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# Florida Department of Natural Resources

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FLORIDA MARINE RESEARCH PUBLICATIONS

Number 34

# Nearshore Marine Ecology at Hutchinson Island, Florida: 1971-1974



**1979**

**Florida Department of Natural Resources**
**Marine Research Laboratory**

**100 Eighth Avenue SE** **St. Petersburg, Florida 33701**

# VI. Plankton Dynamics, 1971-1973

## ABSTRACT

Walker, L. M. and K. A. Steidinger. 1979. Nearshore Marine Ecology at Hutchinson Island, Florida: 1971-1974. VI. Plankton Dynamics, 1971-1973. Fla. Mar. Res. Publ. No. 34. Pp. 1-15. Two years of phytoplankton, zooplankton and physicochemical data for the western Atlantic off Hutchinson Island, Florida, indicate the dynamic composition of these nearshore waters. Oceanic influences, as judged by plankton composition and abundance, were most obvious in winter and summer. Estuarine influences from the Indian River system were correlated with time of collection and tidal cycles. The estuarine discharge and associated higher inorganic nutrient (e.g. $SiO_2$-Si means of 6.77 to 8.90 $\mu$g-atoms/liter) and higher suspended particulate loads appeared to substantially affect stations closest to the inlet. The shoal station (III) which was furthest from shore was the least influenced. Combined inorganic nitrogen values (means of 1.40 to 2.87 $\mu$g-atoms/liter) and high orthophosphate values (means of 3.16 to 6.79 $\mu$g-atoms/liter) accounted for low N:P ratios of between 1 and 2. Surface chlorophyll *a* minus phaeopigment values (means of 1.02 to 2.34 $mg/m^3$) and primary production estimates (means of 0.26 to 0.46 g $C/m^2$/day) suggest that this fluctuating environment is moderately productive. Plankton species composition reflected strong Caribbean and North Equatorial affinities with many of the species being tropical-subtropical or cosmopolitan. Pelagic plankton in relation to tidal cycles and current structure demonstrates the transient nature of these organisms. The presence and diversity of benthic diatoms in oblique net hauls and high chlorophyll *a* in bottom waters (1.47 to 2.86 $mg/m^3$ station means) implies that a resident or transient phytomicrobenthic flora may be more significant to higher trophic levels in the sampling area than pelagic phytoplankton. These data are presented as part of a "base-line" study to characterize the nearshore waters off Hutchinson Island prior to the operation of the Florida Power and Light Company's St. Lucie Power Plant Unit #1.

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## INTRODUCTION AND RATIONALE

Plankton and hydrographic analyses off Hutchinson Island, Florida, were conducted at five permanent stations (Figure 1) as an integral part of a "base-line" study designed to provide hydrographic, floristic and faunistic data for a nearshore environment immediately adjacent to a proposed nuclear power unit (St. Lucie Unit #1). The structure of the entire study as well as the physical nature of the sampling area determined the extent of parameters measured. Water chemistry, current structure, sediment type, pelagic and benthic assemblages demonstrate the dynamic composition of these nearshore waters.

The purpose of the plankton study was to define the pelagic realm and influencing physicochemical parameters. Chlorophyll *a* (minus phaeopigments) was used as a measurement of phytoplankton biomass or standing stock. Net phytoplankton (202 $\mu$m mesh) was collected to delineate oceanic intrusion and possibly provide indicator species data. A prerequisite for oceanic indicator species is that they be easily identifiable; larger diatoms and dinoflagellates caught in net hauls meet this criterion. Filtration of large volumes of water was required to catch these less abundant oceanic phytoplankters. Photosynthetic nannoplankton was accounted for in chlorophyll *a* biomass estimates; however, quantitative species composition or percent composition (nannoplankton versus net plankton) were not differentiated. Smaller mesozooplankters and larger microzooplankters were numerically quantified from the same metered net haul for major group categories, copepod genera and selected species. These numerical standing stock estimates were used to compare Hutchinson Island data with other coastal areas and to assess possible indicator taxa. Gross primary productivity estimates provide data for comparison purposes on a regional basis. Basic inorganic macronutrients (N, P, Si) were determined to evaluate within sample correlations, to project seawater "fertility" and to characterize influencing water masses. Temperature and salinity data were recorded to express observed ranges for each taxon and, therefore, indicate potential tolerances. Other parameters such as phaeopigments and carotenoid-chlorophyll *a* ratios were determined as auxiliary data.

The first two years' data were based on diurnal collections at five stations; the third year included monthly diel sampling at only three stations. The diel data are presented separately. Recent advances in seawater "fertility" analyses, plankton physiology and plankton interrelationships have revealed complexities of interactions (temporally and spatially) and the difficulties in evaluations of such interactions. These advances will be taken into account in discussing proposed sampling programs.

## METHODS AND MATERIALS

Single plankton tows (0.5 m opening, 202 $\mu$m mesh, 5:1 length) were taken in a wide circle over each fixed station at a speed of about 1-2 kn. Bimonthly collections were taken from September 1971 through August 1972; monthly collections were from September 1972 through August 1973. The haul was step-oblique, 5 min. near the bottom and 5 min. at the surface. A General Oceanics Flowmeter Model 2030 was attached slightly off center for filtered seawater volume estimates. The net was backwashed between tows to avoid clogging. Single hauls can introduce a reported variation of 23 to 50% (UNESCO, 1968); however, the circular path, large volume filtered, step-oblique tow and five stations in a small area were judged to be representative for estimates and comparisons. Plankton samples were preserved in buffered 5% seawater-formalin. Laboratory analyses typically involved subsamples from 0.01 ml to 10 ml, depending on the taxon being counted; at least 100 specimens of the dominant taxon(a) were counted in gridded or lined petri dishes. Usually two random rows of 5 squares each were observed for the zooplankton, while whole aliquots were observed for the phytoplankton (see Walker, et al., 1979 and Tester and Steidinger, 1979 for details). Methods used for collection and analyses followed those recommended by UNESCO, 1968; Edmondson and Winberg, 1971; Schlieper, 1972; Slack et al., 1973.

Basic inorganic nutrient analyses ($NO_3$-N, $NO_2$-N, $NH_3$-N, $PO_4$-P, $SiO_2$-Si) were contracted to the University of South Florida Marine Science Institute for determination by Autoanalyzer techniques (Environmental Protection Agency, 1971). Samples were immediately preserved with mercuric chloride, kept at ambient temperature, filtered back at the field laboratory (Jensen Beach, Florida) and then refrigerated for "cooler" transport to St. Petersburg for analyses. Monthly nutrient analyses were initiated in February 1972.

Chlorophyll *a* was determined by the spectrophotometric methods outlined in UNESCO (1966) and Lorenzen (1967). Water samples were brought to the field laboratory, filtered, ground, extracted with 90% acetone and analyzed immediately or stored in the refrigerator for less than 1 hour. A Bausch and Lomb Model 70 Spectrophotometer with 5 cm light-path length cells was used. Formulae used were those of Lorenzen (1967) to differentiate between chlorophyll *a* and its phaeopigments. Carotenoids at 480 nm (Strickland and Parsons, 1968) were determined at the same time. Bimonthly, and later monthly, chlorophyll *a* analyses were initiated in November 1971 while carotenoids were started in September 1972.

Gross primary productivity was derived from chlorophyll *a* and light data using the Ryther and

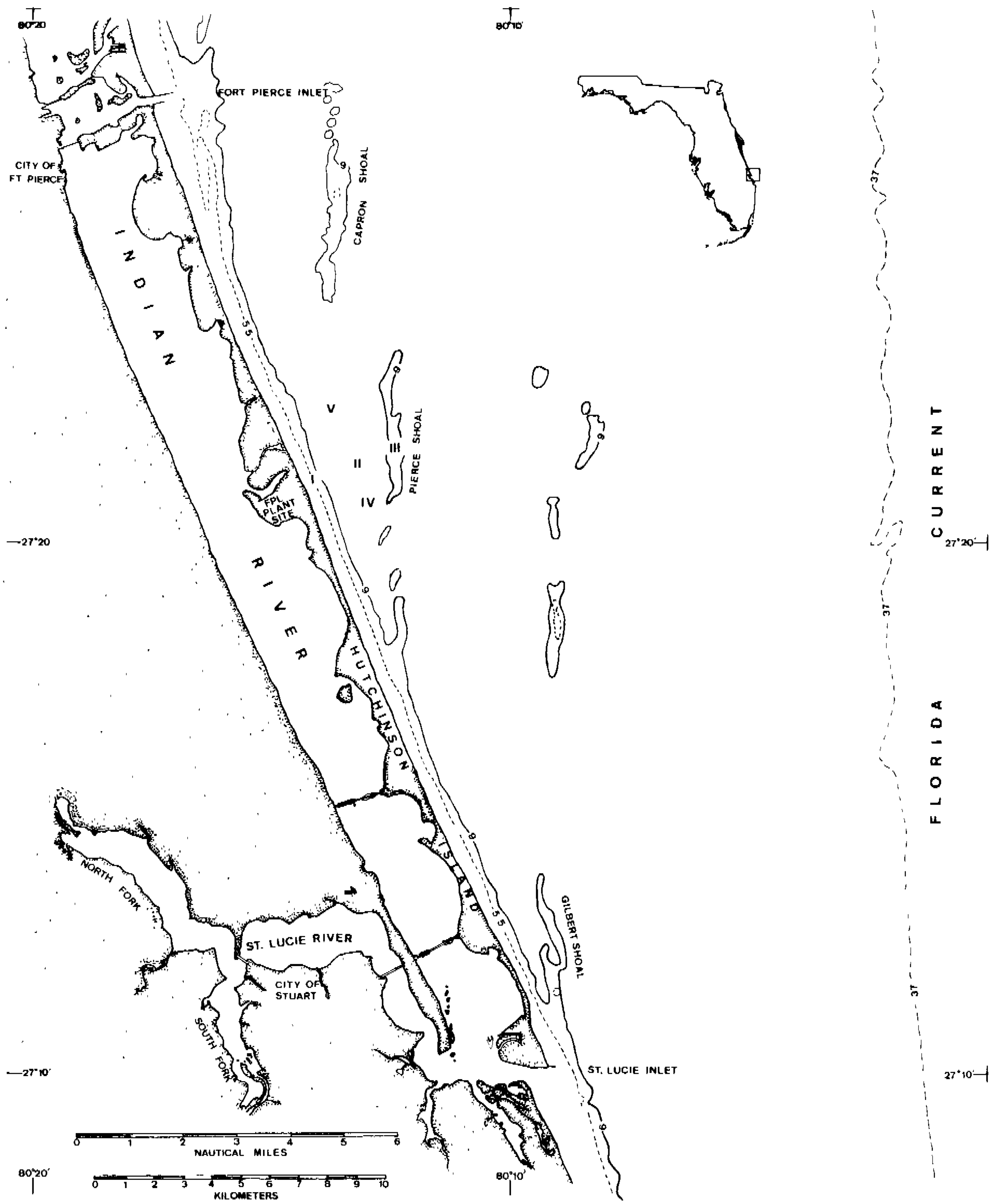


Figure 1. Study area, showing station locations.

Yentsch (1957) method. This technique was selected over the more widely used *in situ* $^{14}C$ and $O_2$ methods because of time and sea state restrictions. The use of a constant assimilation ratio, which is known to change with a variety of environmental and physiological parameters, was employed. The results are considered estimates and probably represent minima since a 3.7 ratio and averaged surface and bottom chlorophyll *a* were used. The $R_d$ value was determined from the total curve of Ryther and Yentsch's graph. Monthly production estimates were initiated in June 1972.

Temperature was determined with a thermistor on a YSI Oxygen Meter Model 51A. Salinity was determined using an American Optical refractometer. Light readings for percent transmittance and gross primary production were obtained with an InterOcean 510 Submarine Illuminance Meter beginning in June 1972 (see Gallagher and Hollinger, 1977 for more details on all field and laboratory procedures).

Reduction of plankton data for temperature, salinity and count ranges as well as X-Y plots for hydrographic and plankton data were contracted to the Florida State University. Net phytoplankton species diversity indices were computer-derived, using the Basharin (1959) correction to the Shannon-Weaver Index (Shannon and Weaver, 1963), as were Pielou (1969) equitability indices. Zooplankton data were not handled in this manner because of varying taxonomic rank identifications. All correlation coefficients were determined by station, using the Spearman's rank correlation analysis (Steel and Torrie, 1960) with the significance level at $P_{.05}$.

## RESULTS AND DISCUSSION

### PLANKTON AND INORGANIC NUTRIENTS

Nutrient chemistry, typically in the form of nitrates, nitrites, ammonia, phosphates and silicates, has been used for several decades to express potential primary production and limiting factors. Unfortunately, measuring ambient loads and their respective ratios does not consider: 1) species composition, 2) physiological races, 3) intracellular concentrations, 4) ambient physicochemical parameters, 5) assimilation rates, 6) turnover rates and 7) uptake and assimilation of organics. An N:P ratio (either as $NO_3$-N:$PO_4$-P or $NH_3$-N + $NO_2$-N + $NO_3$-N:$PO_4$-P) can be biased by excess phosphates, exclusion of organic nitrogen, turnover rates and other factors. Smayda (1974) has suggested that biological limiting factors are best determined by bioassays of natural waters. Such an experimental approach also yields data on successional dynamics.

The above commentary would suggest that positive correlations between ambient levels of soluble $NO_3$-N, $PO_4$-P and chlorophyll *a* (within samples) are difficult to attain. Margalef (1971), however, gives a formula based on nutrients, and other investigators have noted such relationships. There were significant positive correlations between $NO_3$-N, $NO_2$-N, $PO_4$-P and chlorophyll *a* biomass in the Hutchinson Island data for certain stations and depths (Table 1). Similarly, nutrients and pigments correlated with tidal variations; silicates and chlorophyll *a* were higher during periods of low and slack tide, while the converse was shown for high tide (Worth and Hollinger, 1977).

TABLE 1. SPEARMAN'S RANK CORRELATION ANALYSIS: $r_s$ SIGNIFICANT AT $P_{.05}$.

| Variables | | Stations | N | $r_s$ Values |
|---|---|---|---|---|
| $Y_1$ | $Y_2$ | | | |
| $NO_3$-N | Chl *a* | IS* | 19 | 0.5829 |
| | | IB** | 18 | 0.5335 |
| | | IVS | 19 | 0.5386 |
| | | IVB | 19 | 0.6316 |
| $NO_2$-N | Chl *a* | IIB | 20 | 0.7586 |
| | | IIIS | 19 | 0.6513 |
| | | IIIB | 17 | 0.6501 |
| | | IVS | 18 | 0.7183 |
| $PO_4$-P | Chl *a* | IS | 19 | 0.5561 |
| | | IIB | 20 | 0.4853 |
| | | IIIS | 19 | 0.5500 |
| | | IVS | 19 | 0.5526 |
| | | VS | 19 | 0.5561 |
| $SiO_2$-Si | Chl *a* | VS | 19 | 0.5724 |
| Lux | Chl *a* | IB | 15 | −0.7759 |
| | | IIB | 16 | −0.5294 |
| | | IVB | 14 | −0.8495 |
| | | VB | 15 | −0.7554 |
| Phytoplankton | Chl *a* | -no correlation- | | |
| Zooplankton | Chl *a* | IS | 14 | −0.6923 |
| | | IB | 14 | −0.7846 |
| | | VS | 15 | −0.7366 |
| Zooplankton | $PO_4$-P | IS | 14 | −0.6615 |
| | | IB | 14 | −0.6308 |
| | | VS | 15 | −0.6473 |
| | | VB | 15 | −0.6714 |
| Zooplankton | $SiO_2$-Si | -no correlation- | | |
| Zooplankton | Phaeopigments | -no correlation- | | |
| Zooplankton | Phytoplankton | -no correlation- | | |
| Zooplankton | $NH_3$-N | -no correlation- | | |
| Temperature | Zooplankton | IIB | 19 | −0.4912 |
| Temperature | Chl *a* | -no correlation- | | |
| Temperature | $PO_4$-P | -no correlation- | | |
| Temperature | Phytoplankton | -no correlation- | | |
| Temperature | Salinity | -no correlation- | | |
| Temperature | $SiO_2$-Si | IS | 19 | 0.5237 |
| | | IB | 19 | 0.7606 |
| | | IIS | 20 | 0.4861 |
| | | IIIS | 19 | 0.4606 |
| | | IIIB | 19 | 0.4895 |
| | | IVS | 18 | 0.6677 |
| | | VB | 19 | 0.5347 |
| Salinity | $PO_4$-P | -no correlation- | | |
| Salinity | $SiO_2$-Si | IIS | 20 | −0.4722 |
| | | IVS | 18 | −0.5036 |

*S = surface
**B = bottom

Observed ranges and means for the basic nutrients and related data are listed in Tables 2-6. Phosphate-phosphorus and $SiO_2$-Si maxima and means (surface and bottom $\bar{x}$: 3.16 to 6.79 $\mu$g-atoms P/liter and 6.77 to 8.90 $\mu$g-atoms Si/liter) indicate land-derived nutrient loads (Armstrong, 1965; Ryther and Dunstan, 1971). Mean $PO_4$-P values far exceed those reported for upwelling areas, although they do not exceed those in some enriched poorly-flushed estuaries (Raymont, 1963; Turner and Hopkins, 1974). Mean $NO_3$-N values (0.75-1.23 $\mu$g-atoms/liter) as well as combined inorganic nitrogen (nitrates, nitrites, ammonia) were lower, often less than 2 $\mu$g-atoms/liter (Total N $\bar{x}$ from 1.40 to 2.87 $\mu$g-atoms/liter). These values, although low, are comparable to other runoff enriched coastal areas with low N:P ratios where microbiotic uptake is thought to keep nitrogen (regardless of form) at low levels. The lower nitrogen values and higher phosphorus values accounted for the majority of low N:P ratios (1.06 to 2.03 with February 1972 data omitted due to specious high $NH_3$-N values). The N:P ratio could be periodically higher if the $NH_3$-N determinations were minimal due to treatment techniques as suggested by DeGobbis (1973). Nitrate-nitrogen was highest in spring, while $NH_3$-N appeared to peak in summer and fall at times of high temperatures. Correspondingly, chlorophyll *a* values were higher in spring, summer and fall, at times of higher net phytoplankton abundance. Seasonality, although inferred from the data, cannot emphatically be stated based on single monthly collections.

Speculated relationships or within sample statistical correlations between zooplankton biomass (as abundance or volume) and $NH_3$-N and $PO_4$-P levels have been reported (Reid, 1962; Pomeroy et al., 1963; Martin, 1965; McCarthy, 1972). No statistical correlation was observed for zooplankton versus $NH_3$-N; however, a negative correlation was derived from zooplankton abundance versus $PO_4$-P at Stations I and V (Table 1, Figures 2-11). The negative relationship may be indirect or direct. Zooplankters could have been higher when $PO_4$-P was low because zooplankton phosphorus excretion (lipid reserves) was low when phytoplankters were abundant (or vice versa) as suggested by Martin (1968).

Silicate-silicon concentrations were high and had a positive correlation with temperature (5 stations) and a negative correlation with salinity (2 stations) (Table 1, Figures 12-21). The inference is that land-derived silicates were seasonally or periodically delivered to the coastal system by runoff through the Ft. Pierce Inlet (Worth and Hollinger, 1977). Silicate-silicon and chlorophyll *a* had a positive correlation only at Station V, surface. Stations I, II, IV and V, based on bottom Lux, total particulate loads, $SiO_2$-Si, $PO_4$-P and salinity -$SiO_2$-Si correlations, appeared to be more affected than Station III by runoff from the inlet.

Intrastation and interstation variations indicated that Stations I, II and V were the most influenced by estuarine discharge (Worth and Hollinger, 1977). Visually, Ft. Pierce Inlet runoff can appear as a surface plume, usually flowing south. This runoff would be expected to have the greatest influence on the closest-to-shore stations at the surface, depending on discharge rate, wind, currents and mixing. Worth and Hollinger's (1977) tidal variation correlations with salinities, silicates and chlorophyll *a* also indicate the influence of surface runoff from the Indian River inlets.

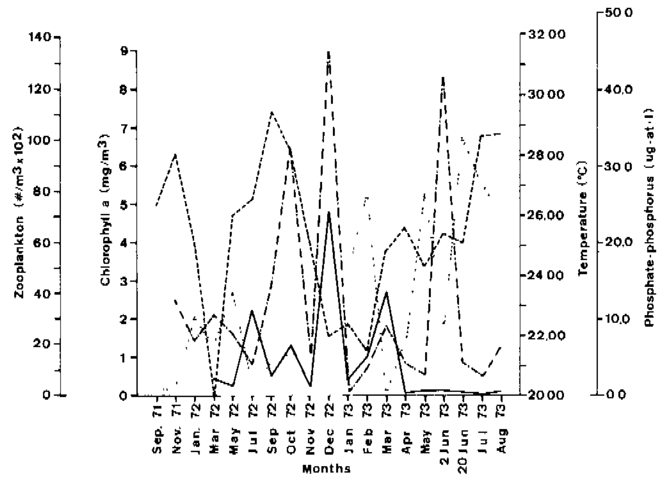


Figure 2. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station I, surface.

