49.0	88.7 ± 2.5	106.2 ± 33.6	200.8 ± 12.1	282.0 ± 27.6	144.0 ± 36.0	134.2 ± 7.8
10/15/85	← 258.3 ± 24.0 →		← 113.2 ± 1.5 →		← 212.2 ± 12.1 →		← 74.9 ± 19.2 →	

Table 13). Light extinction measurements show that the entire water column (3 m) at Melbourne is usually in the euphotic zone, assuming that photosynthesis occurs down to a depth limit of 1% of surface light intensity. The higher phytoplankton productivity (and standing crop) at the Melbourne site may be a result of the greater nutrient loading to the lagoon at this site.

The phytoplankton productivity in the lagoon ranged from 0.16 g C/m^2-day (Grant, December) to 3.7 g C/m^2-day (Melbourne, October), and averaged 1.08 and 1.85 g C/m^2-day for Grant and Melbourne, respectively (Table 13). The wide range in productivity observed in the Indian River lagoon during the 12 months of sampling is probably typical, where fluctuations in light, temperature, and rainfall affect primary production. The average daily primary productivity at Melbourne was significantly higher ($p<0.05$) than the average productivity rate for the waters at Grant.

The photysynthetic rates are high: the chlorophyll-normalized rates of carbon fixation ranged from 1.1 to 21.4 (mean of 6.0) with many of the monthly assimilation ratios comparable to maximum ones observed for cultures (Glover 1980). There were no major differences in assimilation ratios between the Melbourne and Grant sites. The high variability in the monthly assimilation ratios (coeff. variations of 76% and 96% for Melbourne and Grant, respectively) over the eleven month sampling period is to be expected since assimilation numbers vary as a function of nutrient regime, temperature, cell size, and light history (Falkowski 1981). Boyton et al. (1982) found that the average seasonal productivity ranged from near zero to 2.5 g C/m^2-day for 45 mostly temperate estuarine systems, with the mean of all annual average rates being 0.52 g C/m^2-day. The mean primary production rates from both Grant and Melbourne waters are well above the average for all estuaries, clearly

Table 13. Daily phytoplankton productivity at two sites in the Indian River.

DATE	MELBOURNE	GRANT
	-----Productivity (g C m^{-2} day^{-1})-----	
11/14/84	1.55	0.74
12/11/84	0.70	0.16
01/08/85	1.12	0.82
02/14/85	1.50	0.77
03/12/85	1.20	0.70
04/18/85	1.86	0.61
05/16/85	0.81	0.29
06/20/85	2.67	2.37
07/30/85	2.43	1.12
09/03/85	2.79	2.41
10/15/85	3.72	1.91

indicating that the Indian River lagoon is a very productive estuary. In fact, the average daily phytoplankton production for Melbourne waters (1.85 g C/m^2-day) is the highest reported rate for any estuary; primary productivity at Grant is only superceded by four of the 45 estuarine rates provided by Boynton et al. (1982).

Monthly fluctuations in volumetric productivity rates for the surface waters at the center stations of the two sampling sites appear unrelated to changes in phytoplankton standing crop. The coefficient of determination for a simple linear correlation between chlorophyll a and productivity at the Grant site was low ($r^2 = 0.30$). For Melbourne, the coefficient of determination was zero. Chlorophyll a concentrations have been found to be a good indicator of temporal and spatial variations in daily photosynthetic rates in certain freshwaters (Megard 1972) and estuaries (Boynton et al. 1982), but the distribution of production was not similar to that of chlorophyll a in our study.

Diversity

Only nine bivalve taxa were collected and identified during the entire study (Table 14), with Mulinia lateralis (coot clam) making up 98 percent (53,351 individuals) of the total number. Mercenaria mercenaria (hard clam) was the second most abundant species (464 individuals) collected, but was present in the bivalve community only 1 percent of the total number. This low diversity is contrary to the higher bivalve diversity of previous mollusk work done in the Indian River (e.g., Applied Biology, Inc. 1980; Brevard County 1975; Reish and Hallisey 1983; Virnstein et al. 1983; Young and Young 1977). Also Mercenaria mercenaria was reported in only two (Applied Biology, Inc. 1980; Virnstein et al. 1983) of the eight studies which presented a bivalve species list (see Appendix A for annotated bibliography on bivalve and hytoplankton of the Indian River). The higher diversities and absence of Mercenaria mercenaria from the earlier studies may have been from: (i) a low hard clam population and richer bivalve species present during 1973-81; (ii) limited sampling; and/or (iii) geographical variability between sampling locations and distribution of bivalve taxa.

Distribution and Relative Abundance

Hard clams, Mercenaria mercenaria, occurred mainly in the region near Grant where clam harvesting has been the heaviest (Fig. 5; Table 15). Densities averaging 36.3 per m^2 (4-104 per m^2) from 38 quantitative samples are the same as the higher densities reported by Walker and Tenore (1984) for small feeder creeks in Wassaw Sound, Georgia, and higher than the 6.4 per m^2 collected at Core Sound, North Carolina (Peterson et al. 1983).

Table 14. Total number of individuals of each bivalve species collected from 110 stations (sampling area was 1/4 m^2 at each station) at the Grant, Melbourne, and Merritt Island sites.

Species	Common Name	Number of Individuals
Mulinia lateralis	coot clam	53,351
Mercenaria mercenaria	hard clam	464
Amygdalum papyrium	paper mussel	152
Anomalocardia auberiana	pointed venus	25
Dosinia discus	disk dosinia	10
Noetia ponderosa	ponderous ark	8
Parastarte triquetra	brown gem clam	7
Corbula contracta	contracted corbula	2
Tellina alterna	alternate tellin	2

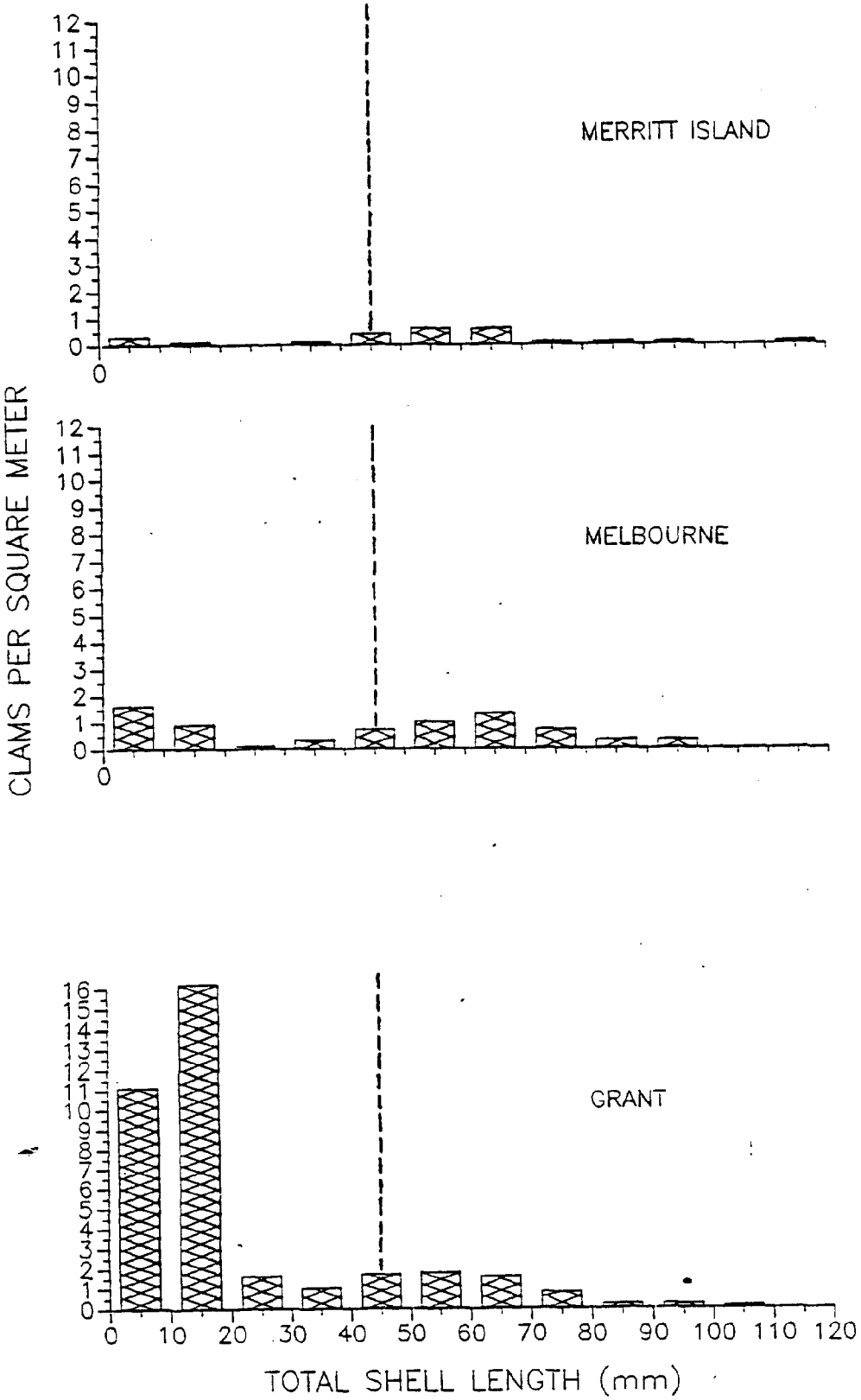

Figure 5. Differences in size (length)-frequency distributions of Mercenaria mercenaria from the Indian River at the Merritt Island, Melbourne, and Grant sampling sites. The vertical dashed line represents the shell length equal to the minimum legal width of 7/8 inch across the hinge allowed by Florida statute.

Table 15. Density of the hard clam, Mercenaria mercenaria, collected from three areas in the Indian River lagoon in Brevard County, Florida. Four transects, each transect consisting of 7 to 11 sampling stations, were sampled from each area.

SHELL LENGTH (mm)	CLASSIFICATION + (APPROXIMATE SHELL LENGTH)	HARD CLAM DENSITY (Individuals/m^2)			ANALYSIS OF VARIANCE*
		Grant	Melbourne	Merritt Island	
		.....$\bar{X} \pm 1$ S.E.....			
2.8 - 9.9	"seeds"	11.1 ± 2.1	1.6 ± 0.8	0.3 ± 0.3	P< 0.001
10.0 - 19.9	(< 1 in.)	16.2 ± 3.0	0.9 ± 0.4	0.0	P< 0.001
20.0 - 29.9	"beans"	1.6 ± 0.6	0.1 ± 0.1	0.3 ± 0.2	P< 0.05
30.0 - 39.9	(1-1.5 in.)	1.0 ± 0.6	0.3 ± 0.2	0.2 ± 0.1	NS
40.0 - 49.9**	"buttons" (1.5-2 in.)	1.8 ± 0.4	0.7 ± 0.6	0.4 ± 0.2	NS
50.0 - 59.9	"little necks" (2-2.5 in.)	1.8 ± 0.3	1.0 ± 0.2	0.6 ± 0.3	P< 0.05
60.0 - 69.9	"top necks"	1.6 ± 0.3	1.3 ± 0.4	0.7 ± 0.3	NS
70.0 - 79.9	(2.5-3 in.)	0.8 ± 0.3	0.7 ± 0.2	0.1 ± 0.1	NS
80.0 - 89.9	"cherrystones" (3-3.5 in.)	0.2 ± 0.1	0.4 ± 0.2	0.2 ± 0.1	NS
90.0 - 99.9	"chowders" (>3.5 in)	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	NS

+Size classification based on a 2:1 ratio of longitudinal (i.e., anterior-posterior) shell length to shell thickness across the hinge as per conversation with David Chanley, August 25, 1985.

*Probabilities of significant differences in clam density ($\alpha = 0.05$) are given based on critical values of the F-distribution (d.f. = 2,9).