(Key: ________Phosphate; - - - - - - - -Temperature; . . . . . . . . . . . . . .Zooplankton; _._._._._. Chlorophyll.)

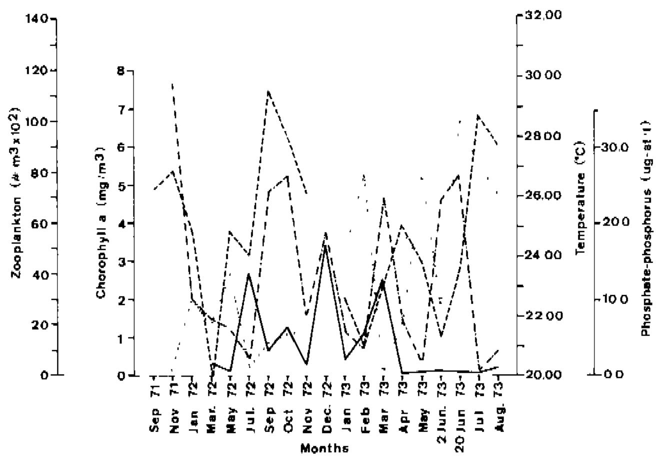


Figure 3. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station I, bottom.

(Key: ________Phosphate; - - - - - - - -Temperature; . . . . . . . . . . . . . .Zooplankton; _._._._._. Chlorophyll.)

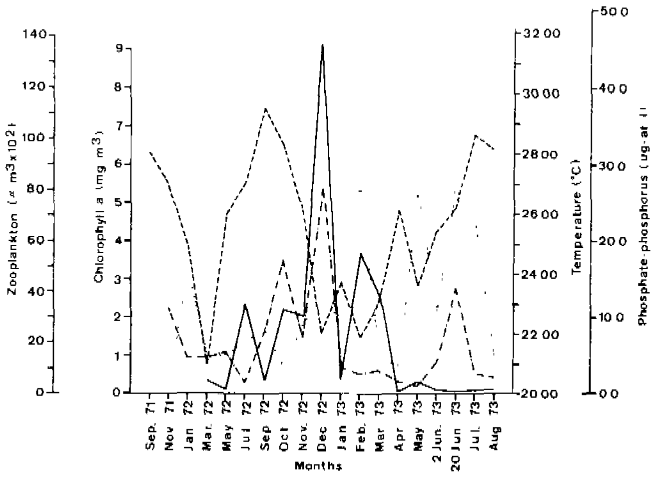


Figure 4. Relationships between zooplankton biomass, chlorophyll $a$, temperature and phosphates at Station II, surface.

(Key: ——— ——Phosphate; ------------ Temperature; ............. Zooplankton; . . .—.—.—.— Chlorophyll.)

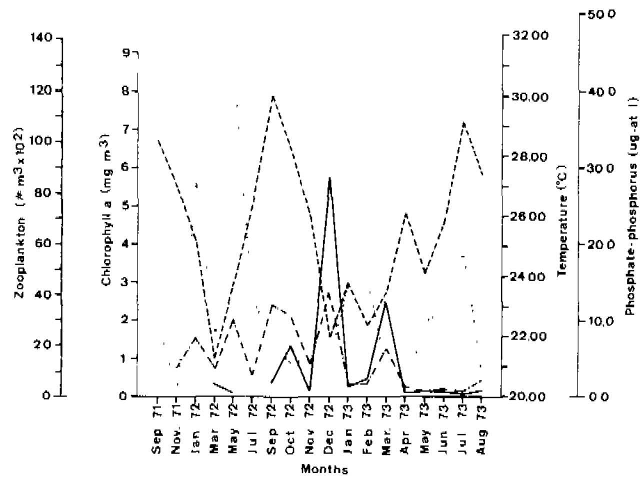


Figure 6. Relationships between zooplankton biomass, chlorophyll $a$, temperature and phosphates at Station III, surface.

(Key: —. ———Phosphate; ------------ Temperature; ............. Zooplankton; . .—.—.—. . . Chlorophyll.)

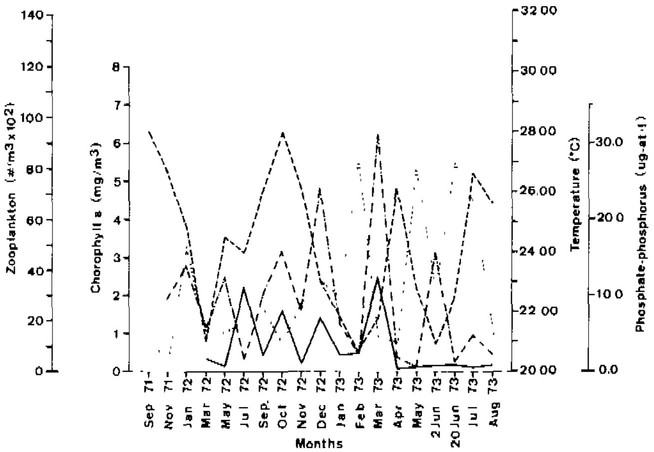


Figure 5. Relationships between zooplankton biomass, chlorophyll $a$, temperature and phosphates at Station II, bottom.

(Key: —— .——Phosphate; ------------ Temperature; ............. Zooplankton; .— . . .—.—.— Chlorophyll.)

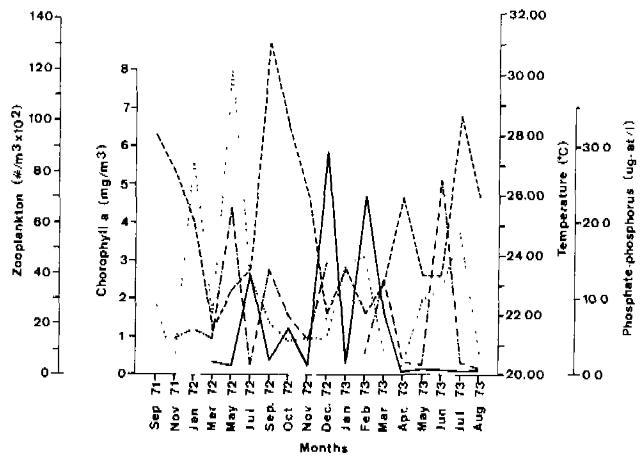


Figure 7. Relationships between zooplankton biomass, chlorophyll $a$, temperature and phosphates at Station III, bottom.

(Key: —— ———Phosphate; ------------ Temperature; ............. Zooplankton; .—.—. .—.—.— Chlorophyll.)

## STANDING STOCK AND PRIMARY PRODUCTION

Mean bottom chlorophyll $a$ ranged from 1.47 to 2.86 mg/m$^3$, while surface values ranged from 1.02 to 2.34 mg/m$^3$ (Tables 2-6). Highest bottom values were obtained for Stations I and V, while Station III had the lowest. These values corresponded closely with the highest mean inorganic particulate loads at Stations I and V and the lowest at Station III (Tables 2-6). This suggests the presence of resident phytomicrobenthic populations (tychoplankton) in the form of siliceous diatoms, at least at the more stable Station V. Benthic chain-forming diatoms were recorded at all stations with prominent abundance fluctuations possibly due to turbulence or tidal cycle. Highest organic loads (particulate) were associated with high chlorophyll values (Worth and Hollinger, 1977). Additionally, Lux and chlorophyll $a$ correlations were negative for bottom samples except at Station III (the shoal station)

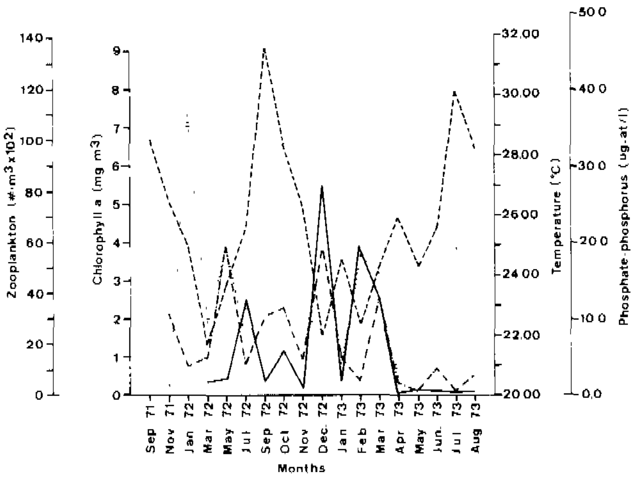


Figure 8. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station IV, surface.

(Key: ———— Phosphate; - - - - - - - - - - - - - - Temperature; . . . . . . . . . . . . . . Zooplankton; —.—.—. . . . —. Chlorophyll.)

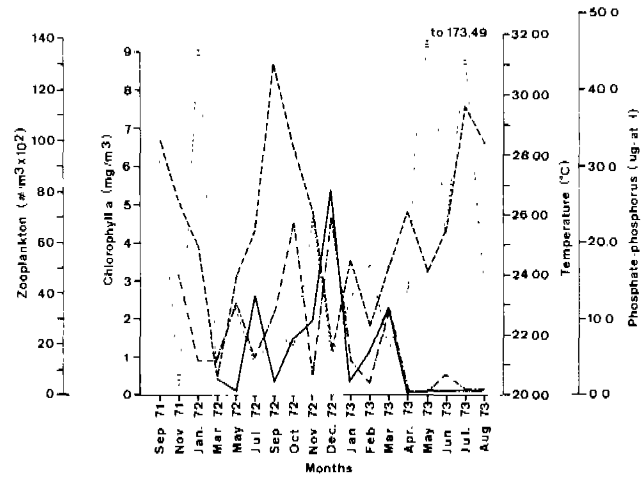


Figure 10. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station V, surface.

(Key: ———— Phosphate; - - - - - - - - - - - - - - Temperature; . . . . . . . . . . . . . . Zooplankton; —.—.—.—. —.—. Chlorophyll.)

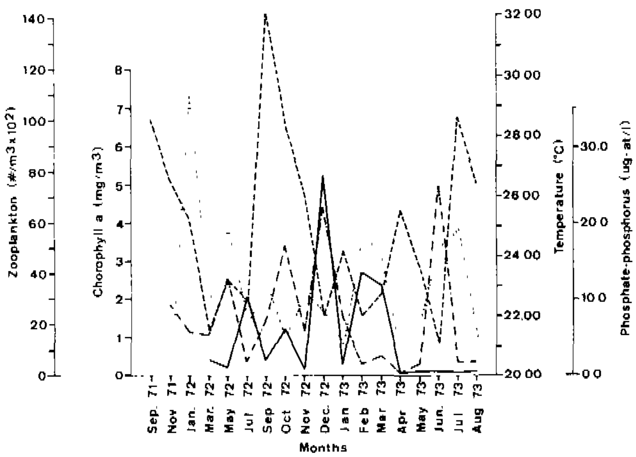


Figure 9. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station IV, bottom.

(Key: ———— Phosphate; - - - - - - - - - - - - - - Temperature; . . . . . . . . . . . . . . Zooplankton; —.—.—.—. . . Chlorophyll.)

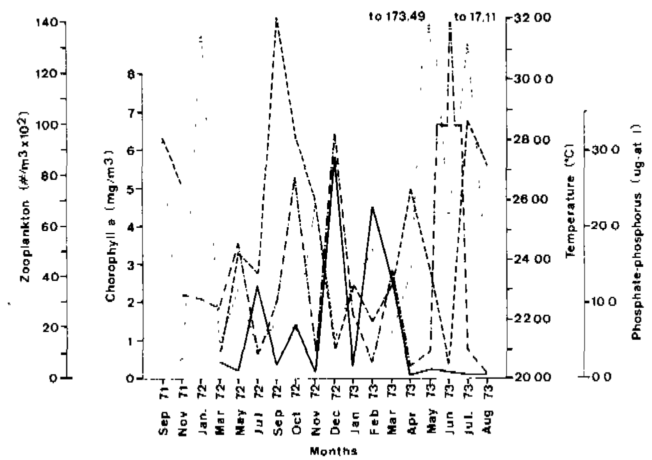


Figure 11. Relationships between zooplankton biomass, chlorophyll *a*, temperature and phosphates at Station V, bottom.

(Key: ———— Phosphate; - - - - - - - - - - - - - - Temperature; . . . . . . . . . . . . . . Zooplankton; —.—.—.—.—. Chlorophyll.)

suggesting light adaptation of bottom communities. The light-chlorophyll relationship may reflect increased turbidity from land runoff at all stations except Station III.

Surface chlorophyll *a* concentrations were highest in spring, fall and winter while primary production appeared highest in summer and corresponded to chlorophyll *a* minima. A similar inverse relationship was previously recorded for temperate nearshore and estuarine waters (Williams and Murdoch, 1966; Hitchcock and Smayda, 1975) although annual fluctuations and areal differences in plankton dynamics are common (Smayda, 1976). This inverse relationship may be attributed to rapid recycling of nutrients (Williams and Murdoch, 1966) or changes in size component dominance and corresponding differences in metabolic rates.

Gross primary production means by station varied from 0.26 to 0.46 gC/m²/day and may represent minima. Margalef (1971) reported primary production values of 0.3 to 1.0 gC/m²/day and 0.2 to 0.5 mg chl *a*/m³ from productive Caribbean waters, including highly

TABLE 2. MEANS AND RANGES FOR PHYSICAL AND CHEMICAL DATA, STATION I.

| | | $\bar{X}$ | Range | N |
|---|---|---|---|---|
| Salinity, ‰ | S** | 35.51 | 33.00-38.50 | 25 |
| | B*** | 35.92 | 34.00-38.00 | 25 |
| Temperature, °C | S | 25.44 | 20.00-29.40 | 25 |
| | B | 24.89 | 20.00-29.50 | 24 |
| D.O., ppm | S | 6.19 | 4.50- 7.80 | 23 |
| | B | 6.18 | 4.80- 8.10 | 23 |
| Lux | S | 55665 | 6510-109740 | 15 |
| | B | 4877.45 | 12-11160 | 15 |
| $NO_3$-N ($\mu$g-at/l) | S | 1.14 | .16- 2.43 | 19 |
| | B | .87 | .18- 2.70 | 20 |
| $NO_2$-N ($\mu$g-at/l) | S | .13 | 0.00- .59 | 19 |
| | B | .14 | .01- .60 | 20 |
| $NH_3$-N ($\mu$g-at/l) | S | .92 | .07- 4.00 | 19 |
| | B | .89* | .07- 2.93 | 19 |
| $PO_4$-P ($\mu$g-at/l) | S | 4.30 | .23-24.02 | 19 |
| | B | 3.93 | .32-17.11 | 20 |
| $SiO_2$-Si ($\mu$g-at/l) | S | 8.13 | 1.43-21.93 | 19 |
| | B | 8.65 | 1.43-32.04 | 20 |
| Chl *a* ($\mu$g/l) | S | 2.34 | .09- 8.23 | 24 |
| | B | 2.86 | .15- 7.70 | 24 |
| Phaeopigment | S | .55 | .04- 2.70 | 24 |
| ($\mu$g/l) | B | 1.39 | 0.00- 9.57 | 24 |
| Primary production (gmC/m²/day) | | .403 | .085- 2.042 | 16 |
| Total Particulate | S | 8790.65 | 2257-26983 | 23 |
| load (mg/m³) | B | 16427.89 | 2110-64481 | 24 |
| Inorganic partic- | S | 6276.70 | 1514-20517 | 23 |
| ulate load (mg/m³) | B | 12305.83 | 760-47333 | 23 |
| Organic particu- | S | 2513.52 | 586-8180 | 23 |
| late load (mg/m³) | B | 4744.57 | 822-17148 | 23 |

*High $NH_3$ values deleted.
**S = surface
***B = bottom

TABLE 3. MEANS AND RANGES FOR PHYSICAL AND CHEMICAL DATA, STATION II.

| | | $\bar{X}$ | Range | N |
|---|---|---|---|---|
| Salinity, ‰ | S** | 35.60 | 33.00-38.20 | 26 |
| | B*** | 36.11 | 34.00-38.00 | 26 |
| Temperature, °C | S | 25.43 | 21.00-29.50 | 26 |
| | B | 24.35 | 20.70-28.00 | 26 |
| D.O., ppm | S | 6.38 | 4.30- 8.90 | 24 |
| | B | 6.10 | 4.10- 7.90 | 23 |
| Lux | S | 54114.38 | 4650-115320 | 16 |
| | B | 5426.13 | 8-18200 | 16 |
| $NO_3$-N ($\mu$g-at/l) | S | .79 | .06- 2.50 | 20 |
| | B | .96 | .18- 2.70 | 20 |
| $NO_2$-N ($\mu$g-at/l) | S | .13 | .01- .56 | 20 |
| | B | .12 | 0.00- .39 | 20 |
| $NH_3$-N ($\mu$g-at/l) | S | .53 | .07- 1.70 | 19 |
| | B | .81* | .07- 2.43 | 19 |
| $PO_4$-P ($\mu$g-at/l) | S | 6.43 | .19-45.85 | 20 |
| | B | 3.16 | .19-13.14 | 20 |
| $SiO_2$-Si ($\mu$g-at/l) | S | 7.48 | 1.18-25.81 | 20 |
| | B | 7.21 | 1.43-18.37 | 20 |
| Chl *a* ($\mu$g/l) | S | 1.29 | .20- 5.37 | 24 |
| | B | 1.72 | .13- 6.27 | 24 |
| Phaeopigment | S | .40 | 0.00- 1.84 | 24 |
| ($\mu$g/l) | B | .80 | .06- 2.30 | 24 |
| Primary production (gmC/m²/day) | | .328 | .103- .918 | 16 |
| Particulate load | S | 7415.63 | 1659-22360 | 24 |
| (mg/m³) | B | 10015.50 | 2054-30000 | 24 |
| Inorganic partic- | S | 5130.21 | 760-15920 | 24 |
| ulate load (mg/m³) | B | 6914.75 | 333-18583 | 24 |
| Organic particu- | S | 2283.21 | 775-6440 | 24 |
| late load (mg/m³) | B | 3100.75 | 723-11417 | 24 |

*High $NH_3$ values deleted.
**S = surface
***B = bottom

productive upwelling areas such as northeast Venezuela. Strickland (1965), however, suggested ranges of 10-40 mg chl *a*/m³ for bloom conditions in fertile coastal areas, 0.5 mg/m³ for temperate oceans with a 5-10X increase in coastal waters during productive seasons, and 0.05 mg/m³ for oligotrophic areas. Hutchinson Island standing stock and primary production values equate to richer Caribbean areas, and on a worldwide basis these values equate to some coastally productive areas.

The dominant size or taxonomic component exerting seasonal or yearly influence on primary production off Hutchinson Island cannot be determined from the present study. Nannoplankton and ultraplankton are significant components in inshore, nearshore and even upwelling areas (Williams and Murdoch, 1966; Beers et al., 1971; Malone, 1971; Van Valkenburg and Flemer, 1974; Pomeroy, 1974). Representatives of these size categories could contribute substantially to the Hutchinson Island primary production.

The inverse relationship between zooplankton (>202 $\mu$m) abundance and chlorophyll *a* levels at Stations I and V may well reflect state of grazing pressure described by Bainbridge (1953). The lack of correlation at the remaining stations could also apply to grazing pressures. Turbulence fields, however, could also regulate distribution and abundance of phytoplankton (Platt, 1972). Zooplankton at inshore Beaufort, North Carolina, were supported by about 0.1 to 1% of the daily net primary production (Williams, 1965), and zooplankton in upwelled waters off Peru in June 1969 only grazed 25% of the daily net primary production yield (Beers et al., 1971). Zooplankton or planktivorous fish grazing has been correlated with phaeopigments (Glooschenko et al., 1972; Gold, 1975); however, we found no within sample correlation between zooplankton abundance and phaeopigment levels.

One aspect of plankton research that needs immediate attention pertains to trophic levels and their interrelationships, particularly at the lower levels. Presently, difficulties are encountered because primary production values and harvest yield do not equate (Rounsefell, 1971; El-Sayed et al., 1972; Steidinger, 1973; Smayda, 1976) and are due to loss of available organic matter from the system, importance of benthic macrophytes in shallow waters, benthic-pelagic interrelationships, food webs versus food chains, lowered efficiencies, preferential feeding, feeding rates and unexploited yields.

TABLE 4. MEANS AND RANGES FOR PHYSICAL AND CHEMICAL DATA, STATION III.

| | | $\bar{X}$ | Range | N |
|---|---|---|---|---|
| Salinity, ‰ | S** | 35.60 | 34.00-37.70 | 25 |
| | B*** | 35.91 | 34.00-38.50 | 25 |
| Temperature, °C | S | 25.51 | 21.30-29.10 | 25 |
| | B | 25.06 | 21.50-31.00 | 25 |
| D.O., ppm | S | 6.33 | 3.90- 9.10 | 23 |
| | B | 6.08 | 4.40- 7.20 | 23 |
| Lux | S | 62577.00 | 16740-115320 | 15 |
| | B | 11646.40 | 600-30690 | 15 |
| $NO_3$-N ($\mu$g-at/l) | S | .75 | .22- 1.67 | 19 |
| | B | .93 | .16- 2.00 | 19 |
| $NO_2$-N ($\mu$g-at/l) | S | .15 | 0.00- .86 | 18 |
| | B | .21 | 0.00- .88 | 19 |
| $NH_3$-N ($\mu$g-at/l) | S | .78* | .07- 5.00 | 17 |
| | B | 1.22* | .07- 6.35 | 18 |
| $PO_4$-P ($\mu$g-at/l) | S | 3.93 | .45-28.80 | 18 |
| | B | 6.79 | .35-32.29 | 19 |
| $SiO_2$-Si ($\mu$g-at/l) | S | 6.77 | 1.60-15.17 | 19 |
| | B | 7.55 | 1.57-18.51 | 19 |
| Chl *a* ($\mu$g/l) | S | 1.02 | .14- 2.76 | 23 |
| | B | 1.47 | .17- 5.08 | 22 |
| Phaeopigment | S | .27 | 0.00- .93 | 23 |
| ($\mu$g/l) | B | .41 | 0.00- 2.26 | 22 |
| Primary production (gC/m²/day) | | .257 | .069- .981 | 15 |
| Particulate load | S | 5908.09 | 1850-14320 | 23 |
| (mg/m³) | B | 8422.73 | 1800-18520 | 22 |
| Inorganic particulate load (mg/m³) | S | 4381.13 | 1080-11493 | 23 |
| | B | 5479.95 | 1300-13480 | 22 |
| Organic particulate load (mg/m³) | S | 1527 | 130-4870 | 23 |
| | B | 2940.45 | 290-19760 | 22 |

*High $NH_3$ values deleted.
**S = surface
***B = bottom

TABLE 5. MEANS AND RANGES FOR PHYSICAL AND CHEMICAL DATA, STATION IV.

| | | $\bar{X}$ | Range | N |
|---|---|---|---|---|
| Salinity, ‰ | S** | 35.76 | 33.90-38.50 | 26 |
| | B*** | 35.91 | 33.00-38.50 | 26 |
| Temperature, °C | S | 25.60 | 21.30-31.50 | 26 |
| | B | 24.97 | 21.10-32.00 | 26 |
| D.O., ppm | S | 6.46 | 3.20- 8.40 | 21 |
| | B | 6.06 | 3.80- 7.40 | 21 |
| Lux | S | 82570.71 | 50220-112530 | 14 |
| | B | 7858.14 | 310-16740 | 14 |
| $NO_3$-N ($\mu$g-at/l) | S | .93 | .31- 1.96 | 19 |
| | B | .95 | .20- 4.06 | 19 |
| $NO_2$-N ($\mu$g-at/l) | S | .14 | 0.00- .34 | 19 |
| | B | .23 | 0.00- 1.50 | 19 |
| $NH_3$-N ($\mu$g-at/l) | S | .71* | .07- 3.00 | 17 |
| | B | .71* | .07- 2.57 | 18 |
| $PO_4$-P ($\mu$g-at/l) | S | 5.25 | .35-27.44 | 19 |
| | B | 4.61 | .29-26.31 | 19 |
| $SiO_2$-Si ($\mu$g-at/l) | S | 7.39 | 1.25-17.34 | 18 |
| | B | 6.98 | 1.00-18.66 | 19 |
| Chl *a* ($\mu$g/l) | S | 1.27 | .11- 3.92 | 23 |
| | B | 1.75 | .08- 5.24 | 23 |
| Phaeopigment | S | .40 | .02- 1.71 | 23 |
| ($\mu$g/l) | B | .45 | 0.00- 1.54 | 23 |
| Primary production (gmC/m²/day) | | .289 | .087- 1.03 | 15 |
| Particulate load | S | 6327.61 | 1810-13420 | 23 |
| (mg/m³) | B | 10715.52 | 2060-48750 | 23 |
| Inorganic particulate load (mg/m³) | S | 4054.57 | 970-10280 | 23 |
| | B | 7569.00 | 1120-39700 | 23 |
| Organic particulate load (mg/m³) | S | 2229.57 | 214-4500 | 23 |
| | B | 3150.00 | 453-12369 | 23 |

*High $NH_3$ values deleted.
**S = surface
***B = bottom

## PLANKTON AND CURRENTS

The hydrography off Hutchinson Island, Florida is influenced by tidal currents, oceanic currents and presumably eddies or meanders of the Gulf Stream. Tidal currents particularly influence the sampling area (0.5 to 3.5 km offshore) by delivery of high inorganic nutrient loads and particulate loads; this effect is most evident at Stations I, II and V. Stations III and IV appear less affected, yet all stations are subjected to oceanic intrusion as evidenced by frequent presence of oceanic plankters. In addition, "upwelled" deeper water is indicated by lower surface temperatures (Worth and Hollinger, 1977) and deeper water plankters, e.g. *Amphisolenia* spp. in summer months. The proximity of the Gulf Stream and the narrow shelf (approximately 20 km) influence this phenomenon.

Hutchinson Island plankters have definite Caribbean affinities; Gulf Stream water masses off the southeast Florida coast transport oceanic plankton typical of the Caribbean system (Caribbean Sea, Gulf of Mexico, Florida Current, Antilles Current) with much of their origin from the North Equatorial Current (Margalef, 1971; Wood, 1971). Wood (1971) recorded 169 diatom, dinoflagellate and blue-green algae common to the Gulf of Guinea, the western tropical Atlantic, Caribbean Sea and Straits of Florida. The Caribbean Sea diversity was higher than the Straits of Florida, even though fewer samples were collected. Over 88% of these 169 taxa are also found in the Gulf of Mexico (derived from El-Sayed et al., 1972), indicating again the influence of Caribbean water masses in the Gulf Stream System. Wood (1971) and Margalef (1971) were able to show the strong influence of the North Equatorial Current on phytoplankton occurrence in the Caribbean Sea, Straits of Florida and, therefore, the Gulf Stream. The species are of wide distribution and/or of subtropical-tropical affinities. Oceanic influences, with respect to phytoplankton occurrence and abundance, are most noted in winter and summer with the least influence in October, November and December. Fall is usually the period of weaker oceanic current structure. Oceanic zooplankters identified to species also showed strong affinities with Caribbean waters and the North Equatorial Current (Walker et al., 1979).

Net phytoplankton (236 taxa of diatoms, dinoflagellates and blue-green algae) collected near Hutchinson Island represented only 43% of Wood's list (4 oceanic regions), yet they both showed cosmopolitan or subtropical-tropical affinities. More importantly, the occurrence of such diatoms as *Nitzschia*, *Navicula*,

TABLE 6. MEANS AND RANGES FOR PHYSICAL AND CHEMICAL DATA, STATION V.

| | | $\overline{X}$ | Range | N |
|---|---|---|---|---|
| Salinity, ‰ | S** | 35.62 | 34.00-38.50 | 25 |
| | B*** | 35.79 | 34.00-38.50 | 25 |
| Temperature, °C | S | 25.63 | 20.60-31.00 | 25 |
| | B | 25.06 | 20.50-32.00 | 24 |
| D.O., ppm | S | 6.54 | 3.30-10.30 | 21 |
| | B | 6.31 | 3.90- 8.90 | 20 |
| Lux | S | 80538.00 | 33480-161820 | 15 |
| | B | 5737.87 | 17-12200 | 15 |
| $NO_3$-N ($\mu$g-at/l) | S | 1.23 | .14- 5.34 | 19 |
| | B | .81 | .19- 2.11 | 19 |
| $NO_2$-N ($\mu$g-at/l) | S | .17 | 0.00- .76 | 19 |
| | B | .25 | .01- 1.34 | 19 |
| $NH_3$-N ($\mu$g-at/l) | S | .68* | .07- 2.50 | 17 |
| | B | .81* | .07- 3.14 | 18 |
| $PO_4$-P ($\mu$g-at/l) | S | 4.95 | .29-27.00 | 19 |
| | B | 5.60 | .97-29.19 | 19 |
| $SiO_2$-Si ($\mu$g-at/l) | S | 8.25 | 1.00-24.71 | 19 |
| | B | 8.90 | 1.50-19.44 | 19 |
| Chl *a* ($\mu$g/l) | S | 1.40 | .07- 4.66 | 23 |
| | B | 2.73 | .16-17.11 | 23 |
| Phaeopigment | S | .45 | 0.00- 1.91 | 23 |
| ($\mu$g/l) | B | .58 | 0.00- 2.07 | 23 |
| Primary production (gC/m²/day) | | .460 | .057- 2.977 | 15 |
| Particulate load | S | 6922.17 | 1714-15392 | 23 |
| (mg/m³) | B | 12523.17 | 2000-69360 | 23 |
| Inorganic partic- | S | 4655.57 | 1471-10094 | 23 |
| ulate load (mg/m³) | B | 9363.09 | 714-49960 | 23 |
| Organic particu- | S | 2267.00 | 243-6078 | 23 |
| late load (mg/m³) | B | 3162.00 | 480-19400 | 23 |

*High $NH_3$ values deleted.
**S = surface
***B = bottom

TABLE 7. PHYTOPLANKTON DIVERSITY (SHANNON-WEAVER WITH BASHARIN CORRECTION).

| Date | Sta I | Sta II | Sta III | Sta IV | Sta V |
|---|---|---|---|---|---|
| Sept. 71 | 1.133 | 1.927 | 1.922 | 1.632 | 2.173 |
| Nov. 71 | 0.595 | 1.315 | 1.314 | 1.209 | 0.864 |
| Jan. 72 | 1.681 | 2.011 | 1.253 | 1.663 | 1.756 |
| Mar. 72 | 1.456 | 1.232 | 1.679 | 1.211 | 1.126 |
| May 72 | 1.909 | 1.653 | 1.980 | 1.942 | 1.884 |
| 5 July 72 | 2.321 | 2.162 | 0.827 | 1.101 | 1.833 |
| 18 July 72 | 2.339 | 1.842 | 2.272 | 1.976 | 2.535 |
| Sept. 72 | 2.392 | 2.677 | 2.359 | 2.420 | 2.080 |
| Oct. 72 | 1.212 | 0.977 | 1.266 | 0.774 | 0.865 |
| Nov. 72 | 0.620 | 1.300 | 1.581 | 1.720 | 1.454 |
| Dec. 72 | nd | 1.022 | 2.079 | 0.691 | 0.521 |
| Jan. 73 | 2.028 | 1.370 | 1.720 | 1.936 | 1.522 |
| Feb. 73 | 0.788 | 1.809 | 1.370 | 1.562 | 0.719 |
| Mar. 73 | 1.367 | 1.179 | 0.976 | 1.035 | 1.239 |
| April 73 | 0.824 | 0.480 | 0.360 | 0.804 | 1.044 |
| May 73 | 0.254 | 2.268 | 1.831 | 1.734 | 2.037 |
| 2 June 73 | 1.192 | 1.360 | 1.125 | 1.174 | 1.294 |
| 20 June 73 | 0.543 | 1.251 | nd | nd | nd |
| July 73 | 1.460 | 1.194 | 0.713 | 0.597 | 0.981 |
| August 73 | 1.550 | 1.509 | 0.760 | 0.876 | 2.080 |

TABLE 8. PHYTOPLANKTON EQUITABILITY INDEX (PIELOU'S INDEX).

| Date | Sta I | Sta II | Sta III | Sta IV | Sta V |
|---|---|---|---|---|---|
| Sept. 71 | 0.385 | 0.538 | 0.577 | 0.485 | 0.616 |
| Nov. 71 | 0.176 | 0.415 | 0.344 | 0.392 | 0.281 |
| Jan. 72 | 0.426 | 0.570 | 0.368 | 0.468 | 0.553 |
| Mar. 72 | 0.383 | 0.352 | 0.484 | 0.306 | 0.355 |
| May 72 | 0.511 | 0.451 | 0.557 | 0.538 | 0.492 |
| 5 July 72 | 0.729 | 0.695 | 0.219 | 0.299 | 0.564 |
| 18 July 72 | 0.628 | 0.472 | 0.613 | 0.541 | 0.663 |
| Sept. 72 | 0.605 | 0.604 | 0.565 | 0.549 | 0.652 |
| Oct. 72 | 0.297 | 0.234 | 0.316 | 0.182 | 0.202 |
| Nov. 72 | 0.185 | 0.387 | 0.548 | 0.467 | 0.389 |
| Dec. 72 | nd | 0.301 | 0.568 | 0.228 | 0.160 |
| Jan. 73 | 0.547 | 0.362 | 0.447 | 0.498 | 0.378 |
| Feb. 73 | 0.212 | 0.456 | 0.354 | 0.406 | 0.206 |
| Mar. 73 | 0.416 | 0.334 | 0.311 | 0.281 | 0.324 |
| April 73 | 0.271 | 0.144 | 0.114 | 0.239 | 0.313 |
| May 73 | 0.822 | 0.760 | 0.608 | 0.619 | 0.627 |
| 2 June 73 | 0.328 | 0.371 | 0.305 | 0.316 | 0.361 |
| 20 June 73 | 0.147 | 0.323 | nd | nd | nd |
| July 73 | 0.466 | 0.386 | 0.257 | 0.203 | 0.354 |
| August 73 | 0.436 | 0.475 | 0.236 | 0.288 | 0.553 |

*Bacillaria*, *Paralia*, *Isthmia*, *Cylindrotheca*, *Gyrosigma*, *Pleurosigma*, *Synedra*, *Amphora*, etc., in net hauls indicate the presence of benthic assemblages. Pennates accounted for 33% of all diatom species recorded. The source of these benthic assemblages, based on species abundance and sediment characterizations, is assumed to be the local coastal sediments, particularly the trough stations (II, IV, V).

Certain plankton populations can originate in eastern Gulf of Mexico waters and be carried around the Florida Keys into the Straits of Florida to the Gulf Stream and, subsequently, to the Florida east coast. Drift bottle data (Williams et al., 1977) for Florida central west coast releases (5.6 to 170 km offshore) showed high recoveries, principally in winter, on the lower east coast usually one to two months after release. Ednoff (1974) and Murphy et al. (1975) suggested entrainment and transport of eastern Gulf neritic phytoplankton species to the Straits of Florida. Current boundaries can entrain and concentrate plankton (Fuglister and Worthington, 1951; Maul, 1973) and this mechanism no doubt contributes to the occurrence of certain plankters off Hutchinson Island.

Much of the recorded pelagic standing stock, whether meroplanktonic or holoplanktonic, is transient, carried in by outgoing tides or oceanic intrusions and downstream by migrating eddies or longshore currents. The only resident populations in the sampling area clearly reside in the Indian River System as euryhaline estuarine-neritic species or exist as local benthic communities (i.e., tychoplankton or hypoplankton). These resident populations, particularly seasonal pulses of meroplankton, should be further studied in regard to immediate loss, not to the area but rather to the system. Estuarine influences on the Hutchinson Island coastal system are significant, and can be demonstrated using the occurrence of the dominant Indian River diatom *Skeletonema costatum* (Harbor Branch Consortium, unpublished report).

Species diversity and evenness indices (Tables 7 and 8) usually reflected the abundance or lack of abundance of *Skeletonema costatum*, a chain-forming

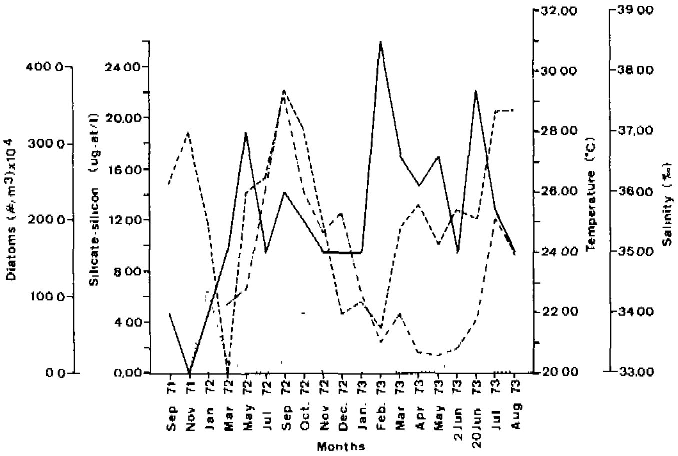


Figure 12. Relationships between diatom abundance, silicates, temperature and salinities at Station I, surface.

(Key: ———— Salinity; - - - - - - - Temperature; . . . . . . . . Diatoms; .—.—.—. Silicates.)

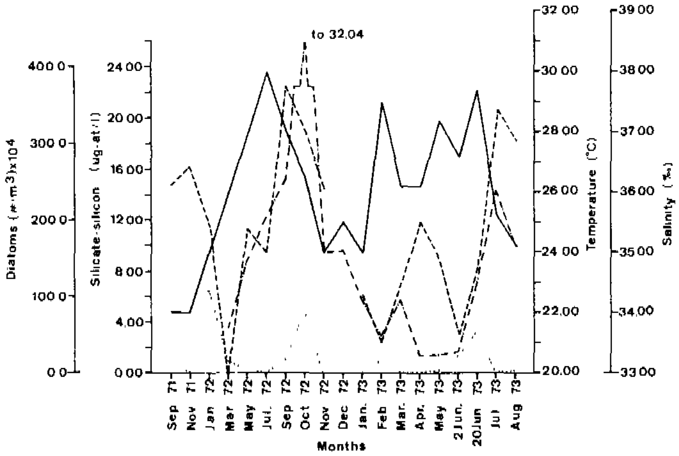


Figure 13. Relationships between diatom abundance, silicates, temperature and salinities at Station I, bottom.

(Key: ———— Salinity; - - - - - - - Temperature; . . . . . . . . Diatoms; .—.—.—. Silicates.)

centric diatom, which often dominates tropical and temperate nearshore and inshore waters. Ninety percent of *S. costatum* peaks (>500,000 cells/m³) were associated with collections made on low or slack low tides. The one exception was associated with slack high tide. Seventy percent of total absence of this species was associated with collections made on high or slack high tide. These data emphasize the contribution of estuarine plankton to the nearshore oceanic system on outgoing tide. Tidal contributions from the Indian River system no doubt accounted for our high surface chlorophyll *a* values.

## CONCLUSIONS AND RECOMMENDATIONS

Two years of bimonthly, and later monthly, plankton and hydrographic analyses 0.5 to 3.5 km off Hutchinson Island, Florida indicate that the sampling area is continually influenced by oceanic and estuarine waters. The magnitude of these influences changes tidally and seasonally. Nearshore circulation patterns are influenced by the proximity of the western edge of the Gulf Stream. Plankton data indicate that the origin of the oceanic pelagic populations is closely associated with Caribbean waters (e.g. Caribbean Sea, Gulf of Mexico Loop Current, Florida Current, Antilles Current). Representative oceanic species are typically cosmopolitan or subtropical-tropical in distribution. Oceanic plankters were most obvious from winter through summer, and this can be correlated with known current patterns. Fall is typically a period of lower current velocities along the southeast coast of Florida.

Indian River plankton contributions are difficult to quantify because of the gear used; nonetheless, this contribution can be inferred from fluctuating abundances of the estuarine-neritic diatom, *Skeletonema costatum*. The highest *Skeletonema* counts were obtained from collections on low or low slack tides and, conversely, a majority of *Skeletonema* absences were correlated with sampling on high or slack high tides. The association of tidal stage and abundance of this Indian River diatom is further supported by a correlation between surface chlorophyll *a* and tidal stage.

Indian River influence was also demonstrated by the extremely high surface and bottom water nutrient loads in this coastal area, e.g., mean $PO_4$-P values of 3.16 to 6.79 $\mu$g-atoms/liter and mean $SiO_2$-Si values of 6.77 to 8.90 $\mu$g-atoms/liter. Ground and aerial observations as well as interstation and intrastation physical and chemical data indicated that Stations I, II and V were the most frequently affected by inlet discharge. Intake of Indian River plankters at the nuclear power plant's cooling water inlet in the vicinity of Station I is probable.

Nutrient, standing stock and primary production data suggest that the sampling area is comparable to other productive locales, e.g. coastal areas influenced by runoff and some Caribbean upwelling areas. Organic material from planktonic primary production, although available in the study area, may not result in higher biomass and production at other trophic levels. The Indian River and oceanic planktonic standing stock are continually and cyclically delivered and removed from the sampling area. The inferred coastal and Indian River phytomicrobenthic communities are of more immediate significance to higher trophic levels.

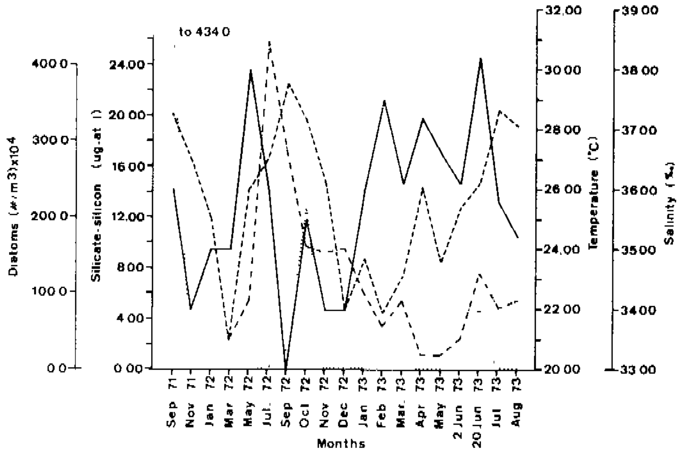


Figure 14. Relationships between diatom abundance, silicates, temperature and salinities at Station II, surface.

(Key: ________________Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._. . . . . . . . . Silicates.)