**Approximate legal minimum size for harvest (>7/8 in. across the hinge) is longer than 44 mm total shell length.

According to Carriker (1961), a commercially exploitable density in northern waters is 23.6 clams per m^2, with dense beds yielding approximately 22 to 33 clams per m^2. In comparison, for clam mariculture, 1500-3000 individuals per m^2 is considered an optimum density (M. Castagna, pers. commun., September 7, 1985). By contrast, the clam density from 38 quantitative samples taken at Melbourne was nearly 5-fold less (average 7.4 per m^2) than at Grant, and ranged from 0 to 40 individuals per m^2 (Fig. 5). Still, according to Carriker's criterion, the clam density is sufficient to yield a commercially viable crop. However, clams surveyed in the unharvested waters off Merritt Island (34 samples) averaged only 2.9 per m^2 (range of 0 to 16 individuals per m^2), and are not dense enough to warrant commercial harvesting.

Compared to the hard clam, densities for the coot clam (*Mulinia lateralis*) were considerably greater, being approximately 10-fold more numerous at Grant, 300-fold more abundant at Melbourne, and 1000-fold greater at Merritt Island (Table 16). Significant differences in the *Mulinia* population existed between Grant and Melbourne, and Grant and Merritt Island, but not between Melbourne and Merritt Island. It is interesting that the numbers of *Mulinia* increased with decreasing populations of *Mercenaria* among the three areas. Size-frequency distribution is not reported for this species as its small size (<20 mm) does not allow for such an analysis to be made.

Population Size Structure

Variation in the number of individuals among the four transects within an area was remarkably low (e.g., coefficient of variation was 37 percent for "seeds" from Grant)(Table 15). This similarity in the hard and

Table 16. Abundance of the coot clam, *Mulinia lateralis*, sampled from three areas of the Indian River lagoon in Brevard County, Florida.

TRANSECT	COOT CLAM DENSITY (Individuals/m^2)			ANALYSIS OF VARIANCE*
	Grant	Melbourne	Merritt Island	
1	216	2040	1313	
2	176	3304	4029	
3	196	2812	3696	
4	292	1780	3624	
$\bar{X} \pm 1$ S.E.	220 ± 25.4	2484 ± 350	3165 ± 624	$P<0.001$

*Probabilities of significant differences in clam density ($\alpha = 0.05$) are based on critical values of the F-distribution (d.f. = 2,9).

coot clam population structure among transects within an area indicated both a uniform distribution and a thorough sampling methodology. For instance, the 4 in. harvesting depth was adequate since the number of individuals taken in April along transect A (when the temperature was cooler and the shellfish possibly deeper in the sediment) are not greater than they are in June (Transect C). See Appendix B.

The mean size of clams from Grant was smaller (21 $\pm$ 24 s.d. mm) than for beds in Melbourne (44 $\pm$ 39 s.d. mm) and Merritt Island (51 $\pm$ 49 s.d. mm) (Table 15). Size-frequency distribution (Fig. 5) of hard clams collected at Grant was dominated by small clams: 85% of the total individuals sampled were less than 7/8 in. across the hinge (44 mm total shell length), the minimum size for legally harvestable clams in Florida. There are two possible explanations for the decrease in the number of clams greater than one inch at Grant: (i) the more likely reason is that harvesting in the conditionally approved waters near Grant has reduced the numbers of larger clams to levels similar to those areas of the lagoon where populations are naturally lower (Fig. 5); or (ii) because larval sets of hard clams are naturally sporadic (Hibbert 1976), unsuccessful sets of larvae for a two-year period, or mortality of juveniles, resulted in low numbers as the survivors grew to marketable sizes. Note the number of "beans", an illegal size, is very low at Grant (Table 15).

Only 5.5 clams/m^2 make up the legally harvestable stock at Grant, which is close to Carriker's (1961) minimum of 3.6 clams/m^2 density necessary to commercially harvest. Still, the legal sized clam density at Grant was the highest of the three sections sampled in the lagoon. Melbourne and Merritt Island had 4.0 and 1.9 legally sized clams per m^2, but for all except one

(50.0-59.9 mm) of the six legal sized shell length divisions, the differences were not statistically significant among sampling locations (Table 15). However, the abundance of "seeds" (27 "seed" clams/m^2) at Grant yielded highly significant differences among the three harvested areas for clams in that size range. By contrast, the numbers of "seed" clams at the Melbourne and Merritt Island locations are considerably less than those found at Grant, indicating recruitment failure or juvenile size-selective mortality.

Apparently the extensive harvesting pressure exerted at Grant during the past two-three years has not deleteriously affected recruitment up to now. Whether increasing harvesting can continue unabated without affecting the recruitment success is uncertain. Peterson et al. (1983) believed the relatively low numbers in the younger age classes was a result of reduced reproductive effort caused by a reduction in the spawning population of M. mercenaria in North Carolina through increased commercial harvest. However, the authors readily admit that they had no way of distinguishing reduced reproductive effort from increased mortality of larvae and early post larvae.

The "button" law of 1984, where clams <7/8 inch must be returned to insure continued recruitment, is debatable considering the low reproductive potential of buttons compared to larger clams and the effects of predators on the returned, unprotected buttons. There clearly is a need for more scientific information on the efficacy of the "button" law and the strength and nature of spawner-recruit relationships, which is the single biggest barrier to effective management of clams.

Allometric Relationships

The best fitted curve through all points in describing the relationship between total wet weight and shell length, and dry meat weight and shell length, for the two dominant marine bivalves (*M. mercenaria* and *M. lateralis*) collected in the Indian River is a logarthmic function in the form (Hibbert 1976):

$$W = a\ (L)^b \qquad (2)$$

Figures 6-9 provide an estimate of length-specific biomass of the two bivalve species, and were used to calculate total biomass of the two species.

Bivalve Biomass

Although dry meat biomass for *Mercenaria* was highest at Grant (mean of 9.74 g m^{-2}), it was not significantly different from the average found at Melbourne (mean of 8.61 g m^{-2}) (Table 17 and Fig. 10). However, the lower number of hard clams (and thus lower biomass) at Merritt Island resulted in that area having a clam biomass (3.59 g m^{-2}) that was significantly different from that at Grant, but not Melbourne, and lead to an overall ANOVA that produced a significant difference ($P < 0.05$) in the hard clam biomass among all three sampled areas.

The low number of *Mulinia* individuals at Grant (Table 16) translated into a very low dry meat biomass (mean of 0.95 g m^{-2}), which was significantly different than the larger biomass estimates for Melbourne and Merritt Island (Table 18), where higher numbers of *Mulinia* were found (Table 16). The average biomass of the coot clam from Melbourne and Merritt Island (mean of 5.13 and 5.18 g m^{-2}, respectively) were not significantly different from each other (Fig. 10).

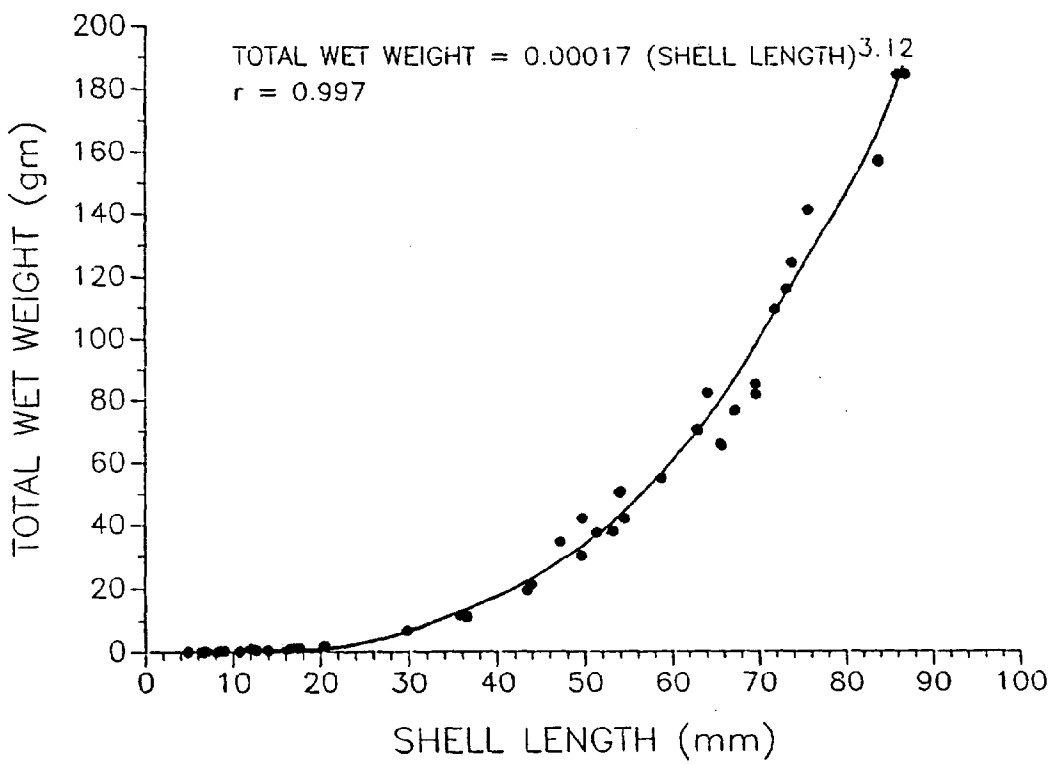

Figure 6. Regression relationship [$W_1 = a(L)^b$] between total wet weight (W_1, gm) to shell length (L, mm) for 50 hard clams (Mercenaria mercenaria) collected from three areas in the Indian River between April and July, 1985.

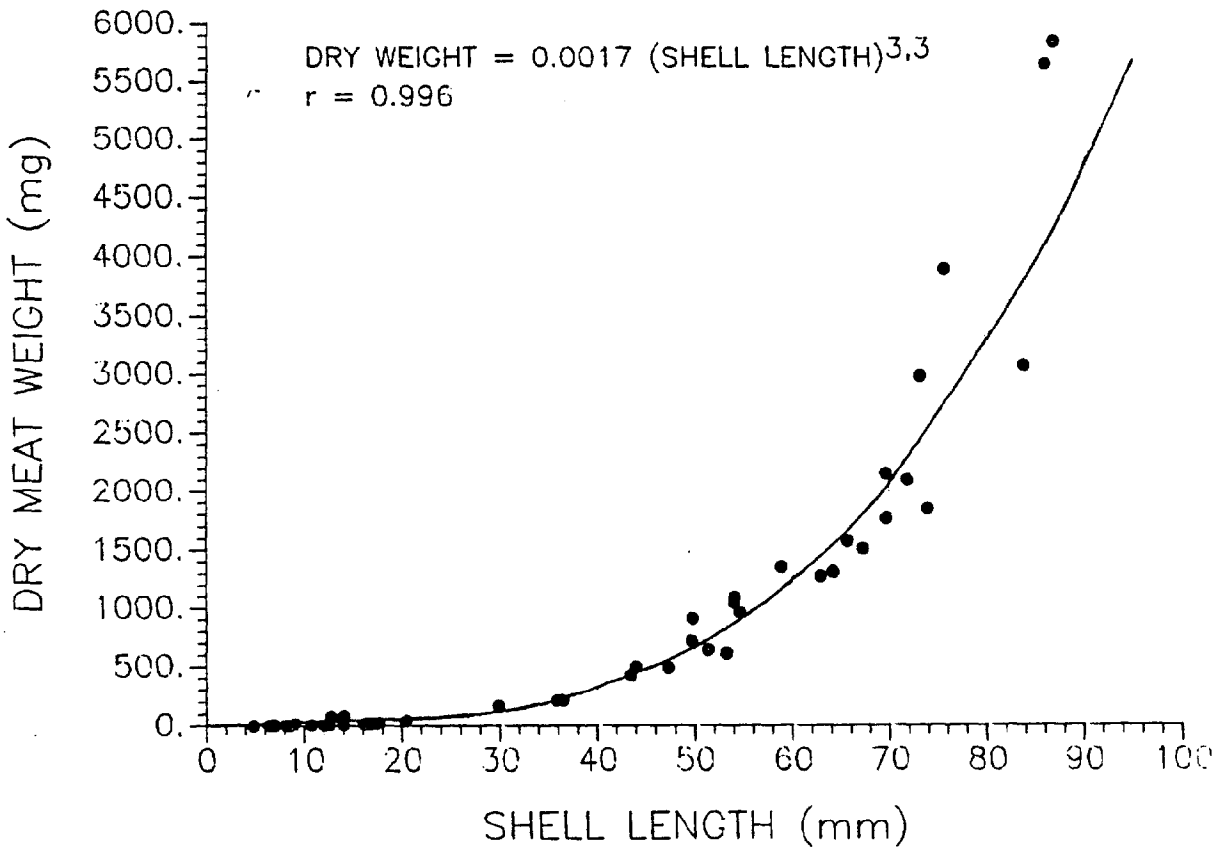

Figure 7. Regression relationship [$W_2 = a(L)^b$] between dry meat weight (W_2, mg) shell length (L, mm) for 50 hard clams (Mercenaria mercenaria) collected from three areas in the Indian River between April and July, 1985.