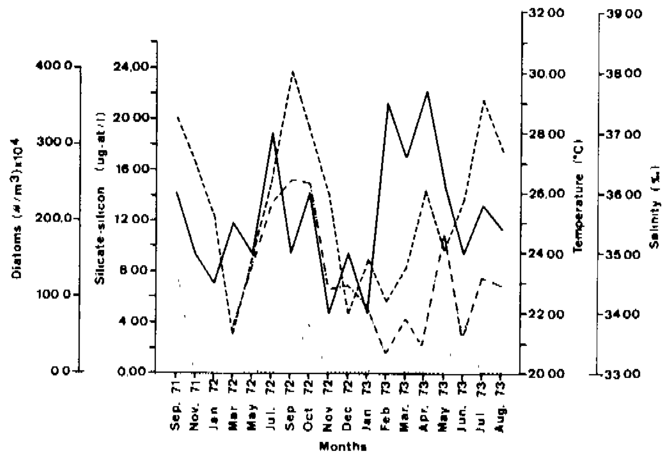


Figure 16. Relationships between diatom abundance, silicates, temperature and salinities at Station III, surface.

(Key: ________________Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._._. ._._._._._Silicates.)

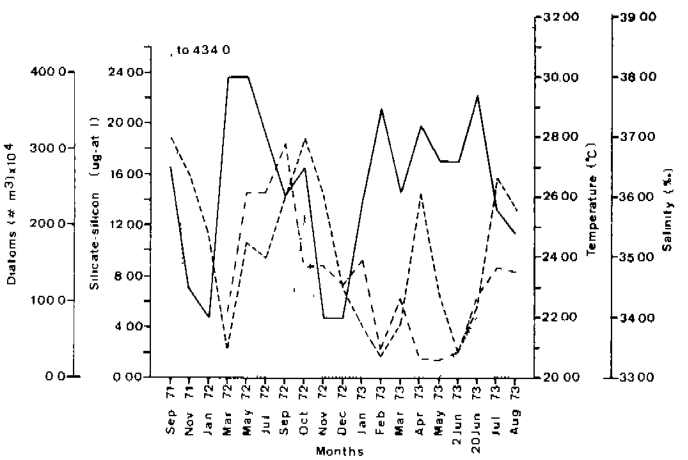


Figure 15. Relationships between diatom abundance, silicates, temperature and salinities at Station II, bottom.

(Key: ________ Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._._. . . . . . . .Silicates.)

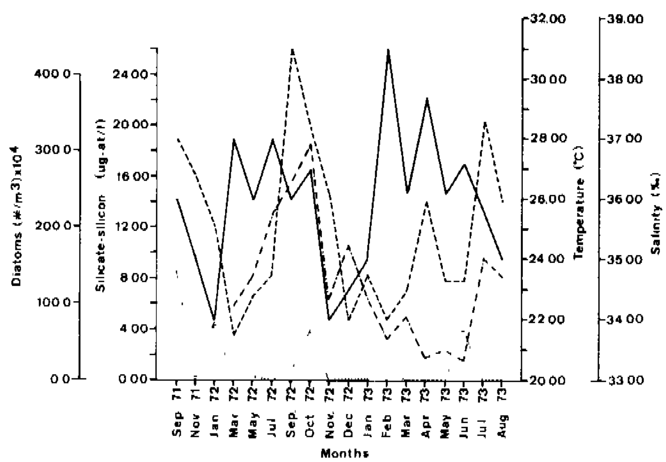


Figure 17. Relationships between diatom abundance, silicates, temperature and salinities at Station III, bottom.

(Key: ________ __Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._._._._._. . . .Silicates.)

This "base-line" study has demonstrated a dynamic pelagic realm subject to estuarine and oceanic intrusions and systematic removal of planktonic organisms. It would be extremely difficult even over a 5-10 year period, to predict natural cycles because natural variation can be extreme on a short (daily) or long term (yearly) basis (Steidinger, 1973; Smayda, 1976). Smayda (1976), in a discussion of plankton processes in neritic waters, stated, "It is at present impossible, on the basis of field and experimental data, to predict the most probable type of community reorganization (if any) in response to an anthropogenic perturbant, the levels that would induce such changes, when they would occur, and the speed of recovery to normal conditions upon alleviation of the stress." The authors agree with this conclusion and would like to reemphasize the importance of benthic or sessile communities as study subjects. Such organisms are either immobile or of limited mobility; they must adjust or be reduced in numbers. Measurements of planktonic production, phyto- and zooplankton biomass or species diversity in an area adjacent to or downstream from a thermal discharge may therefore be of limited value in evaluating cause-effect relationships in a dynamic, transient system.

Temperature increases above ambient (e.g. $\Delta t \geq 5°C$) have been associated with changes in population metabolism and community structure (e.g., Gurtz and Weiss, 1974; Goldman and Ryther, 1976). *In situ* downstream recovery or inhibition, however, is

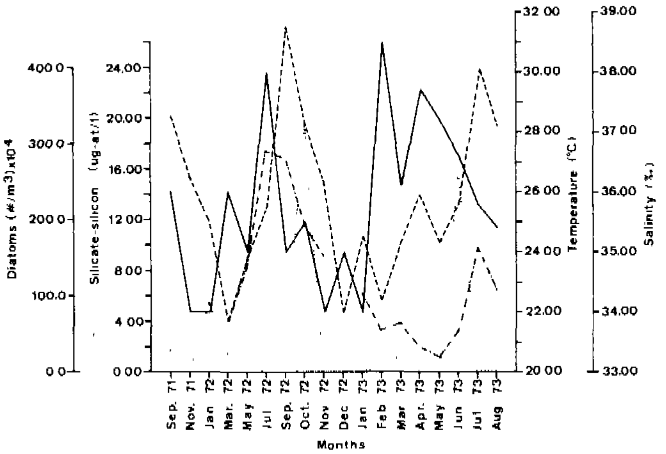


Figure 18. Relationships between diatom abundance, silicates, temperature and salinities at Station IV, surface.

(Key: ______________Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;. . . . . . . . . ._._.Silicates.)

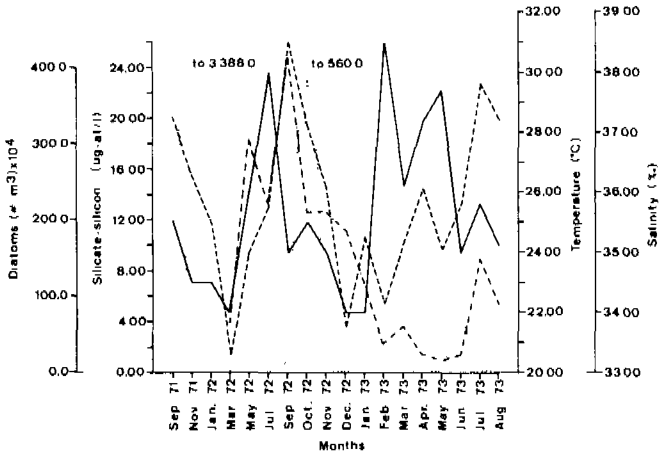


Figure 20. Relationships between diatom abundance, silicates, temperature and salinities at Station V, surface.

(Key: __________ Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;. . . . . . ._._._._.Silicates.)

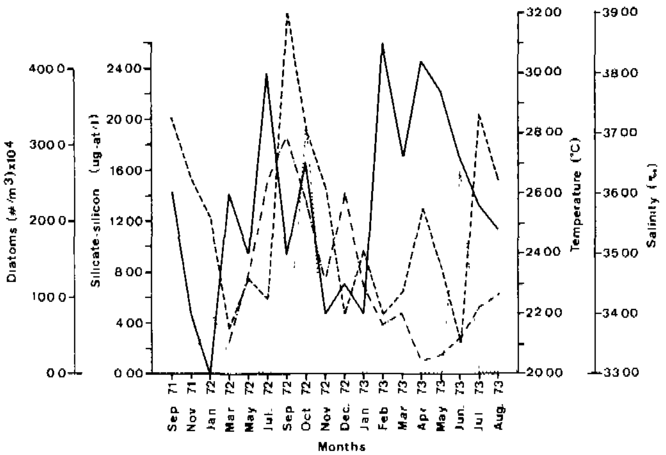


Figure 19. Relationships between diatom abundance, silicates, temperature and salinities at Station IV, bottom.

(Key: ______________Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._. . . . . . . . ._._.Silicates.)

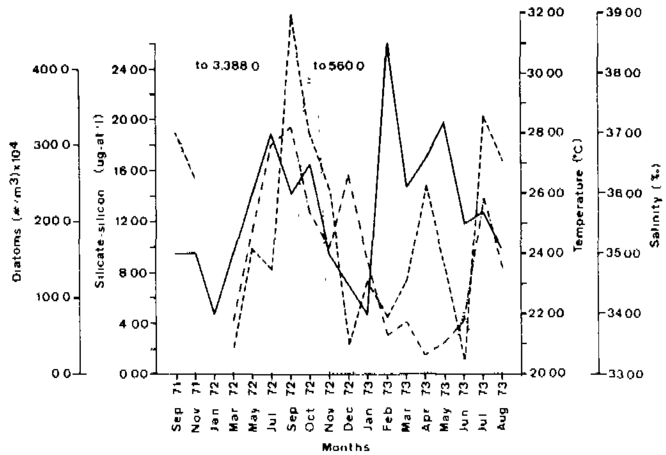


Figure 21. Relationships between diatom abundance, silicates, temperature and salinities at Station V, bottom.

(Key: ______________Salinity; - - - - - - - - - - - - - - - -Temperature; . . . . . . . . . . . . . . . .Diatoms;._._._. . . . . . . . .Silicates.)

difficult to evaluate experimentally. It would therefore seem reasonable to limit evaluation of possible plankton effects to entrainment studies—specifically, mortality and structural damage. Phytoplankton and zooplankton species, particularly meroplankton larvae, could be identified, enumerated and separated into living and dead categories. Associated parameters such as ATP may also be worthwhile in comparing intake versus discharge data. Destruction of entrained meroplankton would probably represent the most long term impact on this nearshore system.

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# VII. Phytoplankton, 1971-1973


## ABSTRACT

Tester, L. S. and K. A. Steidinger. 1979. Nearshore Marine Ecology at Hutchinson Island, Florida: 1971-1974. VII. Phytoplankton, 1971-1973. Fla. Mar. Res. Publ. No. 34. Pp. 16-61. One hundred thirty-two diatom taxa, 102 dinoflagellate taxa and two blue-green algae were recorded from 96 plankton tows (1971-1973). Resistant dinoflagellates (preservable) were less abundant than diatoms except in two months. Diatom taxa represented widely distributed (>80%), cold temperate to tropical (>50%) and estuarine/neritic (>60%) species. Resistant dinoflagellates represented oceanic (>50%) and tropical/warm temperate (>50%) species, also of wide distribution (>65%). More than 90% of the taxa identified to species have been previously recorded for the Gulf of Mexico and Caribbean.

Forty-five species are presented as indicators of oceanic influence. Large dinoflagellates, particularly *Ceratium* spp. were better indicators than diatoms. Rare, large, shade-adapted dinoflagellates were used as upwelling indicators. Data show that an oceanic assemblage inhabits coastal waters year-round but that these species are more abundant in summer and winter. Highest counts of large, or chain-forming net phytoplankton represented estuarine and coastal species, suggesting a substantial resident population of the Indian River System. Nearshore waters of Hutchinson Island, as indicated by phytoplankton composition, are continually admixed by tidal exchange, estuarine export and oceanic import.

## INTRODUCTION

Plankton samples off Hutchinson Island, Florida were analyzed as part of an interdisciplinary program to provide baseline data prior to a nuclear power plant start-up. The program rationale was summarized by Gallagher and Hollinger (1977) and Walker and Steidinger (1979). Plankton tows were taken principally to identify and quantify zooplankton. However, preserved net phytoplankton, specifically diatoms and resistant dinoflagellates, were identified and enumerated to provide data on possible indicator species of hydrographic alterations and water mass interaction. Related plankton data (e.g. water chemistry, phytoplankton biomass as chlorophyll *a*, primary productivity) and statistical correlations between various measured parameters are reported and discussed elsewhere (Worth and Hollinger, 1977; Walker et al., 1979; Walker and Steidinger, 1979).

## METHODS AND MATERIALS

Step-oblique plankton tows (0.5 m opening, 202 µm mesh, 5:1 length) were conducted at five stations in coastal waters off Hutchinson Island (Figure 1) with depths of 5 to 12 m. A flowmeter was attached off center to record total volume of seawater filtered. Clogging of the net was reduced by backwashing between stations. Ninety-six single tow samples, representing bimonthly (September 1971 through August 1972), monthly (September 1972 through August 1973), or incidental collections were preserved in 5% buffered formalin. Gallagher and Hollinger (1977) discussed field sampling techniques in more detail.

Sample jars (946 ml) containing preserved material were inverted several times to randomly disperse the organisms. An initial 10 ml aliquot was dispensed, with a wide-bore pipette, into a standard petri dish with parallel lines (5-10 mm apart) etched on the bottom. The lines served as guides in conducting traverses of whole aliquots. The first 10 ml was scanned with a dissecting microscope, but not counted, to record the presence of familiar and frequent species. Another 10 ml aliquot was used to record all species and count the larger species. A further aliquot of 0.01 ml was always scrutinized for the smaller species under a compound microscope. Additional analyses of 5 ml, 1 ml, and 0.1 ml aliquots were sometimes necessary depending on the abundance of different size classes. Total cell counts ranged from 121 to 3,282 per sample and averaged 903 cells. Abundance was recorded for each aliquot (total volume) and converted to cells/m$^3$ of sample. Enumeration data is not representative for the <200 µm size components, but can indicate order of magnitude differences for chain-forming diatoms, particularly within one sampling regime. No distinction between living and dead organisms was made in these preserved samples and the data were analyzed as if all specimens were living.

Photomicrographs were taken using Zeiss microscopes with brightfield and phase-contrast optics to illustrate the morphology of selected species.

## RESULTS

Large mesh plankton tows, e.g., 202 µm, can be used for quantification of this size fraction and larger plankton, e.g., certain dinoflagellates, meso- and macrozooplankton, but not for nannoplankton and the smaller microplankton. Phytoplankton data in the species account is therefore minimal, i.e. temperature and salinity tolerance, geographical distribution (using Briggs' 1974 boundaries for pelagic regions), mean count, and frequency of occurrence based on 96 tow samples. Our mean count data are not useful for statistical analyses, but do reflect the paucity of many species that would not have been detected unless large sample sizes (50-150 m$^3$) were collected. These count data can also be used along with frequency to qualitatively evaluate standing stock contribution of various larger-sized components.

One hundred thirty-two diatom taxa, 102 dinoflagellate taxa and two blue-green algae were recorded over a two year period. The diel study (1973-74) increases this list by 40 taxa (see Walker, 1979). The blue-greens, planktonic *Oscillatoria erythraea* (Ehrenberg *ex* Gomont) Geitler and endophytic *Richelia intracellularis* J. Schmidt *in* Ostenfeld & J. Schmidt were recorded as present but not counted. Both of these species are indicators of tropical or subtropical oceanic waters. *Oscillatoria* was present except in July 1972 and April, July and August 1973. *Richelia* occurred in *Rhizosolenia styliformis* in all months except December and no discernible pattern was evident.

Resistant dinoflagellates (armored species and *Pyrocystis*) were far less abundant (22-96 cells/m$^3$ mean count range for stations) than diatoms (17,514-185,954 cells/m$^3$ mean count for stations) but dominated in July 1972 and May 1973 (Figures 2, 3). Since collections represented bimonthly or monthly sampling, and were quantitatively selective for larger and more preservable forms, the interpretation of "dominance" is relative to sampling methods. The total mean count range for pennate diatoms (8,877-79,978 cells/m$^3$) indicates their importance in the sampling area whether they represent assumed resident, benthic populations (Station 3) or pelagic and benthic populations flushed from the Indian River. Most pennate diatoms, with the exception of such genera as *Thalassionema*, *Thalassiothrix* and *Asterionella*, are solely benthic or sessile in habitat and only incidental in

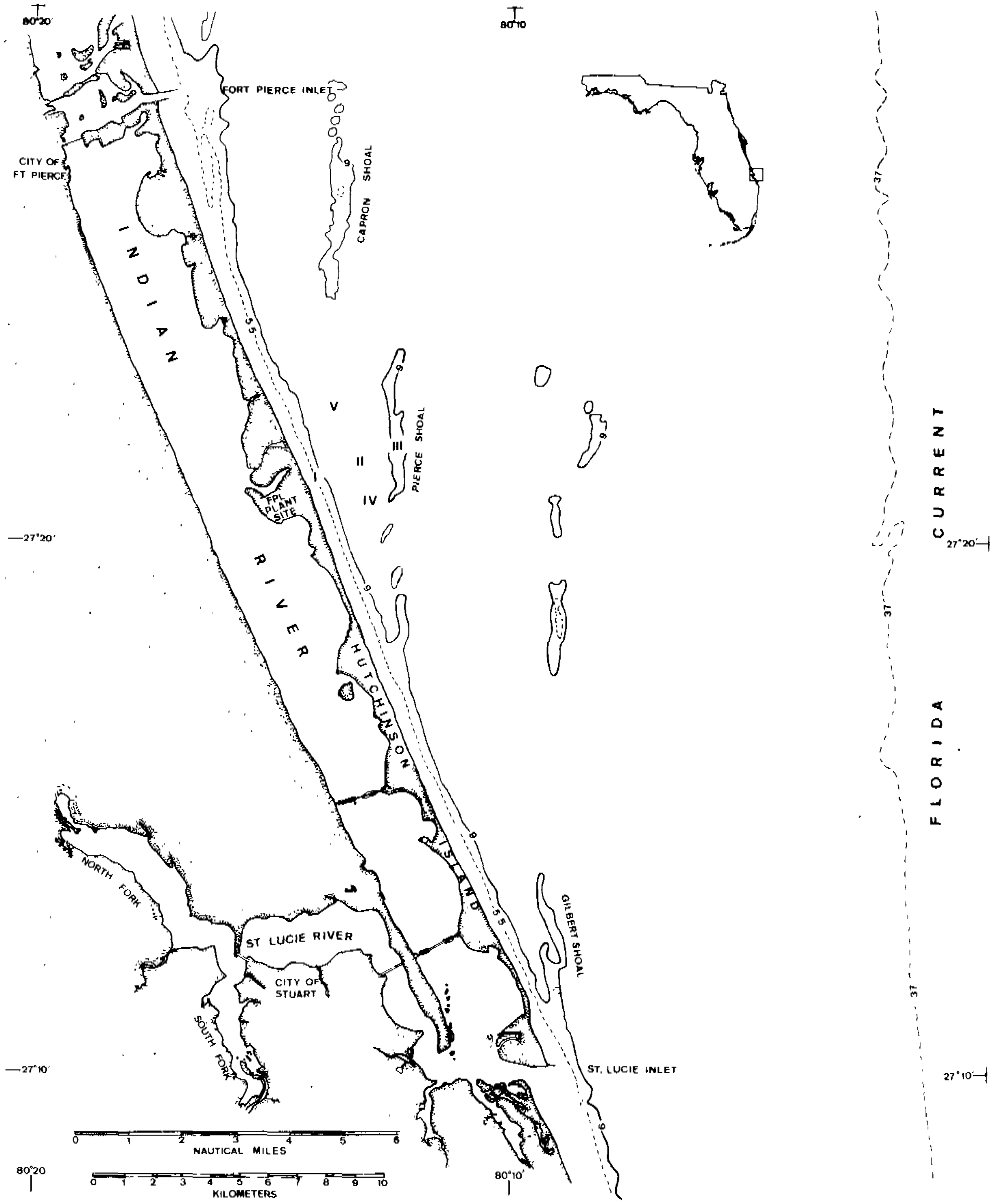


Figure 1. Study area, showing station locations.

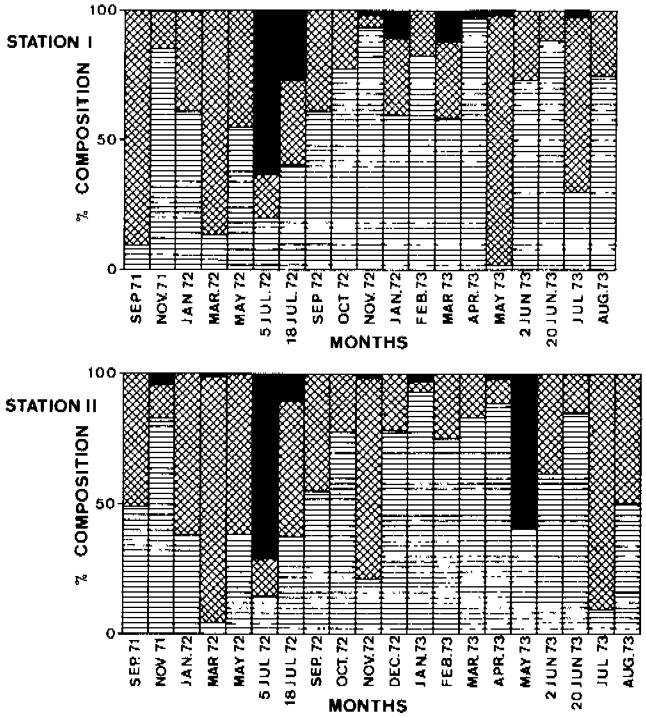


Figure 2. Percentage composition of centric diatoms (horizontal lines), pennate diatoms (hatched) and resistant dinoflagellates (solid) at Stations I and II off Hutchinson Island, Florida.

plankton. The five most abundant net phytoplankton genera were *Skeletonema*, *Chaetoceros*, *Rhizosolenia*, *Thalassionema*, and *Nitzschia* (Figures 4-8).

Station 5, nearest the Ft. Pierce Inlet, had the highest mean total count for dinoflagellates and diatoms. Station 3, on Pierce Shoal, had twice the mean count of pennate versus centric diatoms. Station 1, closest to shore, had the lowest mean counts of all three categories. Species that were recorded in concentrations greater than $1 \times 10^6$ cells/m$^3$ in any one sample were: *Skeletonema costatum*, *Nitzschia pungens* var. *atlanticum*, *Bacillaria paxillifer*, *Asterionella glacialis*, *Thalassionema nitzschoides*, *Chaetoceros affinis*, *C. diversus*, *C. lorenzianus*, and *Bacteriastrum delicatulum*. The highest counts represented estuarine and coastal species and suggest a substantial resident population of the Indian River System.

We have suggested 48 of the taxa as possible indicator species based on their known distribution patterns. Oceanic assemblages have been used in certain cases to suggest oceanic intrusion, upwelling, or estuarine flushing. Dinoflagellates appear to be the best indicators of oceanic influence. Although relative abundances of *Skeletonema costatum*, *Ceratium hircus* and *Bellerochea horologicalis* between stations can be used to demonstrate Indian River discharge, other categories such as identifiable microflagellates might be better estuarine indicators. The presence of

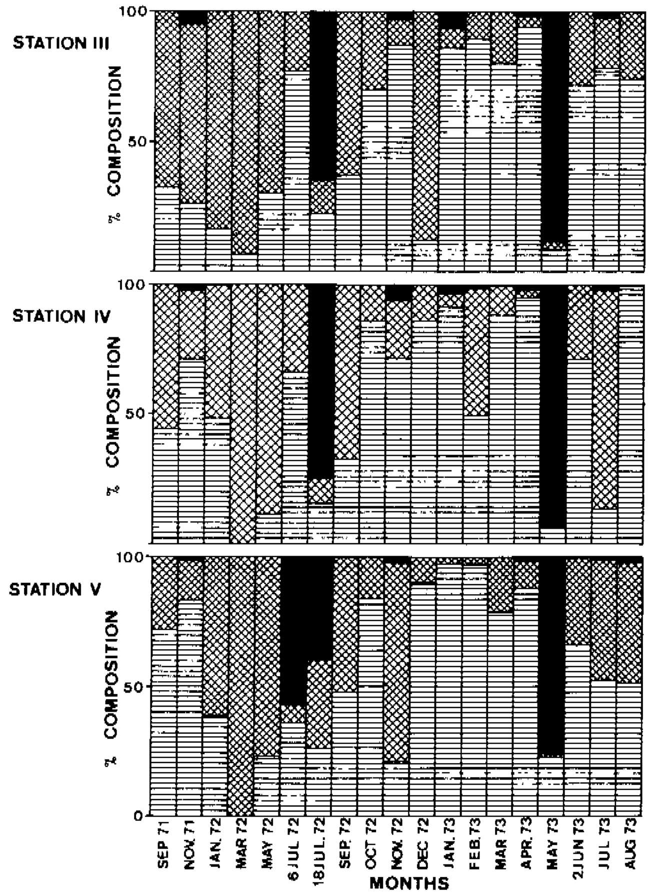


Figure 3. Percentage composition of centric diatoms (horizontal lines), pennate diatoms (hatched), and resistant dinoflagellates (solid) at Stations III-V off Hutchinson Island, Florida.

*Pyrocystis fusiformis*, *Ceratium extensum* and *Chaetoceros coarctatus* in all months; the presence of *Ceratium carriense*, *Ceratium lunula* in all collections except fall; and the presence of other oceanic indicators in either winter, spring and/or summer and only occasionally in fall suggest that oceanic species inhabit coastal waters year-round but are in highest concentrations in summer and winter and lowest in fall. For example, the presence and/or highest count of *Ceratium ranipes* var. *palmatum*, *C. bigelowii*, *C. concilians*, *C. inflatum*, *C. kofoidii*, *Gonyaulax kofoidii*, *Amphisolenia lemmermannii*, *Pyrocystis hamulus* var. *inaequalus* and *Rhizosolenia castracanei* illustrate a strong oceanic influence in July 1972 and June and July 1973, with the possibility of upwelling. The presence and/or highest count of *Ceratium longissimum*, *C. longinum*, *C. longirostrum*, *C. extensum*, *C. belone*, *C. falcatum*, *C. macroceros*, *Protoperidinium grande*, *Pyrocystis lancelata*, *P. fusiformis*, and *Triceratium formosum* f. *pentagonales* suggest another period of strong oceanic influence in January and February 1973. None of these species were ever abundant and several were recorded

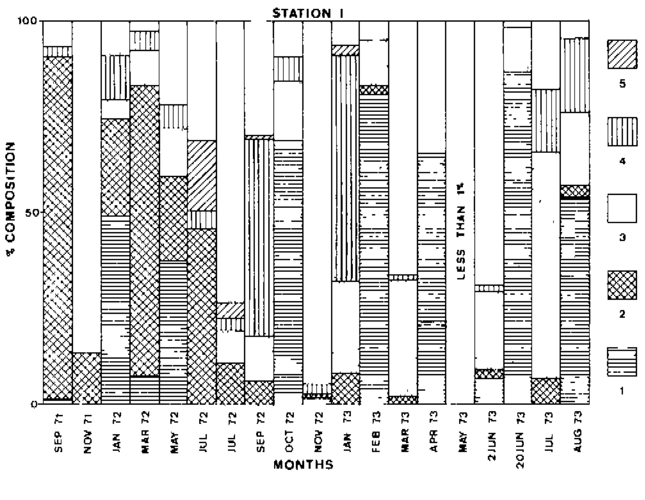


Figure 4. Percentage composition of the dominant preserved net phytoplankton at Station I. 1 = *Skeletonema costatum*, 2 = *Thalassionema nitzschioides*, 3 = *Nitzschia* spp., 4 = *Chaetoceros* spp., 5 = *Rhizosolenia* spp.

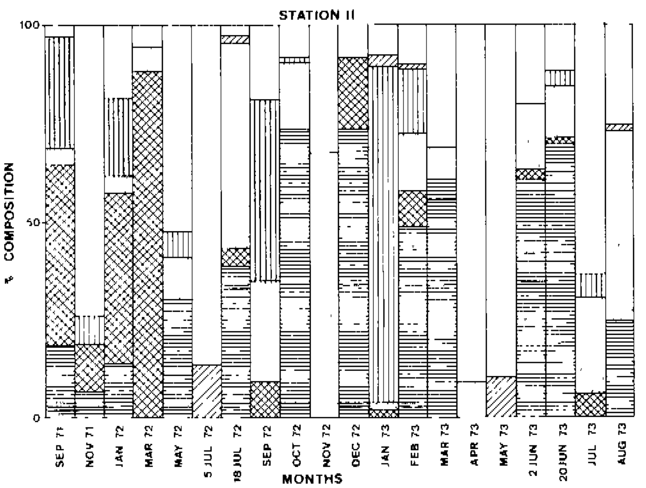


Figure 5. Percentage composition of the dominant, preserved net phytoplankton at Station II, see Figure 4 for code.

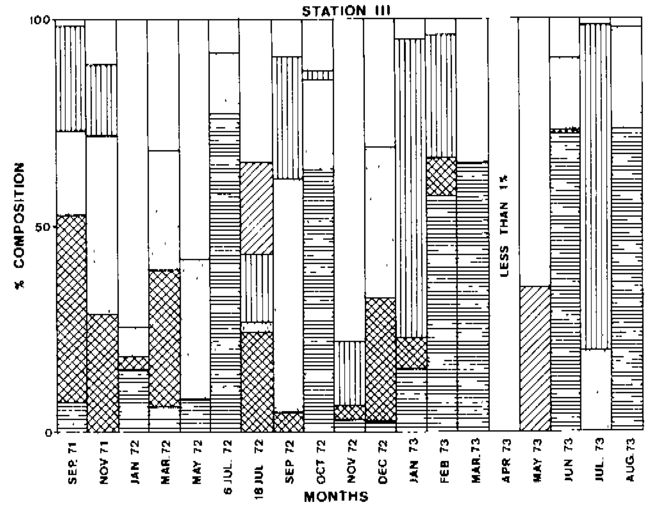


Figure 6. Percentage composition of the dominant, preserved net phytoplankton at Station III, see Figure 4 for code.

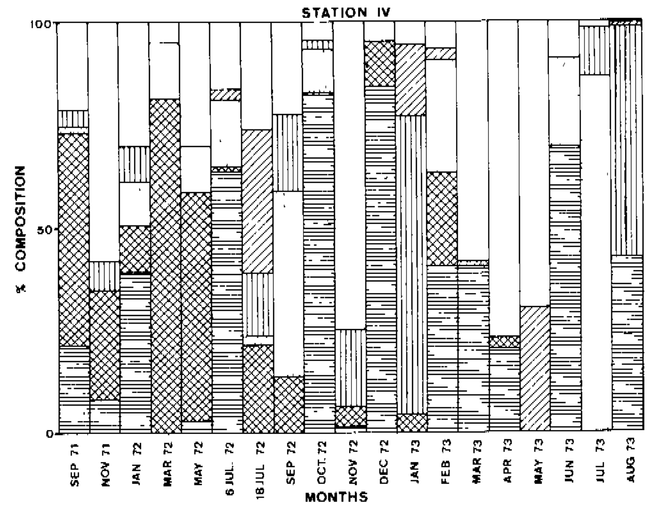


Figure 7. Percentage composition of the dominant, preserved net phytoplankton at Station IV, see Figure 4 for code.

only once or twice in the sampling program. Another less obvious oceanic pulse is suggested for March and April 1973 by the presence of *Planktoniella sol*, *Ornithocercus magnificus*, and *Pyrocystis hamulus*. Species selected as oceanic indicators have an asterisk following the name in the taxa list. Estuarine influence in relation to tidal cycles was shown by Walker and Steidinger (1979) using relative net abundance of trapped *Skeletonema costatum* and by Worth and Hollinger (1977) using nutrient, salinity, phytoplankton biomass (as Chl *a*) and other parameters. Thirty of the suggested indicator species (including three estuarine/neritic species) were photographed as were 55 other species to verify occurrence (Plates I-XIII, see pages 36-61).

## TAXA LIST OF DIATOMS AND DINOFLAGELLATES

### DIATOMS

*Actinoptychus senarius* (Ehrenberg) Ehrenberg (= *A. undulatus*). Frequency: 5.2%. Mean count: 3 cells/m$^3$. Salinity range: 33.0-37.0‰. Temperature range: 23.5-29.5°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic, estuarine, neritic and oceanic form.

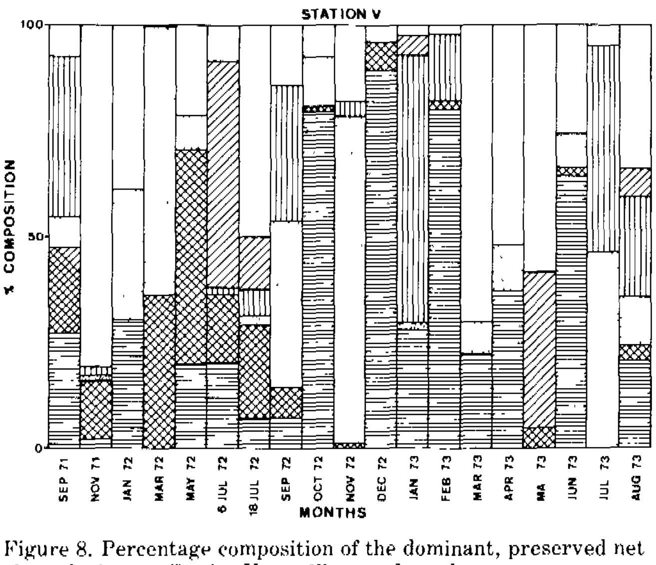


Figure 8. Percentage composition of the dominant, preserved net phytoplankton at Station V, see Figure 4 for code.

*Actinoptychus splendens* (Shadbolt) Ralfs. Plate I, Figure 1. Frequency: 3.1%. Mean count: 4 cells/m³. Salinity range: 35.5-38.5‰. Temperature range: 20.7-28.3°C. Cosmopolitan in cold and warm temperate regions. Tychoplanktonic, neritic, and estuarine form.

*Actinoptychus vulgaris* Schumann. Frequency: 1.0%. Count: 2 cells/m³. Salinity range: 36.0-36.5‰. Temperature range: 28.2-28.3°C. Recorded from warm temperate regions. Tychoplanktonic form.

*Amphora* spp. Pennate diatoms. Frequency: 17.7%. Mean count: 10.3 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 21.0-32.0°C.

*Asterionella glacialis* Castracane (= *A. japonica*). Pennate diatom. Plate I, Figure 2. Frequency: 48.9%. Mean count: 22,459 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. A neritic and estuarine species.

*Asterionella notata* Grunow. Pennate diatom. Frequency: 3.1%. Mean count: 45,854 cells/m³. Salinity range: 35.0-36.6‰. Temperature range: 20.5-28.4°C. North Atlantic records in warm temperate region. Principally a neritic species.

*Asterionella* sp. Frequency: 1.0%. Count: 845 cells/m³. Salinity range: 35.0-36.0‰. Temperature range: 22.8-23.8°C.

*Bacillaria paxillifer* (O.F. Müller) Hendey (= *Nitzschia paradoxa*). Pennate diatom. Plate I, Figure 3. Frequency: 57.2%. Mean count: 22,238 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. Tychoplanktonic, neritic and estuarine species.

*Bacteriastrum delicatulum* Cleve. Frequency: 12.5%. Mean count: 182,102 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 21.1-32.0°C. Cosmopolitan in cold temperate to tropical regions. Oceanic and neritic form.

*Bacteriastrum hyalinum* Lauder. Frequency: 10.4%. Mean count: 13,021 cells/m³. Salinity range: 34.0-38.0‰. Temperature range: 24.8-29.5°C. Cosmopolitan in cold temperate to tropical regions. Neritic form.

*Bellerochea horologicalis* von Stosch. Plate I, Figures 4a, 4b. Frequency: 40.6%. Mean count: 947 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. The species type locality is the eastern Gulf of Mexico. Previously this species was recorded as a form of *B. malleus* (Saunders and Glenn, 1969). A dominant neritic and estuarine form in certain localities.

*Biddulphia alternans* (Bailey) van Heurck. Plate II, Figure 5. Frequency: 37.5%. Mean count: 258 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic, neritic and estuarine form, sometimes found attached to algae.

*Biddulphia longicruris* Greville. Frequency: 1.0%. Count: 6 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C. Cosmopolitan in warm temperate and tropical regions. Neritic species.

*Biddulphia pulchella* Gray. Plate III, Figure 9. Frequency: 3.1%. Mean count: 4 cells/m³. Salinity range: 34.0-36.6‰. Temperature range: 22.4-24.5°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic, neritic and estuarine species, sometimes found attached to algae.

*Biddulphia tuomeyi* (Bailey) Roper. Plate III, Figure 11. Frequency: 13.5%. Mean count: 9 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 21.0-32.0°C. Widely distributed in warm temperate regions. Tychoplanktonic species.

*Cerataulina pelagica* (Cleve) Hendey (= *C. bergonii*). Frequency: 12.5%. Mean count: 103 cells/m³. Salinity range: 34.0-38.0°C. Temperature range: 21.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. Neritic and estuarine species.

*Chaetoceros affinis* Lauder. Frequency: 29.1%. Mean count: 77,274 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 21.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. Found in estuarine to oceanic waters.

*Chaetoceros anastomosans* Grunow. Frequency: 3.1%. Mean count: 475 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 26.0-31.0°C. Cosmopolitan in warm temperate regions. Principally a neritic species.

*Chaetoceros atlanticus* Cleve.* Frequency: 1.0%. Count: 646 cells/m³. Salinity: 35.0‰. Temperature range: 31.5-32.0°C. Cosmopolitan in warm temperate to cold arctic regions. Oceanic species.

*Chaetoceros* sp. cf. *brevis/borealis*. Frequency: 1.0%. Count: 13 cells/m³. Salinity range: 35.0-36.0‰. Temperature: 20.0°C.

*Chaetoceros coarctatus* Lauder.* Plate III, Figure 12. Frequency: 64.5%. Mean count: 771 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 21.0-32.0°C. Cosmopolitan in warm temperate to tropical regions; occasionally found in cold temperate waters. Oceanic species often with contractile-stalked ciliates attached.

*Chaetoceros compressus* Lauder. Frequency: 4.1%. Mean count: 7,311 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 22.4-32.0°C. Cosmopolitan in arctic to tropical regions. Found in neritic and estuarine environments.

*Chaetoceros curvisetus* Cleve. Plate III, Figure 13. Frequency: 1.0%. Count: 108 cells/m³. Salinity: 34.0‰. Temperature range: 26.2-26.3°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species, but found in brackish water.

*Chaetoceros debilis* Cleve. Frequency: 1.0%. Count: 646 cells/m³. Salinity: 35.0‰. Temperature range: 31.5-32.0°C. Widely distributed species in cold temperate to tropical regions. Principally a neritic species, but found in estuarine waters.

*Chaetoceros decipiens* Cleve.* Plate III, Figure 14. Frequency: 28.1%. Mean count: 14,134 cells/m². Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Cosmopolitan in arctic to tropical seas. Principally an oceanic species.

*Chaetoceros didymus* Ehrenberg var. *didymus*. Plate IV, Figure 16. Frequency: 10.4%. Mean count: 3,034 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 26.0-32.0°C. Widely distributed in cold temperate to tropical regions. Principally a neritic species, but found in brackish water.

*Chaetoceros didymus* var. *protuberans* (Lauder) Gran & Yendo. Frequency: 9.4%. Mean count: 4,590 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 22.4-32.0°C.

*Chaetoceros diversus* Cleve. Plate III, Figure 15. Frequency: 4.1%. Mean count: 996,420 cells/m³. Salinity range: 35.0-36.5‰. Temperature range: 28.0-28.5°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species.

*Chaetoceros eibenii* (Grunow) Meunier. Frequency: 5.2%. Mean count: 1,499 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.7-24.5°C. Cosmopolitan in cold and warm temperate regions but uncommon. Principally a neritic species, but also found in brackish waters.

*Chaetoceros gracilis* Schütt. Frequency: 3.1%. Mean count: 3,155 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 26.0-32.0°C. Cosmopolitan in arctic to warm temperate regions. Principally a neritic species.

*Chaetoceros laciniosus* Schütt. Frequency: 12.5%. Mean count: 11,531 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 26.0-32.0°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species, but found in brackish water areas.

*Chaetoceros lauderi* Ralfs. Frequency: 2.0%. Mean count: 1,510 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-31.0°C. Widely distributed in cold temperate to tropical regions. Principally a neritic species.

*Chaetoceros lorenzianus* Grunow. Plate IV, Figure 17. Frequency: 46.8%. Mean count: 178,718 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Cosmopolitan in cold temperate to tropical regions. Principally an estuarine and neritic species.

*Chaetoceros messanensis* Castracane.* Plate IV, Figure 18. Frequency: 2.0%. Mean count: 2,028 cells/m³. Salinity range: 35.0-36.5‰. Temperature range: 28.1-32.0°C. Cosmopolitan in warm temperate and tropical seas. Principally an oceanic species.

*Chaetoceros pendulus* Karsten.* Frequency: 1.0%. Count: 23 cells/m³. Salinity range: 35.1-35.2‰. Temperature range: 27.1-28.4°C. Widely distributed in temperate and tropical seas, but of uncommon occurrence. Principally an oceanic species.

*Chaetoceros peruvianus* Brightwell. Frequency: 20.8%. Mean count: 8,301 cells/m³. Salinity range: 33.0-36.6‰. Temperature range: 21.3-32.0°C. Cosmopolitan in warm temperate and tropical seas; occasionally found in cold temperate regions. Principally an oceanic and neritic species, but found in estuaries.

*Chaetoceros socialis* Lauder. Frequency: 2.0%. Mean count: 1,837 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-31.0°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species.

*Chaetoceros subtilis* Cleve. Frequency: 1.0%. Count: 877 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.2°C. Common only in certain areas and thus far characterized as a temperate, neritic and estuarine form.

*Chaetoceros vistulae* Apstein. Frequency: 1.0%. Count: 2,433 cells/m³. Salinity range: 35.0-36.0‰. Temperature range: 31.0-32.0°C. Uncommon species of broad distribution in warm temperate regions. Principally a tolerant neritic species.

*Chaetoceros* spp. Frequency: 16.7%. Mean count: 29,316 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 22.4-32.0°C.

*Climacodium frauenfeldianum* Grunow. Plate IV, Figure 19. Frequency: 28.1%. Mean count: 1,550 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C. Widely distributed species, usually in warm temperate and tropical regions. Principally oceanic and neritic, but occasionally found in estuaries.