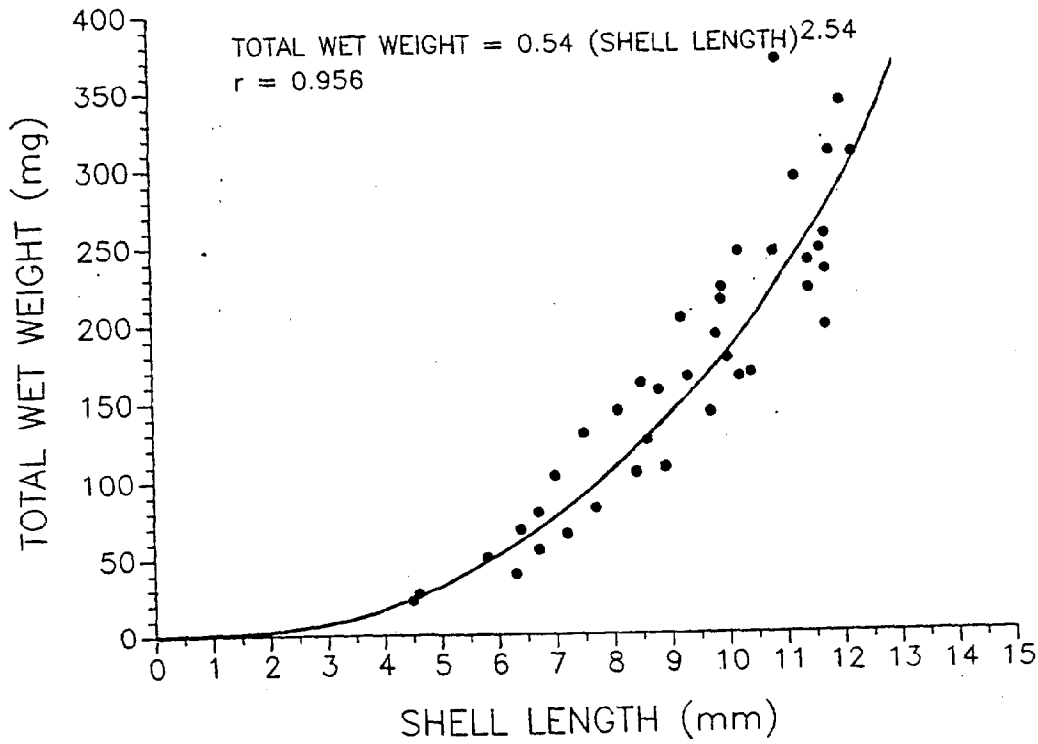

Figure 8. Regression relationship $W_1 = a(L)^b$ between total wet weight (W_1, mg) to shell length (L, mm) for 40 coot clams (Mulinia lateralis) collected from three areas in the Indian River between April and July, 1985.

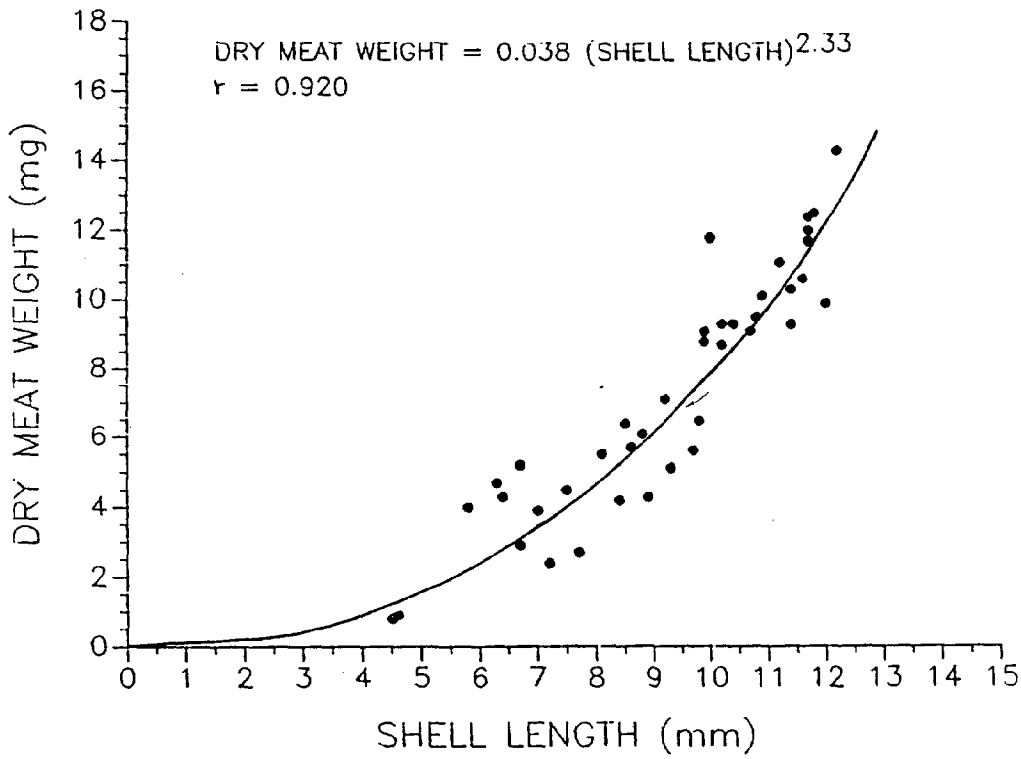

Figure 9. Regression relationship $W_2 = a(L)^b$ between dry meat weight (W_2, mg) to shell length (L, mm) for 40 coot clams (Mulinia lateralis) collected from three areas in the Indian River between April and July, 1985.

Table 17. Biomass of hard clams, *Mercenaria mercenaria*, sampled from three areas of the Indian River lagoon in Brevard County, Florida. Dry meat weight values were calculated from a shell length: dry meat weight relationship derived from individuals ranging from 2.8 - 100.0 mm total shell length (see Figure 7).

TRANSECT	DRY MEAT BIOMASS (g/m^2)			ANALYSIS OF VARIANCE*
	Grant	Melbourne	Merritt Island	
1	8.16	10.49	4.47	
2	9.80	12.98	3.49	
3	11.48	1.94	3.92	
4	9.51	9.03	2.48	
$\bar{X} \pm 1$ S.E.	9.74 ± 0.68	8.61 ± 2.37	3.59 ± 0.42	$P<0.05$

*Probabilities of significant differences in hard clam biomass ($\alpha = 0.05$) are based on critical values of the F-distributions (d.f. = 2,9).

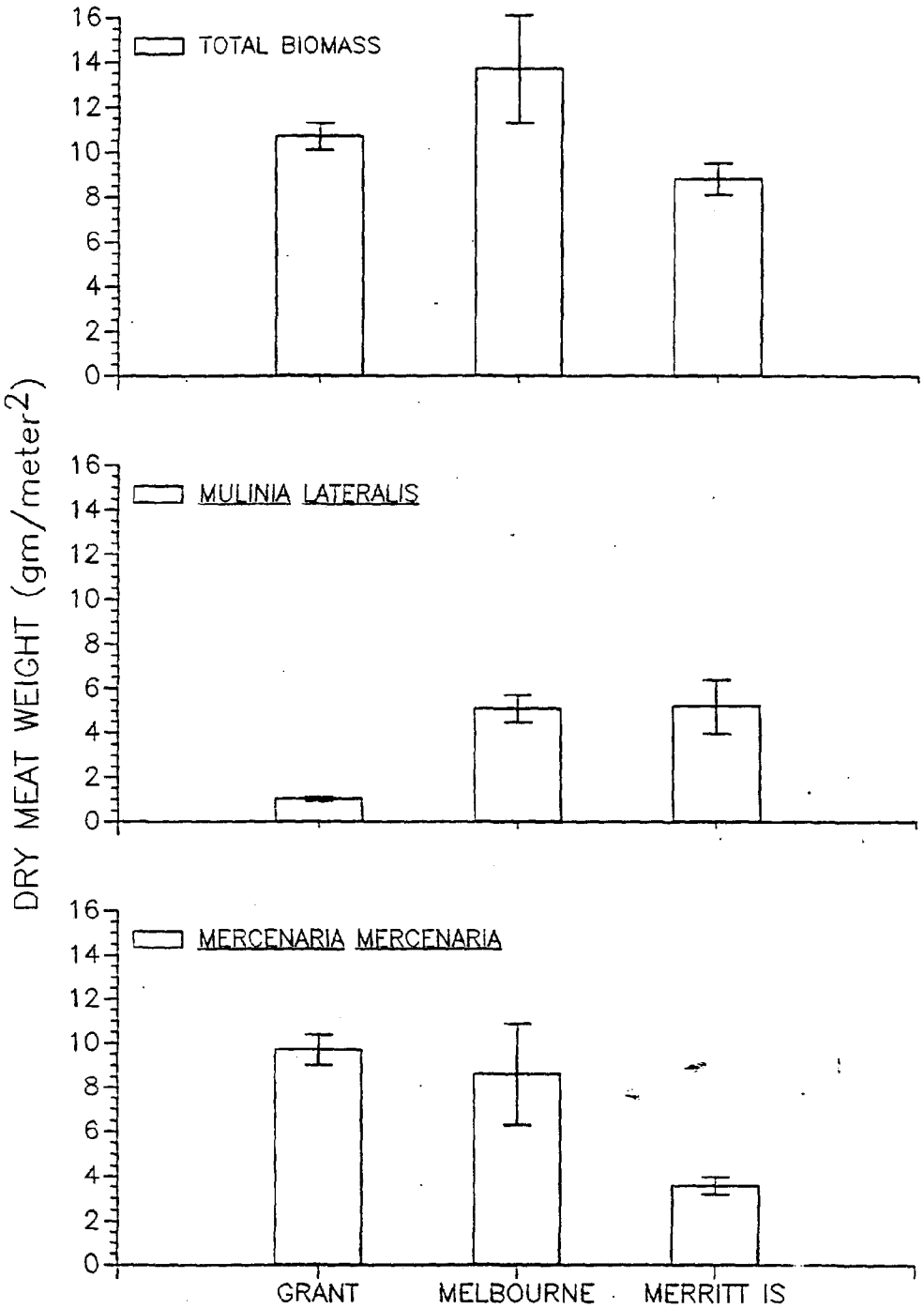

Figure 10. Standing crop for hard clams, Mercenaria mercenaria, and coot clams, Mulinia lateralis, and the total for the two species at three sites in the Indian River lagoon in Brevard County, Florida, during 1985.