*Climacodium* sp. cf. *frauenfeldianum* Grunow. Frequency: 1.0%. Count: 1,701 cells/m³. Salinity: 36.0‰. Temperature: 28.5°C.

*Climacosophenia elongata* Bailey. Frequency: 1.0%. Count: 3 cells/m³. Salinity range: 35.0-36.6‰. Temperature range: 23.3-25.8°C. Uncommon in warm temperate and tropical regions.

*Corethron criophilum* Castracane. Plate V, Figure 20. Frequency: 8.3%. Mean count: 21,923 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 23.1-28.5°C. Cosmopolitan, reported from arctic to antarctic waters, inshore and offshore.

*Coscinodiscus centralis* Ehrenberg. Plate V, Figure 21. Frequency: 23.9%. Mean count: 12 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Widely distributed in cold and warm temperate regions. Principally an oceanic species but brackish water records exist.

*Coscinodiscus granii* Gough. Frequency: 20.8%. Mean count: 4 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.6-32.0°C. Cosmopolitan species in cold temperate to tropical regions. Principally a neritic species. The taxon listed could include *Coscinodiscus concinnus* which was not differentiated.

*Coscinodiscus perforatus* Ehrenberg. Frequency: 1.0%. Count: 5 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C. Widely distributed but not common in many areas. Distribution records include cold temperate to tropical waters.

*Coscinodiscus radiatus* Ehrenberg. Frequency: 14.5%. Mean count: 8 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Widely distributed in cold temperate to tropical regions. Reported for oceanic, neritic and estuarine plankton.

*Coscinodiscus wailesii* Gran & Angst. Plate V, Figure 22. Frequency: 54.1%. Mean count: 52 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Uncommon, but widely distributed in cold and warm temperate regions.

*Coscinodiscus* spp. Frequency: 12.5%. Mean count: 27 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 21.0-29.0°C.

*Cyclotella* spp. Frequency: 26.0%. Mean count: 1,109 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C.

*Cymatosira belgica* Grunow. Pennate diatom. Frequency: 9.3%. Mean count: 38 cells/m³. Salinity range: 33.0-36.5‰. Temperature range: 21.8-32.0°C. Widely distributed in cold and warm temperate regions. A tychoplanktonic and neritic species.

*Dactyliosolen* sp. Frequency: 1.0%. Count: 6 cells/m³. Salinity: 36.0‰. Temperature: 28.5°C.

*Detonula pumila* (Castracane) Schütt (= *Schroderella delicatula*). Frequency: 3.1%. Mean count: 12 cells/m³. Salinity range: 34.0-38.2‰. Temperature range: 22.4-26.2°C. Cosmopolitan in warm temperate and tropical regions. Principally a neritic species.

*Diploneis crabro* Ehrenberg (= *Navicula crabro*) Pennate diatom. Frequency: 2.0%. Mean count: 5 cells/m³. Salinity range: 36.0-38.0‰. Temperature range: 22.5-27.0°C. Uncommon in cold and warm temperate regions. Tychoplanktonic and neritic species.

*Diploneis* sp. cf. *crabro* Ehrenberg. Pennate diatom. Frequency: 1.0%. Count: 11 cells/m³. Salinity range: 34.0-34.5‰. Temperature: 25.0°C.

*Ditylum brightwellii* (West) Grunow. Plate V, Figure 23. Frequency: 10.4%. Mean count: 35 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.6-28.3°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species although recorded from estuarine areas.

*Ditylum* sp. Frequency: 1.0%. Count: 83 cells/m³. Salinity range: 35.0-36.0‰. Temperature: 20.0°C.

*Eupodiscus radiatus* Bailey. Plate V, Figure 25. Frequency: 17.7%. Mean count: 3 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 21.0-32.0°C.

Widely distributed in warm temperate regions. Recorded in neritic and estuarine waters.

*Grammatophora marina* (Lyngbye) Kützing. Pennate diatom. Plate V, Figure 26. Frequency: 4.1%. Mean count: 50 cells/m³. Salinity range: 35.0-37.0‰. Temperature range: 28.0-32.0°C. Common, cosmopolitan species in cold and warm temperate regions. Tychoplanktonic, neritic and estuarine species. Often found attached to marine plants.

*Guinardia flaccida* (Castracane) Peragallo. Plate V, Figure 27. Frequency: 56.2%. Mean count: 53 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. Principally a neritic and estuarine species although recorded in open waters.

*Gyrosigma* spp. Pennate diatoms. Frequency: 4.2%. Mean count: 12 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 21.5-29.5°C.

*Hemiaulus hauckii* Grunow. Plate VI, Figure 28. Frequency: 2.0%. Mean count: 4.5 cells/m³. Salinity range: 33.0-36.6‰. Temperature range: 23.0-29.5°C. Cosmopolitan in cold temperate to tropical regions. An oceanic and neritic species.

*Hemiaulus heibergii* Cleve. Frequency: 19.1%. Mean count: 17 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 20.9-32.0°C.

*Hemiaulus membranaceus* Cleve.* Plate VI, Figure 29. Frequency: 13.5%. Mean count: 31 cells/m³. Salinity range: 35.0-38.5‰. Temperature range: 20.7-29.6°C. Uncommon form in warm temperate and tropical waters. An oceanic species although recorded occasionally in neritic waters.

*Hemiaulus sinensis* Greville. Frequency: 2.0%. Mean count: 488 cells/m³. Salinity range: 35.0-38.2‰. Temperature range: 20.0-26.2°C. Cosmopolitan in warm temperate and tropical regions. Principally a neritic species but reported from estuaries.

*Isthmia enervis* Ehrenberg. Plate VI, Figure 31. Frequency: 16.6%. Mean count: 48 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Widely distributed in cold temperate to tropical regions. Tychoplanktonic and often attached to some substrate. Principally a neritic species.

*Lauderia annulata* Cleve (= *Lauderia borealis*). Frequency: 7.2%. Mean count: 77 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 22.0-28.3°C. Cosmopolitan in cold and warm temperate regions. A neritic and estuarine species.

*Leptocylindrus danicus* Cleve. Frequency: 12.5%. Mean count: 18,167 cells/m³. Salinity range: 34.0-38.2‰. Temperature range: 20.0-28.3°C. A common, cosmopolitan species from cold temperate to tropical regions. Principally a neritic and estuarine species.

*Licmorphora* spp. Pennate diatoms. Frequency: 9.4%. Mean count: 13 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 20.9-31.0°C.

*Lithodesmium intricatum* Grunow (= *Ditylum intricatum*). Plate V, Figure 24. Frequency: 2.0%. Mean count: 4 cells/m³. Salinity range: 37.5-38.5‰. Temperature range: 22.0-22.4°C. Rare species of warm temperate regions.

*Lithodesmium undulatum* Ehrenberg. Plate VI, Figure 32. Frequency: 18.7%. Mean count: 48 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 22.0-32.0°C. Uncommon in tropical regions.

*Navicula lyra* Ehrenberg var. *lyra*. Pennate diatom. Frequency: 7.2%. Mean count: 3 cells/m³. Salinity range: 33.0-36.5‰. Temperature range: 23.1-32.0°C. Cosmopolitan in cold and warm temperate regions. Tychoplanktonic and neritic species.

*Navicula* sp. cf. *lyra* Ehrenberg var. *lyra*. Pennate diatom. Frequency: 2.0%. Mean count: 6.0 cells/m³. Salinity: 34‰. Temperature range: 22.0-24.5°C.

*Navicula lyra* var. *acuta* Pantocsek. Pennate diatom. Frequency: 1.0%. Count: 5 cells/m³. Salinity: 37‰. Temperature range: 23.5-26.4°C. Warm temperate variety.

*Navicula praetexta* Ehrenberg. Pennate diatom. Frequency: 1.0%. Count: 4 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.3°C. Cosmopolitan in cold and warm temperate regions. Tychoplanktonic and neritic species.

*Navicula* spp. Pennate diatoms. Frequency: 15.6%. Mean count: 58 cells/m³. Salinity range: 33.0-37.5‰. Temperature range: 20.7-29.5°C.

*Nitzschia closterium* (Ehrenberg) W. Smith. Pennate diatom. Plate VI, Figure 33. Frequency: 60.4%. Mean count: 15,877 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. A neritic and estuarine species.

*Nitzschia longissima* (de Brébisson) Ralfs. Pennate diatom. Plate VI, Figure 34. Frequency: 38.5%. Mean count: 11,735 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. A neritic and estuarine species.

*Nitzschia pungens* var. *atlantica* Cleve. Pennate diatom. Plate VI, Figure 35. Frequency: 48.9%. Mean count: 107,031 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C. Widely distributed in warm temperate regions. A neritic and estuarine species.

*Nitzschia spathulata* de Brébisson *ex* W. Smith. Pennate diatom. Frequency: 1.0%. Count: 6 cells/m³. Salinity range: 33.0-34.0‰. Temperature range: 25.0-25.2°C. Widely distributed in cold and warm temperate regions. A neritic species.

*Nitzschia* spp. Pennate diatoms. Frequency: 22.9%. Mean count: 4,371 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 20.9-32.0°C.

*Odontella chinensis* Grunow (= *Biddulphia chinensis*). Plate II, Figure 7. Frequency: 23.9%. Mean count: 39 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Planktonic species widely distributed in cold temperate to tropical regions. Principally described as an oceanic species, but reported from estuarine areas.

*Odontella mobiliensis* Grunow (= *Biddulphia mobiliensis*). Plate II, Figure 8. Frequency: 28.1%. Mean count: 23 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Cosmopolitan in cold temperate to tropical regions. Neritic and estuarine species.

*Odontella* sp. cf. *mobiliensis* (Bailey) Grunow. Frequency: 1.0%.Count: 81 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C.

*Odontella obtusa* Kützing. (= *Biddulphia obtusa*). Plate II, Figure 6. Frequency: 9.3%. Mean count: 6 cells/m³. Salinity range: 33.0-36.6‰. Temperature range: 22.0-32.0°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic, neritic and estuarine form.

*Odontella regia* Schultze (= *Biddulphia regia*). Frequency: 4.1%. Mean count: 148 cells/m³. Salinity range: 34.0-38.0‰. Temperature range: 20.6-21.7°C. Planktonic species widely distributed in cold and warm temperate regions. Neritic and estuarine form.

*Odontella rhombus* Kützing (= *Biddulphia rhombus*). Plate III, Figure 10. Frequency: 7.3%. Mean count: 15 cells/m³. Salinity range: 34.0-36.6‰. Temperature range: 22.7-32.0°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic and principally a neritic species although found in brackish waters.

*Orthoneis splendida* (Gregory) Cleve. Pennate diatom. Frequency: 1.0%. Count: 2 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.3°C. Principally a warm temperate, neritic species.

*Palmeriana hardmanianus* Greville (= *Hemidiscus hardmanianus*). Plate VI, Figure 30. Frequency: 22.9%. Mean count: 42 cells/m³. Salinity range: 34.0-37.0‰. Temperature range: 21.0-32.0°C. Distributed in warm temperate and tropical regions. Recorded as a neritic and estuarine species. Sometimes parasitized (phycomycetes of the order Lagenidiales).

*Paralia sulcata* (Ehrenberg) Cleve (= *Melosira sulcata*). Plate VII, Figure 36. Frequency: 27.0%. Mean count: 30 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Cosmopolitan in cold temperate to tropical regions. Common tychoplanktonic species of neritic and estuarine occurrence.

*Plagiogramma vanheurckii* Grunow. Pennate diatom. Frequency: 35.4%. Mean count: 95 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Cosmopolitan in warm temperate regions. A neritic and estuarine species.

*Plagiogramma* spp. Pennate diatoms. Frequency: 2.1%. Mean count: 69 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C.

*Planktoniella sol* (Wallich) Schütt.* Plate VII, Figure 37. Frequency: 20.0%. Mean count: 1 cell/m³. Salinity range: 36.1-38.2‰. Temperature range: 23.1-25.9°C. Cosmopolitan in tropical and warm temperate seas; occasionally found in colder waters. Principally an oceanic species.

*Pleurosigma balticum* (Ehrenberg) W. Smith (= *Gyrosigma balticum*). Pennate diatom. Frequency: 1.0%. Count: 19 cells/m³. Salinity range: 34.0-34.5‰. Temperature range: 25.1-25.2°C. Cosmopolitan in cold temperate to tropical regions. Tychoplanktonic.

*Pleurosigma macrum* W. Smith. Pennate diatom. Frequency: 1.0%. Count: 6 cells/m³. Salinity: 36.0‰. Temperature: 28.5°C.

*Pleurosigma* spp. Pennate diatoms. Frequency: 31.0%. Mean count: 16 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C.

*Rhabdonema adriaticum* Kützing. Pennate diatom. Plate VII, Figure 38. Frequency: 10.4%. Mean count: 13 cells/m³. Salinity range: 34.0-37.5‰. Temperature range: 20.7-32.0°C. Widely distributed in cold and warm temperate regions. Principally a sessile, attached species in neritic and estuarine habitats.

*Rhabdonema arcuatum* (Lyngbye) Kützing. Pennate diatom. Frequency: 1.0%. Count: 11 cells/m³. Salinity: 36.0‰. Temperature range: 21.5-21.7°C. Cosmopolitan in cold and warm temperate regions. A sessile, attached form in the littoral zone.

*Rhaphoneis surirella*(Ehrenberg) Grunow. Pennate diatom. Frequency: 10.4%. Mean count: 57 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 22.0-32.0°C. Widely distributed in cold and warm temperate regions. Tychoplanktonic, neritic and brackish-water species.

*Rhizosolenia alata* Brightwell. Plate VII, Figure 39. Frequency: 45.8%. Mean count: 109 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. Found in oceanic, neritic and estuarine areas. Three varieties are currently recognized and one is associated with oceanic waters.

*Rhizosolenia calcar-avis* Schultze. Plate VII, Figure 40. Frequency: 46.8%. Mean count: 57 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-32.0°C. Mostly a warm water species but found from cold temperate to tropical regions. Widely distributed and occurring in oceanic to estuarine environments, but reported usually as an oceanic form.

*Rhizosolenia castracanei* Peragallo.* Plate VII, Figure 41. Frequency: 2.0%. Mean count: 7 cells/m³. Salinity range: 37.5-37.7‰. Temperature range: 20.7-25.1°C. Widely distributed in warm temperate and tropical regions. Reported as an oceanic species.

*Rhizosolenia delicatula* Cleve. Frequency: 1.0%. Count: 9 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 20.6-20.9°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species.

*Rhizosolenia imbricata* Brightwell var. *imbricata*. Frequency: 36.4%. Mean count: 293 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. Principally a neritic species.

*Rhizosolenia imbricata* var. *shrubsolei* (Cleve) Schröder. Frequency: 1.0%. Count: 17 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C. Cosmopolitan in cold temperate and possibly warmer regions. Principally a neritic species but found in estuarine areas.

*Rhizosolenia robusta* Norman. Plate VII, Figure 42. Frequency: 23.9%. Mean count: 13 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Widely distributed in cold temperate to tropical regions. Found in all realms, oceanic to estuarine.

*Rhizosolenia setigera* Brightwell. Plate VII, Figure 43. Frequency: 8.3%. Mean count: 58 cells/m³. Salinity range: 34.0-38.2‰. Temperature range: 21.1-28.5°C. Common, cosmopolitan species in cold temperate to tropical regions. Recorded from neritic and estuarine waters.

*Rhizosolenia stolterfothii* Peragallo. Plate VIII, Figure 44. Frequency: 43.7%. Mean count: 106 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. Principally a neritic and estuarine form.

*Rhizosolenia styliformis* Brightwell.* Plate VIII, Figure 45. Frequency: 66.6%. Mean count: 180 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Widely distributed in cold temperate to tropical regions. An oceanic species.

*Rhizosolenia* spp. Frequency: 2.1%. Mean count: 2,886 cells/m³. Salinity range: 35.0-36.0‰. Temperature range: 21.5-28.5°C.

*Skeletonema costatum* (Greville) Cleve. Plate VIII, Figure 46. Frequency: 72.9%. Mean count: 377,708 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. The most common centric diatom worldwide, often found dominating the plankton. A neritic and estuarine species. *Skeletonema tropicum* Cleve is included in this taxon and was not separated until 1974 during the diel study.

*Stephanopyxis palmeriana* (Greville) Grunow. Plate VIII, Figure 47. Frequency: 50.0%. Mean count: 35 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Widely distributed in warm temperate and tropical regions from oceanic to estuarine areas.

*Stephanopyxis turris* (Greville & Arnott) Ralfs. Frequency: 8.3%. Mean count: 46 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 21.0-32.0°C. Widely distributed in cold temperate to tropical regions. A neritic species.

*Streptotheca tamesis* Shrubsole. Frequency: 42.7%. Mean count: 42 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.5-32.0°C. Cosmopolitan in cold and warm and cold temperate regions. A neritic and estuarine species.

*Streptotheca* spp. Frequency: 1.0%. Count: 34 cells/m³. Salinity: 37‰. Temperature range: 23.5-26.4°C.

*Striatella unipunctata* (Lyngbye) Agardh. Pennate diatom. Frequency: 7.2%. Mean count: 11 cells/m³. Salinity range: 33.0-37.5‰. Temperature range: 20.7-29.5°C. Common, cosmopolitan species in cold temperate to tropical regions. Tychoplanktonic, neritic and estuarine species. Often found attached.

*Synedra gailloni* var. *elongata* Peragallo. Pennate diatom. Frequency: 1.0%. Count: 2 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-29.5°C. Warm temperate species.

*Synedra* spp. Pennate diatoms. Frequency: 19.8%. Mean count: 29 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C.

*Terpsinöe* sp. Pennate diatom. Frequency: 1.0%. Count: 4 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.2°C.

*Thalassionema nitzschioides* Grunow. Pennate diatom. Plate VIII, Figures 48a, 48b. Frequency: 85.4%. Mean count: 75,534 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions. A neritic and estuarine species.

*Thalassiosira eccentrica* (Ehrenberg) Cleve (= *Coscinodiscus excentricus*). Frequency: 1.0%. Mean count: 4 cells/m³. Salinity: 37.7‰. Temperature range: 23.5-25.1°C. Common and widely distributed species in cold temperate to tropical regions. Principally an oceanic and neritic form.

*Thalassiosira rotula* Meunier. Frequency: 2.0%. Mean count: 106 cells/m³. Salinity range: 35.0-37.0‰. Temperature range: 20.0-21.5°C. Widely distributed in cold temperate to tropical regions. Principally a neritic species.

*Thalassiosira subtilis* (Ostenfeld) Gran. Frequency: 22.9%. Mean count: 4,109 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-26.3°C. Widely distributed in cold temperate to tropical regions, but more common in temperate seas. An oceanic species.

*Thalassiosira* sp. Frequency: 7.3%. Mean count: 1,871 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 21.5-28.5°C.

*Thalassiothrix frauenfeldii* Grunow. Pennate diatom. Plate VIII, Figure 49. Frequency: 51.0%. Mean count: 1,076 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in cold temperate to tropical regions described as principally oceanic but found in estuaries.

*Thalassiothrix* spp. Pennate diatoms. Frequency: 14.6%. Mean count: 11,984 cells/m³. Salinity range: 34.0-38.2‰. Temperature range: 20.5-32.0°C.

*Trachyneis aspera* var. *intermedia* (Grunow) Cleve. Pennate diatom. Frequency: 1.0%. Count: 6 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C. A cold and warm temperate species.

*Triceratium biquadratum* Jan. Frequency: 1.0%. Count: 2 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-29.5°C. Uncommon in warm temperate regions.

*Triceratium favus* Ehrenberg. Plate IX, Figure 50. Frequency: 8.3%. Mean count: 2 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 21.8-32.0°C. Widely distributed in cold temperate to tropical regions. Principally a neritic species, although recorded from estuaries.

*Triceratium* sp. cf. *formosum f. pentagonales*.* Plate IX, Figures 51a, 51b. Frequency: 2.0%. Mean count: 7 cells/m³. Salinity range: 37.5-38.5‰. Temperature range: 20.7-22.4°C. Oceanic species.

Unidentified diatoms: Plate IX, Figures 52, 53. Frequency: 37.5%. Mean count: 26 cells/m³.

## DINOFLAGELLATES

*Amphisolenia bidentata* Schröder.* Plate X, Figure 54. Frequency: 29.1%. Mean count: 4 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.5-28.4°C. Cosmopolitan in warm temperate and tropical regions. Oceanic species sometimes associated with upwelling.

*Amphisolenia bifurcata* Murray & Whitting.* Plate X, Figure 55. Frequency: 2.0%. Mean count: 1 cell/m³. Salinity range: 34.0-37.2‰. Temperature range: 23.1-26.1°C. An oceanic species, cosmopolitan in tropical seas.

*Amphisolenia* sp. cf. *lemmermanii* Kofoid.* Plate X, Figure 56. Frequency: 1.0%. Mean count: 4.0 cells/m³. Salinity: 36.6‰. Temperature range: 21.1-25.6°C. Uncommon, but cosmopolitan in cold to tropical waters. An oceanic species.

*Ceratium belone* Cleve.* Plate X, Figure 57. Frequency: 7.2%. Mean count: 2 cells/m³. Salinity range: 34.0-38.0‰. Temperature range: 21.8-26.2°C. Rare, but widely distributed in warm temperate and tropical regions. An oceanic species.