Table 18. Biomass of coot clams, *Mulinia lateralis*, sampled from three areas of the Indian River lagoon in Brevard County, Florida. Dry meat weight values were calculated from a shell length: dry meat weight relationship derived from individuals ranging from 2.8 -20.0 mm total shell length (see Figure 9).

TRANSECT	DRY MEAT BIOMASS (g/m^2)			ANALYSIS OF VARIANCE*
	Grant	Melbourne	Merritt Island	
1	1.04	3.37	2.15	
2	1.06	5.99	6.55	
3	0.78	6.02	6.00	
4	0.94	5.12	6.03	
$\bar{X} \pm 1$ S.E.	0.95 ± 0.006	5.13 ± 0.62	5.18 ± 1.02	$P < 0.005$

*Probabilities of significant differences in biomass ($\alpha = 0.05$) are based on critical values of the F-distribution (d.f. = 2,9).

When taken together, the total dry meat biomass of the two dominant bivalves were not significantly different ($P < 0.10$) among the three sampling areas (Table 19), suggesting that a maximum sustainable yield for filter feeding bivalves of 8.8 to 13.7 g dry meat weight m^{-2} (Fig. 10) prevailed in the Indian River estuary adjacent to central and south Brevard County in 1985.

The Relationship of Food Supply to Bivalve Production

An often overlooked limiting factor in accounting for the abundance of shellfish is their food supply, which is probably more critical during their larval stages than during their adult life. A way to assess the availability of food to the bivalve community is to divide the net primary productivity rate (g C/m^2-day) at each location by the respective bivalve standing stock (g dry meat wt/m^2) to produce the mg C of phytoplankton made available as a food source per g dry meat of bivalve per day. This can then be compared to Tenore and Dunstan's (1973) regression relationship between food concentration (ug C/L) and absolute feeding rate measured for Mercenaria having an average shell length of 45.4 mm. Although particulate organic carbon was not measured in our investigation, an estimate can be made based on chlorophyll a concentrations and the ratio of 35:1 for phytoplanktonic particulate carbon to chlorophyll a (Ryther and Menzel 1965). Considering that measured chlorophyll a concentrations for the Melbourne and Grant transects averaged 29.4 and 21.1 mg m^{-3}, respectively, living phytoplankton particulate carbon would be 1,029 and 738 ug C/L.

With an average phytoplanktonic carbon at Melbourne of 1,029 ug/L, a feeding rate of 25.2 mg C/g dry meat/day at 20°C for Mercenaria would be predicted according to Tenore and Dunstan's regression analysis. However, the size classes of most of the bivalves collected in the Indian River were

Table 19. Biomass of hard clams, Mercenaria mercenaria, and coot clams, Mulinia lateralis, sampled from thee areas of the Indian River lagoon in Brevard County, Florida. Dry meat weight values were calculated from a shell length: dry meat weight relationship derived for each species (see Figures 7 and 9).

TRANSECT	DRY MEAT BIOMASS (g/m^2)			ANALYSIS OF VARIANCE*
	Grant	Melbourne	Merritt Island	
1	9.21	13.86	6.62	
2	10.86	18.95	10.03	
3	12.26	7.96	9.91	
4	10.44	14.15	8.50	
$\bar{X} \pm 1$ S.E.	10.69 ± 0.63	13.73 ± 0.22	8.77 ± 0.80	P<0.10 (NS)

*Probabilities of significant differences in hard clam biomass ($\alpha = 0.05$) are based on critical values of the F-distributions (d.f. = 2,9).

considerably less than the size class (45.4 mm shell length) used by Tenore and Dunstan (1973). Smaller size classes for Mulinia and Mercenaria would mean the filtration (feeding) rates for Indian River bivalves were higher on a g dry meat wt basis than the rates used by Tenore and Dunstan. Using Hibbert's (1977) empirical relationship between Mercenaria filtration rate and shell length, a filtration rate for the Mercenaria population used by Tenore and Dunstan can be compared to the rates obtained in our study based on the average shell lengths measured for Mulinia (7.7 mm, 5.6 mm, and 5.0 mm for Grant, Melbourne, and Merritt Island, respectively) and Mercenaria (20.7 mm, 44.5 mm, and 50.5 mm for Grant, Melbourne, and Merritt Island, respectively). In addition, knowledge of what proportion of the total bivalve biomass was comprised by each species at each sampling area permits a weighted (according to size and relative biomass abundances) filtration rate for the bivalve community to be computed.

For Melbourne, the maximum feeding rate would be 14.4 X higher (i.e., 364 mg C/g dry meat/day) than the feeding rate reported by Tenore and Dunstan (25.2 mg C/g dry meat/day). When this rate is compared to the amount of phytoplankton carbon made available daily per g dry meat wt of bivalve at the Melbourne section (1.85 g C/m^2-day ÷ 13.7 g dry meat/m^2 = 135 mg C/g dry meat/day), only 37 percent of the amount of food is being produced than what is required by the bivalve community. This assumes Mulinia lateralis feeds at a similar rate as does Mercenaria mercenaria in the same size class. If the lowest daily primary productivity rate (0.7 g C/m^2-day) of the year (in December 1984) and its associated chlorophyll a concentration (13.7 mg m^{-3}) is used as a "worst case" example, then 51 mg C/g dry meat/day is available to the bivalves, which is still less than 50 percent of what the maximum feeding rate (125 mg C/g dry meat/day) would be required for a food concentration of 480 ug C/L (= 13.7 mg chl a m^{-3}).

An average phytoplanktonic carbon concentration of 738 ug/L at Grant resulted in an absolute feeding rate of 8.1 X the 16.4 mg C/g dry meat/day reported by Tenore and Dunstan at this food concentration. When compared to the daily produced food available for bivalve grazing (1.08 g C/m^2-day ÷ 10.7 g dry meat/m^2) of 101 mg C/g dry meat/day, primary productivity at Grant produces 76 percent of the daily maximum requirement of food for the bivalve community. Again, if the lowest recorded primary productivity rate (0.16 g C/m^2-day in November) and its associated chlorophyll a concentration (7.1 mg m^{-3}) is used, then primary production (15 mg C/g dry meat/day) furnishes the amount of food required by Mercenaria (15 mg C/g dry meat/day) at a food concentration of 248 ug C/L (= 7.1 mg m^{-3} of chlorophyll a).

It appears that the primary productivity rates at Grant and Melbourne are inadequate to sustain the filter feeding bivalve biomass based on maximum filtration rates. However, the grazing rates for the bivalve community is probably less than maximum, meaning the measured primary productivity is meeting the food requirements of the existing standing stock. If primary productivity rates were to increase, a higher bivalve standing stock may be possible. Thus the quantity of food could be limiting to the bivalve community, even though the abundant phytoplankton productivity of the estuary is part of the reason why growth rates and standing stocks of bivalves are high.

There is also a quality aspect to the food resources. Calabrese and Davis (1970) found food requirements for hard clam larvae to differ under different environmental conditions. Although the composition of the phytoplankton community during this investigation is unknown, the almost negligible

information on what species of plankter is best for larval growth at given temperatures, salinities, and larval stages would have precluded any meaningful interpretation of phytoplankton species data.

Literature Review on Bivalves of the Indian River Lagoon

An annotated bibliography found in Appendix A of this report on bivalves and phytoplankton of the Indian River represents an exhaustive search of published and unpublished reports as well as interviews with several scientists. The bibliographic entries are summarized according to emphases chosen by ourselves. Thus methodology, phytoplankton standing crops and rates of production, bivalve species lists and densities, and conclusions are highlighted in the annotations.

Several recurrent ecological observations/principles were noted during the course of the literature search:

1) greater numbers of bivalves (both species diversity and total individuals) are found in seagrass beds than in bare sand substrate.

2) most unpredictable (i.e., stressed) environments is caused by low dissolved oxygen, and leads to less species and total individuals.

3) deposit feeders such as polychaetes can exclude suspension feeders like bivalves.

4) the most common bivalve taxa in decreasing order of numbers were: *Tellina* sp., *Mulinia lateralis*, *Brachidontes exustus*, *Corbula* sp., *Tagelus divisus*, *Chione* sp., *Macoma* sp., *Nucula proxima*, *Parastarte triquetra*, *Musculus lateralis*, *Anadara transversa*, *Barbatia domingensis*, *Amygdalum papyrium*, *Anomalocardia cuneimeris*, *Laevicardium* sp. Most of the dominant taxa were composed of small individuals, some of which can grow in dense clusters (>1,000

individuals/m^2 according to data taken by Brevard County). As previously discussed, only two of the eight studies which presented bivalve species lists reported Mercenaria mercenaria. Another major difference between our study and previous inventories is the minor numbers for Tellina found by us (Table 14), whereas it was the most common bivalve found in the other studies. This could be due to the close morphological appearances of Tellina and Mulinia lateralis, which was 98 percent of the total bivalve number in our study.

None of the previously published or unpublished studies on the Indian River concentrated exclusively on the bivalve population; all examined the macrobenthic community, which includes polychaetes, sipunculans, gastropods, nemertineans, crustacea, and echinoderms in addition to bivalves. Thus the investigations were confined to ecological studies within the macrobenthic faunal community: competitive exclusion between suspension feeders and deposit feeders (Thomas 1974; Weiderhold 1976) or how environmentally unpredictable habitats affect community structure (Grizzle 1979; Young and Young 1977). Most of the studies were quantitative to the point of listing numbers of individuals collected (but not dry or wet weights). Only two studies (Virnstein et al. 1983; Young and Young 1977) addressed the interaction of the benthic macroinvertebrate community with other trophic levels; no study looked at benthic-pelagic coupling of nutrients and/or carbon.

REFERENCES

Abbott, R.T., 1974. American Seashells. The Marine Mollusca of the Atlantic and Pacific Coasts of North America, 2nd ed. Van Nostrand Reinhold Company, New York.

A.P.H.A. 1971. Standard Methods for the Examination of Water and Wastewater. Am. Public Health Assoc., New York, N.Y. 864 pp.

Applied Biology, Inc. 1980. Biological and Environmental Studies at the Florida Power and Light Company Cape Canaveral Plant and the Orlando Utilities Commission Indian River Plant. Volume 2. 641 Dekalb Industrial Way, Atlanta, GA.

The Audubon Society. 1981. Guide to North American Seashells. Alfred A. Knopf, New York.

Boynton, W.R., W.M. Kemp, and C.W. Keefe. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production. In: V.S. Kennedy (ed.), Estuarine Comparisons. Academic Press.

Brevard County Environmental Engineering Dept. (Mr. Conrad White, pers. commun.). 1975-1981.

Calabrese, A., and H.C. Davis. 1970. Tolerances and requirements of embryos and larvae of bivalve molluscus. Helgolander wiss. Meeresunters. 20:553-564.

Carriker, M.R. 1961. Interrelation of functional morphology, behavior, and autecology in early stages of the bivale Mercenaria mercenaria. J. Elisha Mitchell Sci. Soc. 776:168-241.

Falkowski, P.G. 1981. Light-shade adaptation and assimilation numbers. J. Plankton Res. 4:203-216.

Glover, H.E. 1980. Assimilation numbers in cultures of marine phytoplankton. J. Plankton Res. 2:69-79.

Grizzle, R.E. 1979. A preliminary investigation of the effects of enrichment on the macrobenthos in an east-central Florida lagoon. Florida Scient. 42:33-42.

Heffernan, J.H., and R.A. Gibson. 1983. A comparison of primary production rates in Indian River, Florida seagrass systems. Florida Scient. 46:295-306.

Hibbert, C.J. 1976. Biomass and production of a bivalve community on an intertidal mud flat. J. Exp. Mar. Biol. Ecol. 25:249-261.

Hibbert, C.J. 1977. Energy relations of the bivalve Mercenaria mercenaria on an intertidal mud flat. Mar. Biol. 44:77-84.

Lindner, G. 1975. Field Guide to Seashells of the World. Van Nostrand Reinhold Company, New York.

Mahoney, R.K., and R.A. Gibson. 1983. Phytoplankton ecology of the Indian River near Vero Beach, Florida. Florida Sci. 46:212-232.

Megard, R.O. 1972. Phytoplankton, photosynthesis, and phosphorus in Lake Minnetonka, Minnesota. Limnol. Oceanog. 17:68-87.

Peterson, C.H., P.B. Duncan, H.C. Summerson, and G.W. Safrit, Jr. 1983. A mark-recapture test of annual periodicity of internal growth band deposition in shells of hard clams, Mercenaria mercenaria,from a population along the southeastern United States. Fishery Bull. 81:765-779.

Reish, D.J., and M.L. Hallisey. 1983. A check-list of the benthic macroinvertebrates of Kennedy Space Center, Florida. Florida Scient. 46:306-313.

Riley J.P., and R. Chester. 1971. Introduction to Marine Chemistry. Academic Press, London and New York.

Ryther, J.H. 1956. The measurement of primary production. Limnol. Oceanog. 1:72-84.

Ryther, J.H., and D.W. Menzel. 1965. On the production, composition, and distribution of organic matter in the Western Arabian Sea. Deep-Sea Res. 12:199-209.

Strickland, J.D.H., and T.R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Fish. Res. Board Can., Ottawa, 310 pp.

Tenore, K.R., and W.M. Dunstan. 1973. Comparison of feeding and biodeposition of three bivales at different food levels. Marine Biol. 21:190-195.

Thomas, J.R. 1974. Benthic species diversity and environmental stability in the northern Indian River, Florida. M.S. Thesis. Florida Institute of Technology, Melbourne.

Tietjen, J.H. 1968. Chlorophyll and pheo-pigments in estuarine sediments. Limnol. Oceanog. 13:189-192.

Virnstein, R.W., P.S. Mikkelsen, K.D. Cairns, and M.A. Capone. 1983. Seagrass beds versus sand bottoms: The trophic importance of their associated benthic invertebrates. Florida Scient. 46:363-381.

Walker, R.L., and K.R. Tenore. 1984. The distribution and production of the hard clam, Mercenaria mercenaria, in Wassaw Sound, Georgia. Estuaries 7:19-27.

Weiderhold, C.N. 1976. Annual cycles of macrofaunal benthic invertebrates in the northern Indian River, Florida. M.S. Thesis. Florida Institute of Technology, Melbourne.

Williams, P.J. le B., K.R. Heinemann, J. Marra, and D.A. Puerdie. 1983. Comparison of ^{14}C and O_2 measurements of phytoplankton production in oligotrophic waters. Nature 305:49-50.

Young, D.K., and M.W. Young. 1977. Community structure of the macrobenthos associated with seagrass of the Indian River Estuary, Florida, pp. 359-381. In: B.C. Coull (ed), Ecology of Marine Benthos. University of South Carolina Press, Columbia.

APPENDIX A

ANNOTATED BIBLIOGRAPHY

ON

BIVALVES AND PHYTOPLANKTON

ON THE

INDIAN RIVER ESTUARY

1. Applied Biology, Inc. 1980. Biological and Environmental Studies at the Florida Power and Light Company Cape Canaveral Plant and the Orlando Utilities Commission Indian River Plant. Volume 2. 641 DeKalb Industrial Way, Atlanta, GA.

Quarterly sampling from December 1978 to September 1979 at 48 stations near Titusville by box coring (15 cm x 15 cm x 15 cm). Four replicates per station with each replicate core halved and then pooled (=0.05 m^2).

The fauna was dominated by eurytopic and opportunistic species. The most common species in all vegetated habitats was a mussel, Brachidontes exustus, while in unvegetated habitats an ostracod, Parasterope pollex, was most common.

Manatee grass supported the richest fauna followed by, in descending order, the shoal grass, drift algae, channel and sand habitats. Although manatee grass supported the greatest number of species per unit area, drift algae supported the highest total number of species and over-all species richness. Because drift algae was much more abundant then either of the grasses, it is probably the primary vegetation habitat for benthic macroinvertebrates. Although different habitats shared many species in common, shifts in the relative commonness of species with habitat caused the community structure of each habitat to be unique. The most distinct habitat in terms of species composition was the channel.

No north-south gradient in the distribution of the fauna was observed, but the east shore generally supported a richer fauna than the west shore. The difference between the shores was a natural phenomenon unrelated to power plant operation. Channel communities in the Cocoa Pool were characterized by low diversity, species density, and faunal density. Areas within the Canaveral Pool were typically equivalent to, or richer than, areas within the Titusville and Cocoa Pools. Broad spatial variation in the fauna may largely reflect spatial variation in the nature of the substratum.

Impacts of the discharge plumes on species diversity, species evenness, species density, faunal density, and biomass were moderate and were spatially restricted. Species diversity was most affected by discharge plumes. Impacts on diversity were noted over the broadest area in June but were more intensive, over a smaller area, in December. A worst-case areal extent for plume impacts on diversity, as indicated by June data, was 245 ha. In cooler months (December, March and September) the maximum area impacted was considerably smaller, about 142 ha. Impacts were never pervasive within affected areas and, at times, relatively high diversities were observed within 100 m of the discharges. For channel communities, species diversity, species density, and faunal density were not adversely affected by the discharge plumes. Thus, adverse impacts apparently did not extend beyond the 6-ft depth contour.

Impact on faunal density was limited to a much smaller area than impact on diversity. The maximum areal extent for impact on faunal density was about 142 ha. Natural variation in biomass was so great that no zone of impact could be delineated. The spatial variation in faunal density and biomass suggests that combined effects between the two plant discharges, which were limited to a moderate depression of species diversity at certain stations, were of little ecological significance.

The distributions of the most common species substantiated the limited extent of discharge plume effects. For most of these species, population densities in areas exposed to the discharges were not signficantly different from densities in areas not exposed to the discharges. All species whose population densities were affected by the discharges exhibited significantly altered densities only in the immediate vicinity or the discharges. In the area on the west shore where combined effects between the discharges might be expected, no species examined showed significantly altered density.

Bivalves found:	Abundance (units unknown)
Amygdalum papyrium	3093
Anadara transversa	51
Anomalocardia alberiana	884
Brachidontes exustus	69001
Chione cancellata	195
Cyrtopleura costata	2
Laevicardium mortoni	394
Lyonsia hyalina	176
Macoma brevifrons	10
Macoma tenta	2
Mercenaria sp.	6
Mulinia lateralis	13037
Musculus lateralis	3
Mysella planulata	3620
Nucula proxima	162
Parastarte triquetra	1132
Parvilucina multilineata	28
Tagelus divisus	241
Tellina sybaritica	6
Tellina tampaensis	1309
Tellina versicolor	269

2. Brevard County Environmental Engineering Dept. (Mr. Conrad White, per. comm.). 1975-1981.

The most complete data on shellfish populations for the Indian River estuary are quarterly and yearly samples taken since 1975 (1975-1981 period had shellfish identified) by Brevard County Environmental Engineering Department. Mr. Conrad White kindly provided the following data on the County's shellfish program. Two shallow water stations sampled yearly are (i) Sebastian River confluence with Indian River, and (ii) north of the SR 528 bridge; four shallow water stations sampled quarterly are: (i) Mosquito Lagoon; (ii) Titusville; (iii) Banana River; and (iv) Malabar. Various sampling devices were used, including Petersen, Ponar, and Smith-McIntyre types.

Station 550: Banana River north of S.R. 528 between 4th and 5th power poles east of west shore. Water Depth 2.0 m. Petersen (0.1 m^2). 3 replicates and composited.

Species	No. Individuals/m^2
2/15/77	
Amygdalum papyrium	3
Brachidontes exustus	3
Laevicardium sp.	17
Mulinia lateralis	7
Tellina sp. A	10
2/7/78	
Anomalocardia auberiana	50
Laevicardium mortoni	3
Mulinia mortoni	30
Parvilucina multilineata	3
Tellina sp. A	106
Tellina sp. E	10

Species	No. Individuals/m^2
6/17/80 (3 replicates taken with modified Smith-McIntyre dredge)	
Amygdalum papyrium	20
Anomalocardia cuneimeris	10
Brachidontes exustus	360
Tellina versicolor	20
Tellina sp. B	10
Thracia sp. 1	60

Station .0874: Mosquito Lagoon, 125-150 ft. east of CM 41. Water Depth 1.0 m. Petersen (0.1 m^2). 3 replicates and composited.

Species	No. Individuals/m^2
2/25/78	
Mulinia lateralis	43
Nucula proxima	7
Tellina sp. A	23
Unidentified	3
2/13/78	
None found	
2/13/79	
No species data	
6/26/80 (Modified Smith-McIntyre dredge): 1 sample)	
Brachidontes exustus	2
Tagelus divisns	2

9/13/82 (Modified Smith-McIntyre dredge: 1 sample)

Species	No. of individuals/m^2
Amygdalum papyrium	4
Anomalocardia cuneimeris	20
Brachidontes exustus	1
Nucula proxima	2
Mulinia lateralis	12
Tellina sp. B	3
Venus juvenile	1

Station .0876: Titusville west of CM 30. Water Depth 2.5 m. Petersen (0.1 m^2). 3 replicates and composited.

Species	No. of Individuals/m^2
2/25/77	
Nucula proxima	13
Tellina sp. A	3
Unidentified	67
2/13/78	
Anomalocardia auberiana	67
Brachidontes exustus	3
Mulinia lateralis	76
Nucula proxima	23
Tellina sp. a	33
Tellina sp. E	13
6/16/80 (Modified Smith-McIntyre dredge: 3 replicates)	
Mulinia lateralis	150
Nucula proxima	10
Unidentified	60

9/14/82 (Grissile/Stigner: $0.1m^2$, 1 sample)

Species	No. of Individuals/m^2
Mulinia lateralis	30

Station .0878: Malabar 200-250 yds east of CM 20 (CM 21 and 22 in line, and CM 23 in line with large white billboard on U.S. 1). Water depth 2.3 m. Petersen ($0.1\ m^2$). 3 replicates and composited.

Species	No. of Individuals/m^2
1/31/78	
Mulinia lateralis	3,333
Unidentified	10
8/26/80 (Modified Ponar: 3 replicates)	
Amygdalum papyrium	28
Anadara transversa	14
Mercenaria campechiensis	14
Rangia cuneata	126

Station .0335: Confluence of Indian and Sebastian Rivers 100 ft. east of CM 61 Water depth 2.4 m. Petersen dredge ($0.1\ ft^2$). 3 replicates.