*Ceratium bigelowii* Kofoid.* Frequency: 3.1%. Mean count: 2 cells/m³. Salinity range: 35.0-38.2‰. Temperature range: 23.3-26.3°C. Rare oceanic species reported from both Atlantic and Pacific tropical waters. Possibly an indicator of upwelling.

*Ceratium breve* (Ostenfeld & Schmidt) Schröder. Frequency: 5.2%. Mean count: 3 cells/m³. Salinity range: 35.1-38.2‰. Temperature range: 22.4-29.0°C. Uncommon in warm temperate and tropical regions. A neritic and oceanic species.

*Ceratium* sp. cf. *breve/humile*. Frequency: 1.0%. Count: 6 cells/m³. Salinity range: 33.0-34.0‰. Temperature range: 25.0-25.2°C.

*Ceratium buceros* Zacharias. Frequency: 1.0%. Count: 1 cell/m³. Salinity range: 35.0-36.0‰. Temperature: 27.7°C. Cosmopolitan in warm temperate and tropical regions.

*Ceratium* sp. cf. *buceros* Zacharias. Frequency: 2.1%. Mean count: 2 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-29.5°C.

*Ceratium candelabrum* (Ehrenberg) Stein var. *candelabrum*.* Frequency: 3.1%. Mean count: 3 cells/m³. Salinity range: 35.0-38.5‰. Temperature range: 21.0-23.8°C. Cosmopolitan in principally warm temperate and tropical regions although found in cold temperate areas. Fairly common oceanic species.

*Ceratium candelabrum* var. *depressum* (Pouchet) Jörgensen.* Frequency: 6.2%. Mean count: 3 cells/m³. Salinity range: 34.0-37.7‰. Temperature range: 23.3-27.0°C. Widely distributed in warm temperate and tropical regions. An oceanic species.

*Ceratium carriense* Gourret var. *carriense*.* Plate X, Figure 58. Frequency: 57.3%. Mean count: 10 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-30.1°C. Cosmopolitan, principally in tropical seas, although found in warm temperate regions. An oceanic, surface species.

*Ceratium carriense* var. *volans* (Cleve) Jörgensen.* Frequency: 45.8%. Mean count: 6 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-29.0°C. Cosmopolitan in warm temperate and tropical regions. An oceanic species.

*Ceratium concilians* Jörgensen.* Frequency: 1.0%. Count: 4 cells/m³. Salinity: 37.7‰. Temperature range: 23.5-25.1°C. Uncommon in warm temperate and tropical regions. Oceanic species of wide distribution.

*Ceratium contortum* (Gourret) Cleve var. *contortum*. Plate X, Figure 59. Frequency: 17.7%. Mean count: 5 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.0-26.3°C. Widely distributed in warm temperate and tropical regions. Principally an oceanic species.

*Ceratium contortum* var. *karstenii* (Pavillard) Sournia. Plate X, Figure 60. Frequency: 55.2%. Mean count: 10 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.5-31.0°C. Cosmopolitan in warm temperate and tropical regions. An oceanic and neritic species.

*Ceratium contortum* f. *subcontortum* (Schröder) Steemann Nielsen. Frequency: 2.0%. Mean count: 4 cells/m³. Salinity range: 34.0-38.0‰. Temperature range: 24.8-27.7°C. Warm water species in the Atlantic.

*Ceratium extensum* (Gourret) Cleve.* Plate X, Figure 61. Frequency: 77.1%. Mean count: 10 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.7-32.0°C. Cosmopolitan and principally a tropical form in both Atlantic and Pacific Oceans, but recorded from warm temperate areas. An oceanic species.

*Ceratium falcatum* (Kofoid) Jörgensen.* Frequency: 1.0%. Count: 1 cell/m³. Salinity: 35.0‰. Temperature range: 22.4-22.6°C. Cosmopolitan in warm temperate and tropical regions, but infrequent. An oceanic species.

*Ceratium furca* (Ehrenberg) Claparède & Lachmann. Plate XI, Figure 62. Frequency: 75.0%. Mean count: 111 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan in cold temperate to tropical regions. Principally a neritic species although found in estuaries and open waters.

*Ceratium* sp. cf. *contortum* (Gourret) Cleve var. *contortum*. Frequency: 2.1%. Mean count: 12 cells/m³. Salinity range: 34.0-36.6‰. Temperature range: 21.1-25.6°C.

*Ceratium fusus* (Ehrenberg) Dujardin. Plate XI, Figure 63. Frequency: 78.1%. Mean count: 76 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan in cold temperate to tropical regions. Principally a neritic species but found in estuaries and open waters.

*Ceratium* sp. cf. *fusus* (Ehrenberg) Dujardin. Frequency: 2.1%. Mean count: 7 cells/m³. Salinity range: 37.5-38.5‰. Temperature range: 20.7-22.4°C.

*Ceratium hexacanthum* var. *contortum* Lemmermann. Frequency: 2.2%. Mean count: 2 cells/m³. Salinity range: 34.0-37.0‰. Temperature range: 21.3-26.3°C. Probably of similar distribution to the species.

*Ceratium hexacanthum* Gourret var. *hexacanthum*. Plate XI, Figure 64. Frequency: 63.5%. Mean count: 8 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.6-30.1°C. Cosmopolitan in cold temperate to tropical regions, but more common in warm waters.

*Ceratium hircus* Schröder (= *Ceratium furca* var. *hircus*). Plate XI, Figure 65. Frequency: 30.2%. Mean count: 8 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Very common, cosmopolitan species in warm temperate and tropical regions. Principally an estuarine species.

*Ceratium horridum* (Cleve) Gran. Frequency: 27.0%. Mean count: 5 cells/m³. Salinity range: 34.0-38.5‰. Temperature range: 20.7-30.1°C. Widely distributed in cold and warm temperate regions, and although recorded from the tropics, usually considered cold water form. An oceanic and neritic species.

*Ceratium* sp. cf. *humile* Jörgensen. Frequency: 1.0%. Count: 5 cells/m$^3$. Salinity: 37.0‰. Temperature range: 24.8-26.0°C. Cosmopolitan in warm temperate and tropical regions. An oceanic and neritic species.

*Ceratium incisum* (Karsten) Jörgensen.* Plate XI, Figure 66. Frequency: 1.0%. Count: 4 cells/m$^3$. Salinity range: 37.5-38.5‰. Temperature range: 22.0-22.4°C. Widely distributed but rare in warm temperate and tropical regions. Principally an oceanic species.

*Ceratium inflatum* (Kofoid) Jörgensen.* Frequency: 18.7%. Mean count: 4 cells/m$^3$. Salinity range: 33.0-38.5‰. Temperature range: 20.9-28.3°C. Widely distributed but rare in warm temperate and tropical regions. An oceanic species.

*Ceratium kofoidii* Jörgensen.* Frequency: 1.0%. Count: 2 cells/m$^3$. Salinity range: 37.0-38.0‰. Temperature: 28.3°C. Uncommon, tropical and oceanic species.

*Ceratium lineatum* (Ehrenberg) Cleve.* Frequency: 2.0%. Mean count: 2 cells/m$^3$. Salinity range: 36.0-38.0‰. Temperature range: 24.5-28.5°C. Widely distributed from cold to tropical regions: uncommon or rare in many areas. Principally an oceanic species.

*Ceratium longinum* Karsten.* Frequency: 1.0%. Count: 1 cell/m$^3$. Salinity: 34.0‰. Temperature range: 23.1-24.5°C. A rare oceanic species recorded from warm temperate and tropical regions.

*Ceratium longirostrum* Gourret.* Frequency: 8.3%. Mean count: 3 cells/m$^3$. Salinity range: 35.0-38.2‰. Temperature range: 21.0-27.7°C. Principally a rare tropical species; interoceanic.

*Ceratium longissimum* (Schröder) Kofoid.* Frequency: 2.0%. Mean count: 3 cells/m$^3$. Salinity range: 37.0-38.5‰. Temperature range: 22.0-26.0°C. Rare in warm temperate and tropical regions. An oceanic species at depth, possibly associated with upwelling.

*Ceratium lunula* (Schimper *ex* Karsten) Jörgensen.* Plate XI, Figure 67. Frequency: 67.7%. Mean count: 7 cells/m$^3$. Salinity range: 33.0-38.5‰. Temperature range: 20.0-29.0°C. Widely distributed in warm temperate and tropical regions. An oceanic species sometimes associated with upwelling.

*Ceratium macroceros* (Ehrenberg) Vanhoffen var. *macroceros*. Plate XI, Figure 68. Frequency: 21.8%. Mean count: 4 cells/m$^3$. Salinity range: 34.0-38.0‰. Temperature range: 20.0-29.6°C. Widely distributed in cold temperate to tropical regions. An oceanic species.

*Ceratium macroceros* var. *gallicum* Kofoid. Frequency: 2.1%. Mean count: 2 cells/m$^3$. Salinity range: 36.0-38.0‰. Temperature range: 24.0-26.0°C.

*Ceratium massiliense* (Gourret) Karsten. Plate XI, Figure 69. Frequency: 94.7%. Mean count: 86 cells/m$^3$. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Cosmopolitan in warm temperate and tropical regions. An oceanic and neritic species.

*Ceratium* sp. cf. *pavillardii* Jörgensen. Frequency: 1.0%. Count: 2 cells/m$^3$. Salinity: 36.1‰. Temperature range: 21.8-23.1°C. Rare, but widely distributed in warm temperate and tropical regions. An oceanic form, possibly associated with upwelling.

*Ceratium pentagonum* Gourret.* Plate XI, Figure 70. Frequency: 14.5%. Mean count: 12 cells/m$^3$. Salinity range: 34.0-38.5‰. Temperature range: 21.0-28.5°C. Widely distributed in warm temperate and tropical regions. An oceanic species.

*Ceratium ranipes* var. *palmatum* (Schröder) Cleve.* Plate XII, Figure 71. Frequency: 1.0%. Count: 4 cells/m$^3$. Salinity range: 37.7-38.2‰. Temperature range: 22.4-26.2°C. Cosmopolitan in warm temperate and tropical regions. An oceanic species possibly associated with upwelling.

*Ceratium teres* Kofoid.* Frequency: 4.1%. Mean count: 3 cells/m$^3$. Salinity range: 34.0-38.0‰. Temperature range: 23.5-29.0°C. Widely distributed but rare oceanic species in warm temperate and tropical regions.

*Ceratium trichoceros* (Ehrenberg) Kofoid. Plate XII, Figure 72. Frequency: 96.8% Mean count: 205 cells/m$^3$. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common, cosmopolitan species in warm temperate and tropical regions. An oceanic and neritic form.

*Ceratium tripos* (O. F. Müller) Nitzsch var. *tripos*. Frequency: 5.2% Mean count: 10 cells/m$^3$. Salinity range: 35.0-38.0‰. Temperature range: 20.0-21.7°C. World-wide distribution from cold temperate to tropical regions. An oceanic and neritic species.

*Ceratium tripos* var. *atlanticum* (Ostenfeld) Paulsen. Frequency: 35.4%. Mean count: 10 cells/m$^3$. Salinity range: 34.0-38.5‰. Temperature range: 20.0-32.0°C. Cosmopolitan in cold temperate to tropical regions. An oceanic to estuarine species.

*Ceratium vultur* var. *japonicum* (Schröder) Jörgensen.* Frequency: 1.0%. Count: 5 cells/m$^3$. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C. Uncommon, oceanic, tropical form, also recorded in warm temperate waters.

*Ceratium vultur* var. *sumatranum* (Karsten) Nielsen.* Frequency: 2.0%. Mean count: 3.5 cells/m³. Salinity range: 34.0-36.1‰. Temperature range: 21.8-26.3°C. Tropical, oceanic form, possibly associated with upwelling.

*Ceratium vultur* Cleve var. *vultur*.* Plate XII, Figures 73a, 73b. Frequency: 36.4%. Mean count: 8 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-29.5°C. Widely distributed in warm temperate and tropical regions. An oceanic species possibly associated with upwelling.

*Ceratium* sp. cf. *vultur* Cleve. Frequency: 1.0%. Count: 1 cell/m³. Salinity: 34.0‰. Temperature range: 23.1-24.5°C.

*Ceratium* spp. Frequency: 8.3%. Mean count: 2 cells/m³. Salinity range: 34.0-37.2‰. Temperature range: 21.8-26.3°C.

*Ceratocorys horrida* Stein. Frequency: 1.0%. Count: 6 cells/m³. Salinity range: 35.0-36.6‰. Temperature range: 23.3-25.8°C. Widely distributed in warm temperate and tropical regions. An oceanic and neritic species.

*Dinophysis caudata* S. Kent. Plate XII, Figure 74. Frequency: 4.1%. Mean count: 17 cells/m³. Salinity range: 34.0-38.0‰. Temperature range: 22.5-32.0°C. Most specimens of the variety *caudata*. Common and cosmopolitan in warm temperate and tropical regions. Also recorded in cold waters. Principally a neritic and estuarine species.

*Dinophysis* sp. Frequency: 1.0%. Count: 5 cells/m³. Salinity: 37.0‰. Temperature range: 23.5-26.4°C.

*Gonyaulax diacantha* (Meunier) Schiller. Frequency: 1.0%. Count: 15 cells/m³. Salinity range: 35.0-36.0‰. Temperature range: 31.0-32.0°C. Principally an estuarine species of limited record in warm temperate regions.

*Gonyaulax diegensis* Kofoid. Frequency: 6.2%. Mean count: 13 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 20.0-32.0°C. Widely distributed in warm temperate and tropical regions. Principally an oceanic and neritic species.

*Gonyaulax digitalis* (Pouchet) Kofoid. Frequency: 2.0%. Mean count: 10 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 27.2-32.0°C. Common, cosmopolitan species in cold and warm temperate regions. A neritic and estuarine species.

*Gonyaulax kofoidii* Pavillard.* Frequency: 1.0%. Count: 2 cells/m³. Salinity range: 36.0-38.0‰. Temperature range: 27.2-27.7°C. Widely distributed but uncommon oceanic species in warm temperate and tropical regions.

*Gonyaulax polygramma* Stein. Frequency: 4.1%. Mean count: 16 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 23.5-29.5°C. Common and cosmopolitan species in cold temperate to tropical regions. Principally a neritic and estuarine species.

*Gonyaulax* sp. cf. *polygramma* Stein. Frequency: 2.1%. Mean count: 4 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 24.0-32.0°C.

*Gonyaulax* sp. cf. *turbynei* Murray & Whitting. Frequency: 2.1%. Mean count: 5 cells/m³. Salinity: 38.0‰. Temperature range: 22.5-25.5°C.

*Gonyaulax* spp. Frequency: 3.1%. Mean count: 3 cells/m³. Salinity range: 35.5-38.0‰. Temperature range: 22.5-28.3°C.

*Ornithocercus magnificus* Stein.* Plate XII, Figure 75. Frequency: 1.0%. Count: 1 cell/m³. Salinity: 37.7‰. Temperature range: 25.9-26.1°C. Widely distributed in tropical and warm temperate seas. An oceanic species.

*Peridiniopsis assymetrica* Mangin. Frequency: 3.1%. Mean count: 6 cells/m³. Salinity range: 36.0-37.0‰. Temperature range: 21.5-27.0°C.

*Peridiniopsis* spp. Frequency: 2.1%. Mean count: 3 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 20.6-29.5°C.

*Prorocentrum gracile* Schütt. Plate XIII, Figure 79. Frequency: 13.5%. Mean count: 10 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 22.5-29.5°C. Common and cosmopolitan species in cold temperate to tropical regions. Principally a neritic and estuarine species.

*Prorocentrum micans* Ehrenberg. Frequency: 9.3%. Mean count: 6 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 23.5-29.0°C. Common and cosmopolitan in cold temperate to tropical regions. Principally a neritic and estuarine species, but found in open waters.

*Prorocentrum* sp. cf. *minimum* var. *marie-lebourae* (Parke & Ballantine) Hulburt. Frequency: 1.0%. Count: 4 cells/m³. Salinity: 36.0‰. Temperature range: 21.5-21.7°C. Cosmopolitan in cold temperate to tropical regions. Principally an estuarine species.

*Protoperidinium abei* (Paulsen) Balech. Frequency: 2.0%. Mean count: 4 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.3°C. Widely distributed in warm temperate and tropical regions. Principally a neritic and estuarine species.

*Protoperidinium* sp. cf. *acutipes* (Dangeard) Balech. Frequency: 2.1%. Mean count: 3 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.5°C.

*Protoperidinium claudicans* (Paulsen) Balech. Plate XIII, Figure 76. Frequency: 3.1%. Mean count: 642 cells/m³. Salinity range: 35.0-36.0‰. Temperature range: 20.0-28.5°C. Cosmopolitan species in cold temperate to tropical regions. Principally a neritic species although found in estuaries.

*Protoperidinium conicum* (Gran) Balech. Plate XIII, Figure 77. Frequency: 14.5%. Mean count: 7 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 22.0-32.0°C. Common and cosmopolitan species in cold temperate to tropical regions. An estuarine and neritic species of wide tolerances.

*Protoperidinium crassipes* (Kofoid) Balech. Frequency: 5.2%. Mean count: 4 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 22.5-32.0°C. Cosmopolitan in warm temperate and tropical regions. Widely tolerant and found in estuaries to open waters.

*Protoperidinium depressum* (Bailey) Balech. Frequency: 3.1%. Mean count: 3 cells/m³. Salinity range: 34.0-36.5‰. Temperature range: 21.5-28.5°C. Reported from tropical to Arctic waters. A euryhaline and eurythermal species.

*Protoperidinium divergens* (Ehrenberg) Balech. Frequency: 2.0%. Mean count: 483 cells/m³. Salinity range: 35.0-38.5‰. Temperature range: 22.0-28.5°C. Common and cosmopolitan in cold temperate to tropical regions. Principally a neritic species.

*Protoperidinium globulus* var. *quarnerense* (Schröder) comb. nov. Schröder, 1900, p. 18, pl. 1. Frequency: 1.0%. Count: 2 cells/m³. Salinity: 35.0‰. Temperature range: 31.5-32.0°C. Widely distributed in warm temperate and tropical regions. Principally an oceanic species.

*Protoperidinium grande* (Kofoid) Balech.* Frequency: 1.0%. Count: 4 cells/m³. Salinity: 38.5‰. Temperature range: 22.0-22.4°C. Rare tropical species; interoceanic.

*Protoperidinium* sp. cf. *leonis* (Pavillard) Balech. Frequency: 1.0%. Count: 11 cells/m³. Salinity range: 34.0-35.0‰. Temperature range: 24.8-25.0°C.

*Protoperidinium matzenaueri* (Böhm) Balech. Frequency: 2.1%. Mean count: 9 cells/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.3°C. Rare, tropical species.

*Protoperidinium nipponicum* (Abé) Balech. Frequency: 2.0%. Mean count: 483 cells/m³. Salinity range: 33.0-36.0‰. Temperature range: 26.0-29.5°C. Rare, warm temperate species.

*Protoperidinium oceanicum* (Vanhöffen) Balech. Plate XIII, Figure 78. Frequency: 22.9%. Mean count: 94 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C. Fairly common in warm temperate and tropical regions but uncommon in cold temperate waters. A neritic species.

*Protoperidinium* sp. cf. *ovum* (Schiller) Balech. Frequency: 2.1%. Mean count: 7 cells/m³. Salinity range: 37.0-38.0‰. Temperature range: 23.5-28.3°C. Uncommon in warm temperate and tropical regions.

*Protoperidinium pallidum* var. *schilleri* (Paulsen) comb. nov. Paulsen, 1930, p. 56, fig. 27. Frequency: 1.0%. Count: 4 cells/m³. Salinity: 38.5‰. Temperature range: 22.0-22.4°C.

*Protoperidinium pellucidum* Bergh. Frequency: 14.5%. Mean count: 12 cells/m³. Salinity range: 33.0-38.2‰. Temperature range: 20.0-32.0°C. Common and cosmopolitan in cold and warm temperate regions. A neritic and estuarine species.

*Protoperidinium pentagonum* (Gran) Balech. Frequency: 1.0%. Count: 1 cell/m³. Salinity range: 35.5-36.5‰. Temperature range: 28.0-28.2°C. Cosmopolitan in cold temperate to tropical regions, principally a neritic species.

*Protoperidinium punctulatum* (Paulsen) Balech. Frequency: 1.0%. Count: 4 cells/m³. Salinity: 36.0‰. Temperature range: 21.5-21.7°C.

*Protoperidinium solidicorne* (Mangin) Balech. Frequency: 2.0%. Mean count: 3 cells/m³. Salinity range: 35.0-36.6‰. Temperature range: 20.9-25.4°C. Cosmopolitan, oceanic species from cold to warm temperate regions.

*Protoperidinium* sp. cf. *solidicorne* (Mangin) Balech. Frequency: 2.1%. Mean count: 3 cells/m³. Salinity range: 35.0-37.7‰. Temperature range: 23.5-32.0°C.

*Protoperidinium spiniferum* (Schiller) Balech. Frequency: 4.1%. Mean count: 6 cells/m³. Salinity range: 35.0-38.0‰. Temperature range: 20.0-27.0°C. Rare species of limited distribution.