Species	No. of Individuals/m^2
11/14/73	
Arca sp. A	14
Arca sp. B	4
Astarte nana	4
Chione sp.	22
Corhula caribaea	4
Corbula sp. A	7
Corbula sp.	11

Station .0335 (continued)

Species	No. of Individuals/m^2
Donax sp.	220
Eucrassatella speciosa	4
Macoma sp.	54
Unidentifed Sp. A	18
Unidentified sp. B	68
Unidentified sp. C	11
Unidentified sp. D	4
Unidentifed sp. E	4
Unidentified sp. F	14
Tagelus divisus	4
1/16/74 (6" square Ponar dredge: 3 replicates)	
Astarte sp.	56
Chione sp.	42
Donax sp.	695
Macoma sp.	83
Musculus	14
Tagelus divisus	14
Unidentified sp. A	445
Unidentified sp. B	139
Unidentified sp. C	28
Unidentified sp. E	14
5/1/74 (Petit Ponar: 3 replicates)	
Arca sp.	14
Anomia simplex	14
Chione sp.	70
Donax sp.	14

5/1/74 Station .0335 (continued)

Species	No. of Individuals/m^2
Sphenia antillensis	83
Tagelus divisus	28
Unidentified sp. A	681
Unidentififed sp. B	70
Unidentified sp. C	14
7/17/74 (Petit Ponar: 3 replicates)	
Arca sp.	14
Anomia simplex	56
Chione sp.	14
Corbula sp. A	112
Corbula sp. B	42
Donax sp.	14
Sphenia antillensis	154
Tellina sp.	70
Venus	14
11/6/74 (Petit Ponar: 3 replicates)	
Donax sp.	306
Macoma sp. A	778
Macoma sp. B	83
Tellina sp.	288
Venus sp. A	83
Venus sp. B	28

2/5/75 (Petit Ponar: 3 replicates)

Species	No. of Individuals/m^2
Macoma sp. 1	336
Macoma sp. 1	168
Sphenia antillensis	28
Tellina sp. 1	168
Tellina sp. 2	14
5/21/75 (Ponar dredge: 3 replicates)	
Arca sp.	14
Lunatia sp.	14
Macoma sp. 1	588
Macoma sp. 3	42
Tagelus divisus	140
Venus sp. 1	28
8/19/75 (Petersen: 0.1 m^2; 3 replicates)	
Amygdalum papyrium	3
Anadara transversa	50
Chione sp.	3
Corbula sp.	7
Mulinia lateralis	23
Nucula sp.	7
Tagelus divisus	73
Tellina sp. A	218
Tellina sp. B	116
Unidentified	10

2/17/76 (Petersen: 3 replicates)

Species	No. of Individuals/m^2
Chione sp.	10
Nucula proxima	23
Tellina sp. A	320
Tellina sp. B	33
Unidentififed	7

5/10/76 (Petersen grab: 3 replicates)

Barbatia domingensis	99
Chione sp.	10
Lucina nassula	3
Mulinia lateralis	7
Nucula proxima	10
Tagelus divisus	92
Tellina sp. A	158
Tellina sp. B	257
Sphenia	7
Unidentified	56

12/20/76 (Petersen grab: 0.1 m^2; 3 replicates)

Barbatia domingensis	13
Corbula sp.	10
Tellina sp. A.	7
Tellina sp. B	23
Unidentified	7

2/2/77 (Petersen grab: 0.1 m^2; 3 replicates)

Corbula sp.	16
Tellina sp. A	132
Tellina sp. B	50

5/17/77 (Petersen grab: 3 replicates)

Species	No. of Individuals/m^2
Barbatia domingensis	26
Chione sp.	13
Corbula sp.	7
Lucina nassula	7
Mulinia lateralis	7
Tagelus plebius	13
Tellina sp. A	109
Tellina sp. B	10
Unidentified	10

8/23/77 (Petersen grab: 0.1 m^2; 3 replicates)

Chione sp.	7
Corbula sp.	20
Mulinia lateralis	10
Parvilucina multilineata	3
Nucula proxima	23
Tagelus plebius	89
Tellina sp. A	28
Tellina sp. C	16
Tellina sp. D	20
Tellina sp. F	3

11/15/77 (Petersen grab: 0.1 m^2; 3 replicates)

Amygdalum papyrium	3
Anadara transversa	3
Barbatia	10
Corbula sp.	17

11/15/77 (continued)

Species	No. of Individuals/m^2
Lucina sp. B	3
Mulinia lateralis	27
Parvilucina multilineata	3
Sphenia	3
Tabelus plebeius	10
Tellina sp. A	27
Tellina sp. C	7
Tellina sp. D	583
Trachycardium muricatum	3
Unidentified	30
1/31/78 (Petersen: 0.1 m^2; 3 replicates)	
Anadara transversa	20
Barbatia sp.	7
Chione sp.	7
Corbula sp.	3
Mulinia lateralis	30
Nucula proxima	13
Tellina sp. A	127
Tellina sp. C	110
Tellina sp. D	293
Unidentified	10
5/22/78 (Petersen: 0.1 m^2; 3 replicates)	
Anadara transversa	63
Barbatia sp.	17
Chione sp.	14

5/22/78 (continued)

Species	No. of Individuals/m^2
Corbula sp.	13
Mulinia lateralis	17
Nucula proxima	10
Sphenia	7
Tagelus plebeius	133
Tellina sp. A	233
Tellina sp. C	183
Tellina sp. D	153
Unidentified	6
7/20/78 (Petersen: 0.1 m^2; 3 replicates)	
Anadara transversa	10
Corbula sp.	7
Mulinia lateralis	23
Parvilucina multilineata	10
Tagelus plebeius	23
Tellina sp. A	57
Tellina sp. C	27
Tellina sp. D	47
Trachycardium muricatum	10
Unidentified	37
12/13/78 (Grab sample: 0.08 m^2; 3 replicates)	
Chione sp.	32
Corbula sp.	16
Mulinia lateralis	4
Nucula proxima	12

12/13/78 (continued)

Species	No. of Individuals/m^2
Parastarte triquetra	16
Parvilucina multilineata	4
Tellina sp. A	136
Tellina sp. C	12
Tellina sp. D	56
Unidentified	20
1/30/79 (Grab sample: 0.08 m^2; 3 replicates)	
Amygdalum plebeius	8
Anadara transversa	4
Anomalocardia auberiana	4
Chione sp.	56
Corbula sp.	20
Mulinia lateralis	108
Nucula proxima	44
Parvilucina multilineata	12
Tagelus plebeius	8
Tellina sp. A	92
Tellina sp. C	56
Tellina sp. D	384
Unidentified	24
5/22/79 (Grab sample: 0.08 m^2; 3 replicates)	
Anadara transversa	4
Barbatia sp.	4
Chione sp.	68
Mulinia lateralis	136

5/22/79 (continued)

Species	No. of Individuals/m^2
Nucula proxima	16
Parvilucina multilineata	4
Tagelus plebeius	196
Tellina sp. A	60
Tellina sp. C	32
Tellina sp. D	16
Trachycardium muricatum	4
Unidentified	52

8/21/79 (Grab sample: 0.08 m^2; 3 replicates)

Corbula sp.	12
Chione sp.	24
Mulinia lateralis	56
Parvilucina multilineata	4
Tagelus plebeius	84
Tellina sp. A	24
Tellina sp. C	48
Tellina sp. D	32
Unidentified	24

6/10/80 (Modified Smith-McIntyre dredge; 3 replicates)

Anadara transversa	80
Chione sp.	20
Chione cancellata	10
Diplodonta nucleiformis	60
Lucina	40
Mulina lateralis	140

6/10/80 (continued)

Species	No. of Individuals/m^2
Tagelus divisus	130
Tellina sp. A	50
Tellina sp. C	390
Solen viridis	10
Tellina sp. D	25
Tellina versicolor	340
Unidentifi	90

8/26/80 (Modified Smith-McIntyre dredge: 0.10 m^2; 3 replicates)

Anadara transversa	30
Corbula contracta	40
Lucinia proxima	10
Macoma sp.	10
Mulinia lateralis	40
Phyllodina squamifern	50
Nucula proxima	10
Rangia cuneata	10
Thracia sp.	170
Tagelus divisus	120
Tellina versicolor	60
Tellina sp. A	10
Tellina sp. B	30
Tellina sp. C	100
Tellina sp. D	80

10/28/80 (Modified Smith-McIntyre dredge: 0.10 m^2; 3 replicates)

Species	No. of Individuals/m^2
Chione sp.	30
Cumingia coarctata	10
Cyclinella tenuis	20
Macoma sp.	10
Mulinia lateralis	1,040
Nucula proxima	70
Pitar aresta	10
Phyllodina squamifera	190
Rangia cuneata	10
Tellina sp. A	540
Tellina sp. B	110
Tellina sp. C	50
Tellina sp. D	70
Tellina sp. F	50
Thracia sp.	200
Unidentified	30

Data for Station .0581 at S.R. 528, north of bridge between 1st and 2nd unbuffered power poles east of ICW (11/10/75 thru 1/19/81 (quarterly samples) will be examined during the latter part of the study period (Mar.-Sept.) when shellfish sampling is in progress.

3. Grizzle, R.E. 1979. A preliminary investigation of the effects of enrichment on the macrobenthos in an east-central Florida lagoon. Florida Scient. 42:33-42.

Macroinvetebrate collections were made at 6 stations in lower Sykes Creek in July 1975 and in February 1976 near the City of Cocoa and 1 station each in the Indian (September 1975 and March 1976) and Banana River (January and July 1975) lagoons, using a 0.1 m^2 Peterson grab. Three to 5 grabs were taken at each station per sampling occasion and pooled for a composite sample. Each sample was sieved through a 0.42 mm mesh (U.S. Standard No. 40) and the residue fixed in a 5% formalin solution with rose bengal added. Animals were sorted in the laboratory and preserved in 80% EtOH. All specimens were identified, generally to species, and enumerated. Wet weights were made of all speciments by group from each sorted sample by blotting the specimens dry on paper then weighing on a Mettler balance. Molluscs were not removed from their shells before weighing. Sediment samples were taken from the contents of one of the replicate samples on one sampling occasion and analyzed for grain-size distribution (silt-clay particles < 62 μm; sand particles > 62 μm; shell > 1 or 2 mm mesh) and organic content (% volatile).

Sykes Creek stations showed great temporal variability than did the controls in almost all macrobenthic parameters measured (i.e., species diversity, density, biomass, and species ratio differences). Sykes Creek stations also had decreased species numbers and diversity values and a predominance of opportunistic species.

Bivalves found:

Anomalocardia auberiana

Parastarte triquetra

Amygdalum papyrium

Tagelus plebeius

Brachidontes exustus

4. Heffernan, J.H., and R.A. Gibson. 1983. A comparison of primary production rates in Indian River, Florida seagrass systems. Florida Scient. 46:295-306.

Three sites in the Indian River (Jim Island, Link Port, and Vero Beach) were studied to determine primary production in seagrass meadows. Four to six 3-hr incubations were made during spring and summer of 1981. Productivity estimates were determined using radiocarbon techniques. The following primary productivity rates (mg C/m^2-h) were recorded (Percent relative standard deviations are in parenthesis).

	Jim Island		Link Port		Vero Beach
	March	July	March	July	July
Benthic microalgae	1.66(22.9)	3.30(21.5)	33.8(24.2)	28.9(23.6)	15.0(19.2)
Phytoplankton	0.21(20.6)	2.48(19.0)	1.43(51.5)	2.99(20.0)	7.22(4.9)

Benthic microalgae contributed significantly to community productivity in Indian River seagrass beds. During March this fraction accounted for 80-95% of the primary productivity within the various seagrass beds at Jim Island and Link Port. During July this group was the largest contributing component in Vero Beach grass beds. Benthic microalgae had a greater impact on primary productivity at Link Port and Vero Beach than at Jim Island. Sites farther from ocean inlets (i.e., Link Port and Vero Beach) typically had reduced light regimes and current velocities. Sediment microflora proliferate in shallow, sluggish backwater areas with little water movement, high nutrient concentrations and poor light regimes, and actually may be adapted to seemingly stressful conditions. (Round, F.E. 1971. Benthic marine diatoms. Oceanogr. Mar. Biol. Rev. 9:83-139; Jones, R.C. 1980. Productivity of algal epiphytes in a Georgia salt marsh: Effect of inundation frequency and implications for total marsh productivity. Estuaries 3:315-317). Vero Beach and Link Port more closely

satisfied these conditions than Jim Island which characteristically exhibited high flushing rates, low nutrient concentrations and high light penetration.

Phytoplankton had their greatest productivity rates and contribution to overall community production in July at Vero Beach. Phytoplankton values were also higher at Link Port than Jim Island. Though the number of sampling periods was limited, this agreed with trends of chlorophyll a, phytoplankton cell abundance and productivity measurements taken during the Indian River Coastal Zone Study (Gibson, unpubl. data). Weekly measurements of these parameters from 1976 through 1978 showed values consistently highest at Vero Beach, lowest at Jim Island and intermediate at Link Port.

5. Levy, K.D. 1979. The response of the macrobenthos of Turkey Creek, Florida to salinity and other abiotic factors. M.S. Thesis. Florida Institute of Technology, Melbourne.

In the vicinity of Turkey Creek, the Indian River has essentially no flow and little tidal action. Water movement in this area is mostly the result of wind action (Barile, D.D. 1976. An environmental study of the Melbourne-Tillman Drainage District and an evaluation of alternate land use plans for the city of Palm Bay, Florida. M.S. Thesis. Florida Institute of Technology, Melbourne. 317 pp.).

Five stations were sampled in late January, April, July, and October, 1978. Only one station was in the Indian River. Three replicate samples were collected at each station using a coring device operated on the principle of a posthole digger which obtained an undistrurbed plug of sediment (15 cm x 15 cm x 10 cm = 2250 cm^3). The total area sampled at each station was 0.0675m^2 (1/15m^2). The contents of each sample were sieved through a 0.5 mm mesh screen and placed in a solution of approximately 5% $MgCl_2$ which served as a relaxant. Samples were fixed with 10% buffered formalin within 8 hours after collection. The formalin was replaced with 70% EtOH after a minimum of 24 hrs. Animals were then separated from the sieved samples by examination under a dissecting scope and identified to speices when possible. Reference for molluscs identification was Abbott (1974). Analysis of the data included the Canberra metric dissimilarity index and cluster analysis by flexible sorting. Sixty-one macrofaunal taxa were obtained from 60 samples collected during 1978. Nine of the taxa (none of them bivalves) accounted for over 77% of the 6,513 individuals collected; polychaetes were numerically dominant, representing 28.4% of the total number of individuals.

6. Mahoney, R.K., and R.A. Gibson. 1983. Phytoplankton ecology of the Indian River near Vero Beach, Florida. Florida Scient. 46:212-232

Weekly collections made during 1977 in the Indian River near Vero Beach produced the following total phytoplankton results:

	Annual Average	Monthly Range
1. total cell numbers	1.4×10^{10} cells/m^3	2.5×10^{9}-2.5×10^{10} cells/m^3
2. cell size	1.00×10^{3} μm^3	1.62×10^{2}-3.85×10^{3} μm^3
3. biomass	1.82×10^{12} $\mu m/m^3$	5.38×10^{11}-3.30×10^{12} $\mu m/m^3$
4. chlorophyll a	10.69 mg/m^3	1.7-15.6 mg/m^3

5. phytoplankton dynamics:

Spring: high diatom standing stock (Chaetoceros, Skeletonema, Nitzschia, Thalassiosira)

Summer: lower standing stock (decrease in diatoms and slight increases in flagellates and dinoflagellates)

Fall: increase in standing stock due to increase in nutrients from the release of agricultural water into the Indian River during high rainfall

Most total phytoplankton cell density fluctuations were due to variations in the diatom cell densities: the flagellate densities ranged over an order of magnitude during the years' cycle, whereas diatom cell densities range over nearly 3 orders of magnitude.

7. McHugh, J.L., M.W. Summer, P.J. Flagg, D.W. Lipton, and W.J. Behrens. 1982. Annotated bibliography of the hard clam (Mercenaria mercenaria). NOAA Technical Report NMFS SSRF-756. National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce, Rockville, MD.

One citation for the Indian River:

Woodburn, K.D. 1963. Survival and growth of laboratory-reared northern clams (Mercenaria mercenaria) and hybrids (M. mercenaria X M. campechiensis) in Florida waters. Proc. Natl. Shellf. Assn. 52:31-36.

Recorded hard clam production in Florida began in 1880, increased significantly in 1908 when large clam beds near the Ten Thousand Islands on the west coast were discovered, peaked in 1932, remained high through most of WW II and then plummeted to a low in 1950. Production has increased modestly since then. Hurricanes, red tides, fresh water, and mechanical harvesting have been blamed for disappearance of clam stocks in the Ten Thousand Islands area, but the cause has not been identified. Dense concentrations of hard shell clams on the west coast of Florida are found on firm, sticky mud bottoms with abundance of sea grasses, Thalassia testudinum or Diplanthera wrightii. Clam growth is not normally interrupted by winter temps as in northern waters. Clams were carried by air from Milford, Conn. and planted in screened boxes. Northern clams were 0.25 to 0.5 in. long and hybrids of male M. campechieusis and female M. mercenaria were 0.0625 to 0.125 in. long. At Sebastian in Indian River County 50% of hybrids and 10-15% of northern clams were dead 7 days after planting in Nov. 1960. By mid-June 1961 max. length of hybrids was 1.25 in., of northern clams 1.375 in. Salinities were 21 to 29%.

8. Reish, D.J., and M.L. Hallisey. 1983. A check-list of the benthic macroinvertebrates of Kennedy Space Center, Florida. Florida Scient. 46:306-313

A quarterly baseline study of benthic macroinvertebrates was conducted from December 1979 to March 1981 in brackish lagoons surrounding Launch Complex 39A at Kennedy Space Center and from December 1979 to December 1980 in the Banana River. Three replicate benthic grabs were taken with an Eckman Grab (15.24 cm x 15.24 cm x 15.24 cm) at each station. The samples were field-washed through a 0.5 mm sieve. The collected material was then placed in 10% buffered formalin for 48 to 72 hrs, transferred to 70% isopropyl alcohol, sorted, and identified. Bivalves found:

Amygdalum papyrium

Anomalocardia auberiana

Brachidontes exustus

Geukensia demissa

Geukensia d. granosissima

Laevicardium laevigatum

Laevicardium mortoni

Laevicardium sp.

Lyonsia hyalina floridana

Macoma constricta

Mulinia lateralis

Ostreidae unid.

Parastarte triquetra

Rangia cuneata

Tagelus divisus

Tagelus plebeius

Tagelus sp.

Tellina aeguistriata

Tellina mera

Tellina paramera

Tellina tampaensis

Tellina versicolor

Tellina sp.

Bivalvia unid.

9. Thomas, J.R. 1974. Benthic species diversity and environmental stability in the northern Indian River, Florida. M.S. Thesis. Florida Institute of Technology, Melbourne.

Sanders (1958. Benthic studies in Buzzards Bay I: Animal - sediment relationships. Limnol. Oceanogr. 3:245-258) and Nichols (1970. Benthic polychaete assemblages and their relationship to the sediment in Port Madison, Washington. Mar. Biol. 6:48-57) found the sediment, particularly the percentage of clay, to be the most significant correlate of faunal distributions in the benthos. Sanders (1958) and Bloom et al. (1972. Animal sediment relations and community analysis of a Florida estuary. Marine Biol. 13:43-56) related an optimum particle size to the distribution of suspension feeders. Nichols (1970) suggested the importance of the sorting of particle sizes to the diversity of polychaete assemblages. Sediment particle size and sorting coefficients are also probably related to the stability of the substrate and hence may be indicative of disturbances to that substrate although such use as indicators is of doubtful validity. McNulty et al. (1962. Some relationships between the infauna of the level bottom and the sediment in South Florida. Bull. Mar. Sci. Gulf Caribb. 12:322-332) suggest that sediments may play a less important role in shallow waters of Florida. That conclusion is supported in part by Bloom et al. (1972) in Tampa Bay, Florida.

Nichols (1970) concluded that the lower diversity among marine polychaete assemblages at the mouth of an estuary than at deeper stations in Puget Sound, Washington was the result of a shifting substrate and fluctuating salinities at the estuary mouth. In addition, the work of Rhoades and Young (1970. The influence of deposit feeding organisms on sediments stability and community

trophic structure. J. Mar. Res. 28:150-178) and Levinton (1972. Stability and trophic structure in deposit-feeding and suspension-feeding communities. The Am. Naturalist 106:472-486) suggests that the high diversity of deposit feeders as opposed to the low diversity of suspension feeders in benthic communities is a function of the predictability or constancy of food supply. Deposit feeders rely on a detritus sink in which nutrients may be rapidly recycled and which acts as a buffer against any fluctuations in the "rain" of detritus from above. Suspension feeders, on the other hand, are subjected to changes in food availability by currents and seasonal population changes.

Bottom samples from 15 stations (replicated five times and then pooled) were taken during June and July, 1973, with a Ponar grab ($0.05m^2$; depths 2-8 cm) along a 6.4 nautical mile north-south transect in the Indian River just north of Titusville. A sluice box was designed to take an aliquot equal to 1/5 the total area sampled by closing an inner gate subsequent to mixing, which should randomly distribute the organisms. After removal of the outer gate in the sluice box, the organisms were captured on a stack of screens; the smallest mesh size was 0.42 mm. Organisms were fixed in 10% buffered formalin after relaxation for 10-20 minutes in 6% $MgCl_2$. The formalin was replaced after a minimum of 24 hrs by 70% ethyl alcohol for preservation. Taxonomic nomenclature used for Mollusca followed Abbott (1954. American Seashells. D.V. Nostrand Co., Princeton, N.J., 541 pp), Andrews (1971. Seashells of the Texas Coast. Univ. of Texas Press, Austin. 298 pp), and Warmke and Abbott (1962. Caribbean Seashells. Livingston Publ., Wynnewood, PA. 348 pp). The mesh size (0.42 mm) of the sieves used, while smaller than that commonly used for benthic studies (1 mm), was still too coarse to adequately determine

total faunal diversity: 100% retrieval of Nemerteans and Molluscs; 95.5% for Polychaetes; 65.2% for Crustacea; and 3.75% for Nematodes (Reish. 1959. A discussion of the importance of screen size in washing quantitative marine bottom samples. Ecology 40:307-309).

The initial effort of the study was directed toward investigating species diversity with respect to those parameters which may place a physical stress on the benthic community: salinity, temperature, dissolved oxygen, nature of substrate, and depth (indirectly by buffering benthos against rapid or extreme fluctuation in the environment).

Although physical parameters of the sediment have been shown in other studies to be a significant determinant of the benthic community, the physical character of the sediment (i.e., median grain size, sorting coefficient, and % silt and clay) was shown to be sufficiently homogeneous so as to have little effect on the diversity and faunal distribution of the benthos over the length of the transect. No significant correlation ($\alpha = 0.05$) was observed in the regression of species richness on salinity but species richness was significantly correlated with sediment E_h. As the reducing environment of the sediment increased there is a resultant decrease in the number of species present. It appears, then, that the absence of the rooted vegetation to directly supply higher concentrations of dissolved oxygen in the face of high metabolic activity in the sediments limits the number of member species that can exist. In addition, seagrasses provide more stable sediments.

Water depth appears to be strongly correlated with species richness and eveness but in opposite directions. In the deeper water where grasses are absent and temperature and dissolved oxygen are lower, the amount of dissolved oxygen available for respiration serves to decrease the number of species and increase the evenness.

Rhoades and Young (1970) suggested a close relationship between deposit feeders and suspension feeders. The reworking of sediments by the burrowing activities of deposit feeders results in an unstable sediment surface layer that is easily resuspended by weak wave and current action. This unstable sediment layer may preclude the presence of large numbers of suspension feeders through the reduction of stable attachment sites, clogging of gills or other respiratory sturctures, and burying of newly settled larvae. Trophic exclusion was found in the study at the biologically accommodated stations (i.e., not limited by physical parameters) where increasing percentages of suspension feeders were correlated with decreasing percentages of deposit feeders. For physically controlled stations (i.e., low dissolved oxygen and redox), trophic exclusion was not found.

Molluscs found:

1. Pelecypoda

a.	*Gemma* sp.	4	individuals	along	15-station	transect
b.	*Tagelus divisus*	1	"	"	"	"
c.	*Lyonsia hyalina*	27	"	"	"	"
d.	*Chione cancellata*	6	"	"	"	"
e.	*Brachidontes exustus*	241	"	"	"	"
f.	*Amygdalum papyria*	3	"	"	"	"
g.	*Nucula proxima*	3	"	"	"	"
h.	*Mulinia lateralis*	174	"	"	"	"
i.	*Tellina* sp.	10	"	"	"	"
j.	*Laevicardium* sp.	7	"	"	"	"
k.	*Anomalocardia cuneimeris*	3	"	"	"	"

10. Virnstein, R.W., P.S. Mikkelsen, K.D. Cairns and M.A. Capone. 1983. Seagrass beds versus sand bottoms: The trophic importance of their associated benthic invertebrates. Florida Scient. 46:363-381.

Samples were taken from caged and adjacent natural uncaged sand and seagrass with a post-hole type sampler which removed a sediment core 15 x 15 x 15 cm along with any overlying seagrass and animals, which are retained by 0.5-mm mesh sieve covering the top. A sample consisted of 4 replicate cores from each habitat -2 from each cage - to account for variation between cages. Samples were sieved on a 0.5-mm mesh sieve, relaxed in 0.3% propylene phenoxytol in seawater (McKay and Hartz band 1970), fixed for 24 hrs in 10% formalin in seawater with the vital stain rose bengal added (Mason and Yevich 1967), then transferred to 70% ethanol for storage. Samples were sorted under a dissecting microscope, and retained animals were identified to lowest possible taxon. To test for significant differences in mean abundance between pairs of samples, t-tests were used.

Not only are densities of macrofauna much greater in seagrass than in sand, but those animals which are more abundant in seagrass (the epifauna especially) are also more heavily preyed on, and thus are trophically more important than the infauna of seagrass. The epifaunal macrobenthos of seagrass meadows form an important trophic pathway to higher predators via the decapods. Although absolute predation intensities remain unknown, the primary pathway of transfer to higher trophic levels differs between the 2 habitats - though the epifauna in seagrass meadows, and through the infauna in bare sand bottoms.

Bivalves found in 1.26 m^2 sampled seagrass and bare sand substrate:

1.	*Parastarte triquetra*	145	individuals
2.	*Chione cancellata*	53	individuals
3.	*Amygdalum papyrium*	32	"
4.	*Mercenaria mercenaria*	38	"
5.	*Mysella* sp.	25	"
6.	*Crassostrea virginica*	11	"
7.	*Anadara transversa*	7	"
8.	*Lyonsia floridana*	8	"
9.	*Mulinia lateralis*	9	"
10.	*Tellina tampaensis*	10	"
11.	*Tagelus plebeius*	5	"
12.	*Tellina mera*	5	"
13.	*Musculus lateralis*	4	"
14.	*Abra aequalis*	6	"
15.	*Macoma tenta*	3	"
16.	*Sphenia antillensis*	5	"
17.	*Lucina pectinata*	2	"
18.	*Anomalocardia auberiana*	2	"
19.	*Anomala simplex*	1	"
20.	*Corbicula contracta*	1	"
21.	*Nucula crenulata*	1	"
22.	*Macoma brevifrons*	1	"
23.	*Tellina versicolor*	1	"
24.	*Tellina* sp.	1	"
25.	*Tagelus divisus*	1	"
26.	unid. Bivalvia	4	"

11. Weiderhold, C.N. 1976. Annual cycles of macrofaunal benthic invertebrates in the northern Indian River, Florida. M.S. Thesis. Florida Institute of Technology.

A square sample grid 75m on a side was set up in water 1.0-1.5m deep in the Indian River near Kennedy Space Center. At the center and four corners of this grid, benthic core samples were taken with a 15.25 cm diameter ($0.76m^2$) corer. Core samples were obtained by divers using snorkels. The core sample was washed through a 1mm sieve and the retained material was relaxed in a 6% $MgCl_2$ solution for 10 to 20 min. The sample was then placed in a 10% buffered formalin solution for a minimum of 24 hrs, after which it was transferred to 70% ethyl alcohol for preservation until sorted. Monthly analysis of the 5 sample sites over a year's cycle. Taxonomic nomenclature followed Abbott (1954) and Andrews (1971; Seashells of the Texas Coast. University of Texas press, Austin, Texas, 298 pp).

Molluscs found:

1. Pelecypoda
   a. Pellina sp. 2-6mm; 2-10 individuals/core; density of bivalve coincided with sea grass density.
   b. Laevicardium mortoni 4-10mm; 2-4 individuals/core; density of bivalve coincided with sea grass density.
   c. Cylichna auberi 2-6mm; 0-10 individuals/core; density of bivalves coincided with sea grass density.
   d. Brachidontes exustus 2-12mm; 3-10 individuals/core; no pattern established with grass bed density.

2. Gastropoda

a. Marginella apicina 1-8mm; 5 indivuals/core; animal density did not coincide with sea grass density.

Most of the animals whose cycles coincided exactly with the grass bed density cycle were primarily suspension feeders. Suspension feeder cycles also tended to correlate strongly with plankton cycles by a lag of one month (Clark, K.B. 1975. Fourth Quarterly and Annual Report on the Indian River Ecological Study. Submitted to the Orlando Utilities Co., 56 pp), indicating that plankton may be an important alternate food source to these forms.

Because of the fine particle size, the sampling area supported a greater density of deposit feeders than suspension feeders. The inverse relationship between deposit feeders and suspension feeders supported Rhoads and Young (1970. The influence of deposit feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 128:150-178) hypothesis of trophic group exclusion or an amensalistic affect in which deposit feeders limit or eliminate groups of suspension feeders by reworking the bottom sediments, producing a fluid fecal-rich surface which is easily suspended by low velocity tidal currents. This instability tends to: 1) clog the filtering structure of suspension feeding organisms; 2) bury newly settled larvae or discourage the settling of suspension feeding larvae; and 3) prevent sessile epifauna from attaching to an unstable mud bottom.

12. Young, D.K., and M.W. Young. 1977. Community structure of the macrobenthos associated with seagrass of the Indian River Estuary, Florida, pp. 359-381. In: B.C. Coull (ed), Ecology of warine Benthos. University of South Carolina Press, Columbia.

Effects of predation on community structure of macrobenthos associated with dense stands of Halodule wrightii in the Indian River estuary in east central Florida were studied using cages. At the site characterized by a physically unstable and unpredictable environment, the increases of several species within the cage were in accord with predator-prey theory. At the other extreme, where the environment was more physically stable and predictable, increases in diversity of caged macrofauna was inconsistent with current hypotheses of biological interactions affecting community structure.

Bivalves found:

Brachidontes exustus

Amygdalum papyrium

Parastarte triquetra

Tellina tampaensis

Chione cancellata

Lyonsia hyalina floridona

Lucina pectinata

Tagelus plebeius

Anomalocardia anberiana

Macoma constricta

Macoma sp. A

Parvilucina multilineata

Laevicardium sp. A

Corbicula contracta

Tellina versicolor

Codakia orbicularis

Pteria colymbus

Anomia simplex

Mulinia lateralis

Tellina paramera

Crassostrea virginica

The following literature was also searched, but the contents were found not to be pertinent to the major emphasis of our proposed research:

Barnett, D. 1977. Factors influencing the distribution of gastropods living in a soft substrate intertidal area. M.S. Thesis. Florida Institute of Technology, Melbourne.

Theroux, R.B., and R.L. Wigley. 1983. Distribution and abundance of East Coast bivalve mollusks based on specimens in the National Marine Fisheries Service Woods Hole Collection. NOAA Technical Report NMFS SSRF-768. National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce, Rockville, MD.

Although this report is an excellent source on the geographical distribution, bathymetric occurrence, and occurrence according to sediment type for over 108,000 speciments of bivalve mollusks (5 subclasses, 8 orders, 46 families, 99 genera, and 164 species) collected over a period of 21 yrs., the geographic area covered is too broad to be of use for a specific area such as the Indian River Estuary.

Godcharles, M.F., and W.C. Jaap. 1973. Exploratory clam survey of Florida near shore and estuarine waters with commercial hydraulic dredging near. Professional Papers Series Number Twenty-one. Florida Dept. of Natural Resources, St. Petersburg, FL.

This survey addressed the distribution and abundance of commercial clams (*Mercenaria mercenaria*, *Mercenaria campechiensis*, *Macrocallista nimbosa*, *Rangia cuneata*), using hydraulic and escalator dredges at 846 stations along the west and southeast coasts of Florida, during 1970 and 1971. Only coastal nearshore waters were sampled in the Ft. Pierce area; no stations were located in the Indian River.

The following people were interviewed for their knowledge of prior bivalves/ phytoplankton studies on the Indian River estuary:

Dr. Llewlyn Erhardt Professor Biology Department University of Central Florida	- Reported no studies on bivalves conducted at UCF.
Mr. Carlton Hall Marine Ecologist Bionetics Kennedy Space Center	- No studies on shellfish sponsored by NASA.
Dr. S. Mahadevan Research Scientist Mote Marine Lab	- Prepared an annotated bibliography of published and unpublished benthic community studies conducted in Florida's coastal and estuarine waters; only 3 F.I.T. theses were cited for the Indian River.
Dr. Norman Blakes Professor and Dr. Bruce J. Barber Research Associate Dept. of Marine Science University of South Florida	- Applied to Gulf and South Atlantic Fisheries Development Foundation for a research grant entitled: "Stock Assessment, Growth and Reproduction and Transplant Survival of Hard Clams (*Mercenaria sp.*) in the Indian River, Florida." This study, if funded, would complement the research objectives of the Florida Institute of Technology/Harbor Branch Institute study. The stock assessment portion of their study is miniscule compared to our proposed population survey, but the growth, reproduction, and transplant survival aspects of their study will aid in interpreting our data for management implications.

APPENDIX B

NUMBERS ACCORDING TO SIZE CLASS (mm SHELL LENGTH) OF *MERCENARIA MERCENARIA* AND *MULINIA LATERALIS* COLLECTED ALONG TRANSECTS A, B, C AND D IN THE GRANT, MELBOURNE, AND MERRITT ISLAND AREAS OF THE INDIAN RIVER LAGOON.

SHELL LENGTH (mm)

Mercenaria mercenaria

	GRANT				MELBOURNE				MERRITT ISLAND			
	A	B	C	D	A	B	C	D	A	B	C	D
2.8-9.9	3.8	3.1	2.9	1.3	1	0.2	0.1	0.3	-	-	-	0.3
10.0-19.9	5.1	5.3	3.7	2.1	0.1	0.3	0.5	-	-	-	-	-
20.0-29.9	-	0.3	0.6	0.7	-	0.1	-	-	0.2	0.1	-	-
30.0-39.9	0.2	0.1	-	0.7	-	0.2	0.1	-	0.1	-	-	-
40.0-49.9	0.2	0.4	0.6	0.6	0.6	0.1	-	-	0.1	0.2	-	0.1
50.0-59.9	0.7	0.4	0.3	0.4	0.2	0.2	0.2	0.4	0.3	0.2	0.1	-
60.0-69.9	0.4	0.2	0.6	0.4	0.4	0.5	-	0.4	0.3	0.1	0.3	-
70.0-79.9	0.2	0.4	0.1	0.1	0.2	0.3	0.1	0.1	0.1	-	-	-
80.0-89.9	-	0.1	0.1	-	0.1	0.2	-	0.1	0.1	0.1	0.1	-
90.0-99.9	-	-	0.1	0.1	0.1	0.1	-	0.1	-	-	-	0.1
100.0-109.9	-	-	-	-	-	-	-	-	-	-	-	-
110.0-119.9	-	0.1	-	-	-	-	-	-	-	-	0.1	-

Mulinia lateralis

2.80-9.99	45	34	43	67	509	818	684	416	328	1007	924	904
10.0-20.0	9	10	6	6	1	8	19	29	0.3	0.2	0.1	2

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