*Protoperidinium subinerme* (Paulsen) Loeblich. Frequency: 3.1%. Mean count: 4 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 23.5-29.5°C. Recorded from tropical to Arctic waters and principally an oceanic species.

*Protoperidinium venustum* (Matzenauer) Balech. Frequency: 1.0%. Count: 2 cells/m³. Salinity: 35.0‰. Temperature range: 31.5-32.0°C.

*Protoperidinium* spp. Frequency: 6.3%. Mean count: 10 cells/m³. Salinity range: 33.0-37.0‰. Temperature range: 23.5-32.0°C.

*Pyrocystis fusiformis* f. *biconica* Kofoid.* Plate XIII, Figure 81. Frequency: 83.8%. Mean count: 53 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-31.0°C. Similar distribution to the species.

*Pyrocystis fusiformis* Wyville-Thomson *ex* Blackman f. *fusiformis*.* Plate XIII, Figure 80. Frequency: 72.9%. Mean count: 33 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-28.7°C. Common, oceanic species in warm temperate and tropical regions, also recorded in neritic zones.

*Pyrocystis hamulus* Cleve var. *hamulus*.* Frequency: 2.0%. Mean count: 1 cell/m³. Salinity range: 36.1-36.6‰. Temperature range: 22.7-24.3°C. Rare, warm temperate and tropical oceanic species.

*Pyrocystis hamulus* var. *inaequalus* Schröder.* Plate XIII, Figure 82. Frequency: 1.0%. Count: 3 cells/m³. Salinity range: 35.0-36.6‰. Temperature range: 23.3-25.8°C. Very rare, warm temperate and tropical oceanic variety.

*Pyrocystis lancelata* Schröder.* Plate XIII, Figure 83. Frequency: 2.0%. Mean count: 2 cells/m³. Salinity range: 36.1-38.5‰. Temperature range: 21.9-24.3°C.

*Pyrocystis noctiluca* J. Murray *ex* Schütt. Plate XIII, Figure 84. Frequency: 79.1%. Mean count: 27 cells/m³. Salinity range: 33.0-38.5‰. Temperature range: 20.0-32.0°C. Common and cosmopolitan species in warm temperate and tropical regions. An oceanic species often found in the neritic zone.

*Pyrocystis* spp. Frequency: 1.0%. Count: 1 cell/m³. Salinity: 34.0‰. Temperature: 26.5°C.

*Pyrophacus horologium* Stein. Frequency: 13.5%. Mean count: 50 cells/m³. Salinity range: 33.0-38.0‰. Temperature range: 22.5-32.0°C. Cosmopolitan in cold temperate to tropical regions. A neritic and estuarine species often found in open waters.

*Pyrophacus steinii* (Schiller) Wall & Dale. Plate XIII, Figure 85. Frequency: 7.2%. Mean count: 3.6 cells/m³. Salinity range: 35.0-37.0‰. Temperature range: 23.5-32.0°C. Similar distribution to *Pyrophacus horologium*, but restricted to warm temperate and tropical regions.

Unidentified dinoflagellates. Frequency: 9.4%. Mean count: 18 cells/m³.

## DISCUSSION

Diatom taxa (106 identified to species or varieties) represented widely distributed (>80%), cold temperate to tropical(>50%), and estuarine/neritic (>60%) species. The preservable dinoflagellates (81 identified to species or varieties) were principally oceanic (>50%) and tropical/warm temperate (>50%) species, but were also of wide distribution (>65%). Less than 4% of the total taxa identified to species were strictly tropical forms and about 16% were strictly temperate forms. Since diatoms characterize inshore waters of the western Atlantic and dinoflagellates and coccolithophorids are more characteristic of offshore waters (Marshall, 1969, 1971), these distributions would be expected of a warm temperate (subtropical) shelf region where mixing occurs between estuarine and oceanic waters. If a large sample size, e.g. tow, had not been taken, however, the oceanic influence (Gulf Stream) would not have been detected because of the paucity of oceanic specimens, many of which are large (>200 $\mu$m). At least 91% of the 187 taxa identified to species have been identified previously from the Gulf of Mexico and Caribbean (derived from El-Sayed et al., 1972; Wood, 1968, 1971). This would be expected because of the latitude and downstream flow of the Gulf Stream System (Loop Current, Florida Current and Gulf Stream). Very few pelagic phytoplankton species are endemic. When they are reported as limited to a specific province or locale, it may reflect insufficient distribution records, taxonomic confusion, or recognition of genetic strains.

According to Wood (1971) the dominant phytoplankters of open waters do not differ substantially between the western Atlantic, Caribbean Sea and the Straits of Florida. This was attributed to the influence of the North Atlantic Equatorial Current on Caribbean surface waters and consequently the Gulf Stream System. Additionally, many dinoflagellates have worldwide distribution patterns covering more than one temperature-related region. For example, 59% of the species recorded from Hutchinson Island were reported in two studies of the Indian coast (Subrahmanyan, 1958; Subrahmanyan and Viswanatha Sarma, 1960), 72% were reported by Sournia (1970) for Mozambique Channel, and 68% have been recorded from Japanese coastal waters (Yamaji, 1966). Such percentages would undoubtedly increase if more references were included for those areas and if live, concentrated samples had been processed for Hutchinson Island in this work.

Davis (1950) was among the first to report on incidental plankton tows off the Florida east coast and listed 20 phytoplankters identified to species. Marshall (1969, 1971) and Hulburt and Mackenzie (1971) reported on phytoplankton collections off the North Carolina coast and from the western Atlantic including the continental shelf, Gulf Stream and Sargasso Sea.

Marshall's taxa list was derived from preserved, 500 ml water samples, collected over several years in the western Atlantic and contained 31% in common with our phytoplankton account. He identified 100 diatoms and 42 dinoflagellates as well as other phytoplankters. Hulburt and Mackenzie reported 10-30 cells/$cm^3$ for phytoplankters in shelf waters off Hutchinson Island during January, 1968. A mean of 20 cells/$cm^3$ would equal $2 \times 10^7$ cells/$m^3$, a count rarely equalled in our samples. Our lower counts were probably due to gear sampling efficiency and loss of material through the net. Such count data, based on tow material, suggests depauperate coastal waters with occasional inputs of estuarine microbiota. The chlorophyll *a* biomass data (76% exceeded 5 mg/$m^3$) suggests, however, moderately productive waters and not a barren area (Walker and Steidinger, 1979).

Lackey (in Florida Power and Light Company, 1970) was the first to study and evaluate the plankton off Hutchinson Island near the proposed site of the nuclear power plant (St. Lucie #1). At two inlets he found estuarine species on outgoing tides and oceanic representatives on incoming tides and initially concluded that the plankton for the coastal area was diverse but "sparse." He also stated, based on limited collections, that the water column was low in nutrients and primary productivity. Lackey's report lists 46 phytoplankton taxa of which several might serve as oceanic intrusion indicators. Our combined data lists 236 taxa (not including many nannoplankters known to inhabit the Indian River System), specifies 45 possible oceanic indicators, demonstrates considerable nutrient enrichment from the Indian River, and suggests moderate phytoplankton biomass and production in nearshore waters (Worth and Hollinger, 1977; Walker and Steidinger, 1979). In essence, oceanic influence would tend to dilute the plankton contributions in the coastal areas, but the amount of dilution depends on the tidal cycle sampled and intensity and type of oceanic intrusion.

The Indian River is a coastal lagoon basin with a mean depth of 1.5 m and is fed by streams, canals, and land runoff. Unpublished annual reports by the Harbor Branch Consortium (Ft. Pierce, Florida) for 1973 through 1976 (Young, n.d.; Harbor Branch Consortium, n.d.; Robert Gibson, personal communications) suggest maximum phytoplankton species diversity in the basin during greatest water turbulence as well as seasonal chlorophyll *a* peaks of 5mg/$m^3$ for an area close to our study locale. The phytoplankton community was dominated at certain times by diatoms, but weekly and seasonal fluctuations in diatom and flagellate populations were documented through intensive, replicate sampling. The Indian River System, then, is a seasonally rich area capable of augmenting and enriching coastal, nearshore waters with nutrients and plankton.

According to Hulburt (1966), *Oscillatoria erythraea* (= *Trichodesmium thiebautii*) and *Hemiaulus hauckii* are indicators of oceanic intrusion, and Marshall (1971) suggested *Ceratium extensum* as a Gulf Stream indicator. These species as well as several *Ceratium* known to be oceanic were found with few exceptions in nearshore Hutchinson Island water indicating at least an oceanic influence by intrusion but not necessarily the degree or type.

Worth and Hollinger (1977) discussed offshore influence on the sampling area and suggested spring and summer (1972 and 1973) oceanic intrusion based on hydrographic data. Spring and summer are the seasons of maximum velocity (Niiler and Richardson, 1973) and increased flow of the western edge of the Gulf Stream (Lee, 1971). Another possible occurrence of oceanic influence (e.g. eddies) was reported for February, 1973. In two months, July 1972 and June 1973, colder water upwelling was suspected. The large net phytoplankton data and particularly the occurrence of oceanic dinoflagellates illustrate strong oceanic influence in July 1972, June and July 1973, and January and February 1973 supporting the speculations of Worth and Hollinger (1977). The presence of shade species such as *Ceratium bigelowii*, *C. ranipes* var. *palmatum* and *Amphisolenia* spp. in summer also suggests the possibility of upwelling, perhaps by vertical shear.

Drift bottle data (1965-1967) off the Florida west coast showed that bottles released there in November through February had the highest number of returns for the Florida east coast and Keys (Williams et al., 1977). However, August and September releases were among the fewest returns from the east coast. It took 9 days to 2 months for west coast releases to be retrieved on the east coast. These data imply that Gulf of Mexico phytoplankton populations in Loop Current surface waters would contribute to east coast populations, particularly in winter months if the seasonal sequence of Loop Current development was that characterized by Leipper (1970). The presence and concentration of oceanic species in summer may be seeded directly by the Florida Current and/or upwelling.

In summary, the nearshore waters off Hutchinson Island represent a dynamic physical system continually admixed by tidal exchange, estuarine export and oceanic import. Holoplankton and meroplankton components are necessarily transient as they are flushed in and out of an estuarine system as well as being carried away (northward) by Gulf Stream eddies. This conclusion should be considered in the design of future research to study the impact of thermal effluent on plankton communities in such a coastal environment (see Walker and Steidinger, 1979).

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## PLATE I

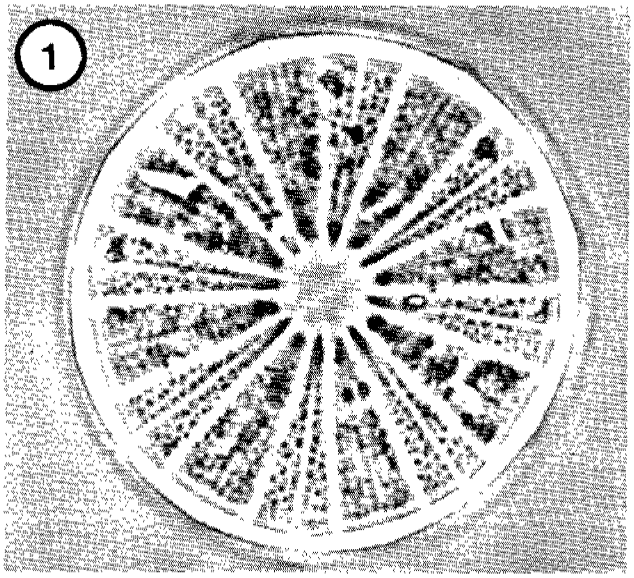
Figure 1. *Actinoptychus splendens* (Shadbolt) Ralfs. Diameter: 85 $\mu$m.

Figure 2. *Asterionella glacialis* Castracane (= *A. japonica*). Cell length: 56 $\mu$m.

Figure 3. *Bacillaria paxillifer* (O. F. Müller) Hendey (= *Nitzschia paradoxa*). Cell length: 96 $\mu$m.

Figure 4a. *Bellerochea horologicalis* von Stosch. Width: 38 $\mu$m.

Figure 4b. *Bellerochea horologicalis* von Stosch. Width: 41 $\mu$m.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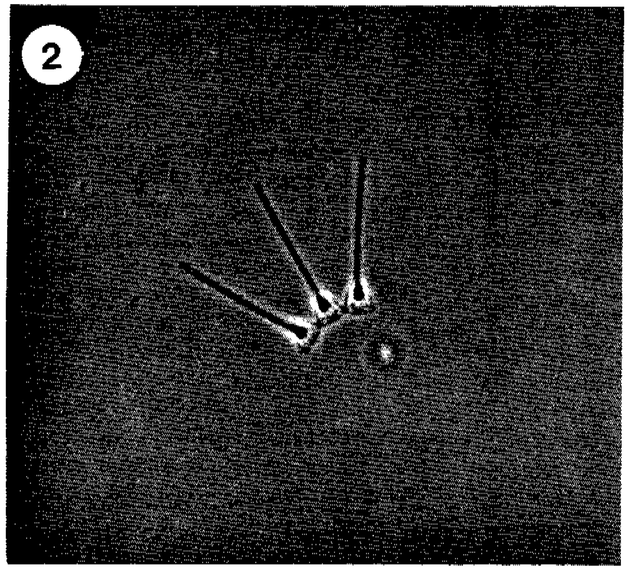
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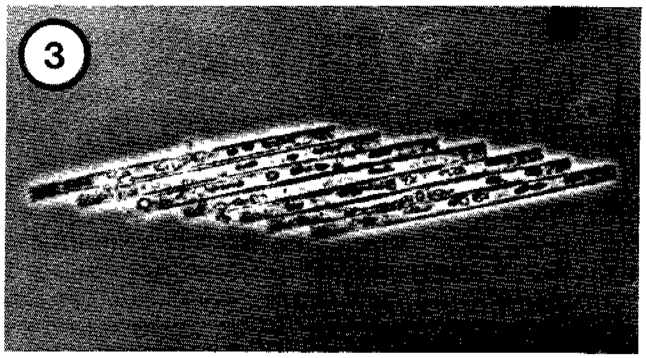
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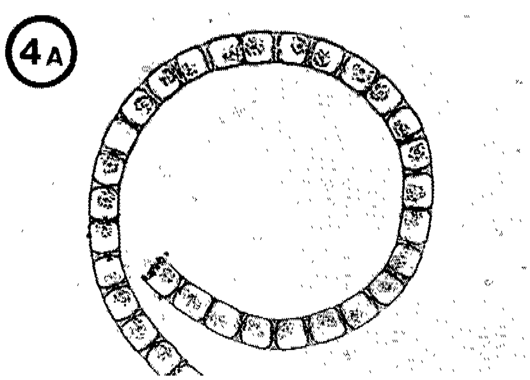
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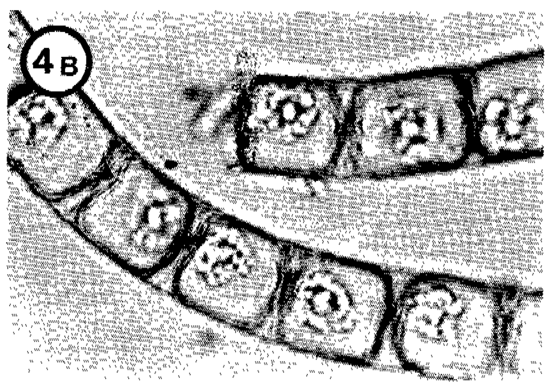
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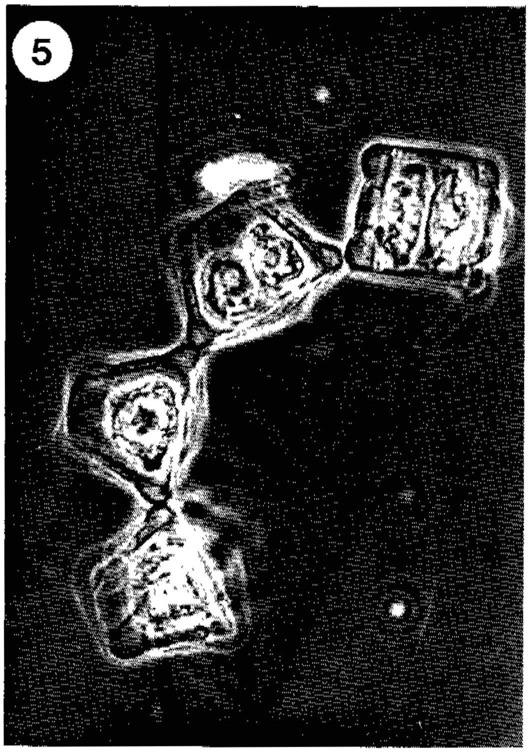
## PLATE II

Figure 5. *Biddulphia alternans* (Bailey) Van Heurck. Width: 33 μm.

Figure 6. *Odontella obtusa* Kützing (= *Biddulphia obtusa*). Width: 65 μm.

Figure 7. *Odontella chinensis* Grunow (= *Biddulphia sinensis*) and *B. chinensis*. Width: 147 μm.

Figure 8. *Odontella mobiliensis* Grunow (= *Biddulphia mobiliensis*). Width: 105 μm.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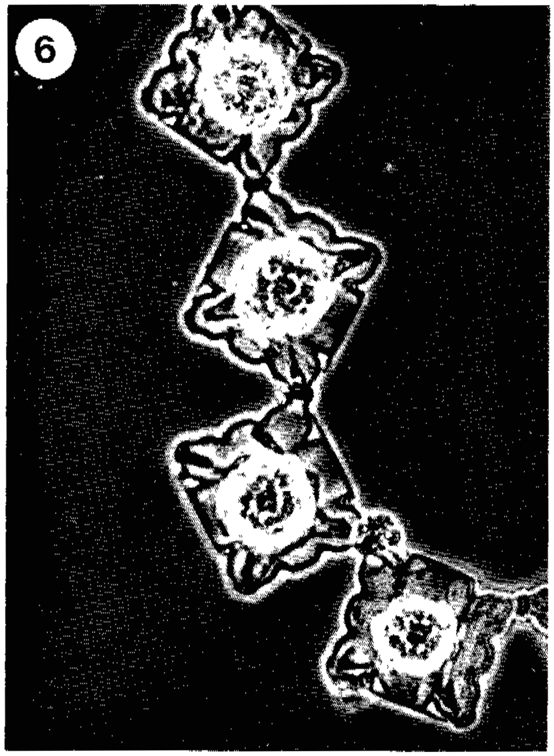
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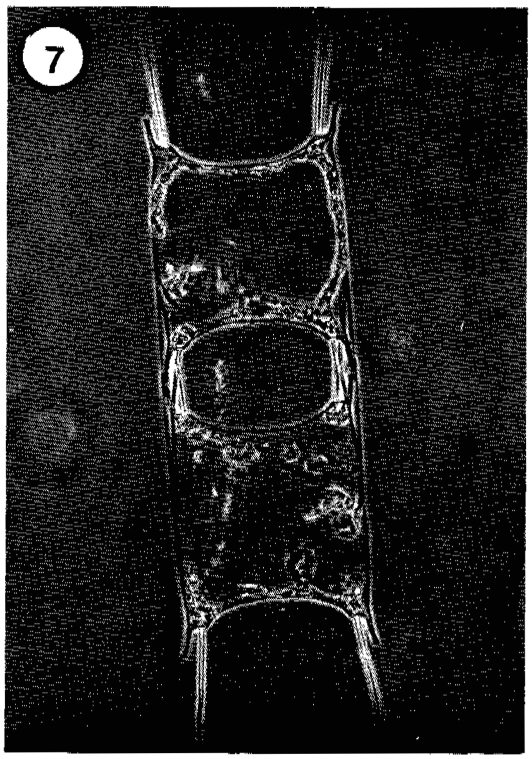
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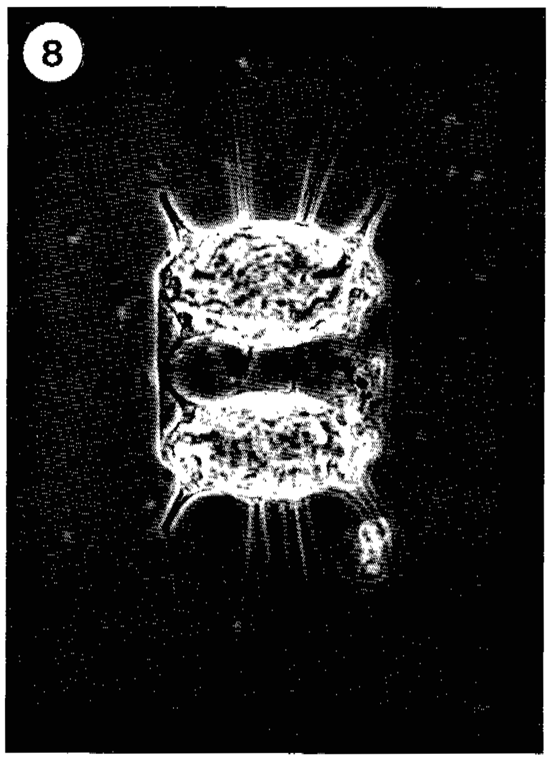
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## PLATE III

Figure 9. *Biddulphia pulchella* Gray. Width: 59 μm.

Figure 10. *Odontella rhombus* Kützing (= *Biddulphia rhombus*). Width: 56 μm.

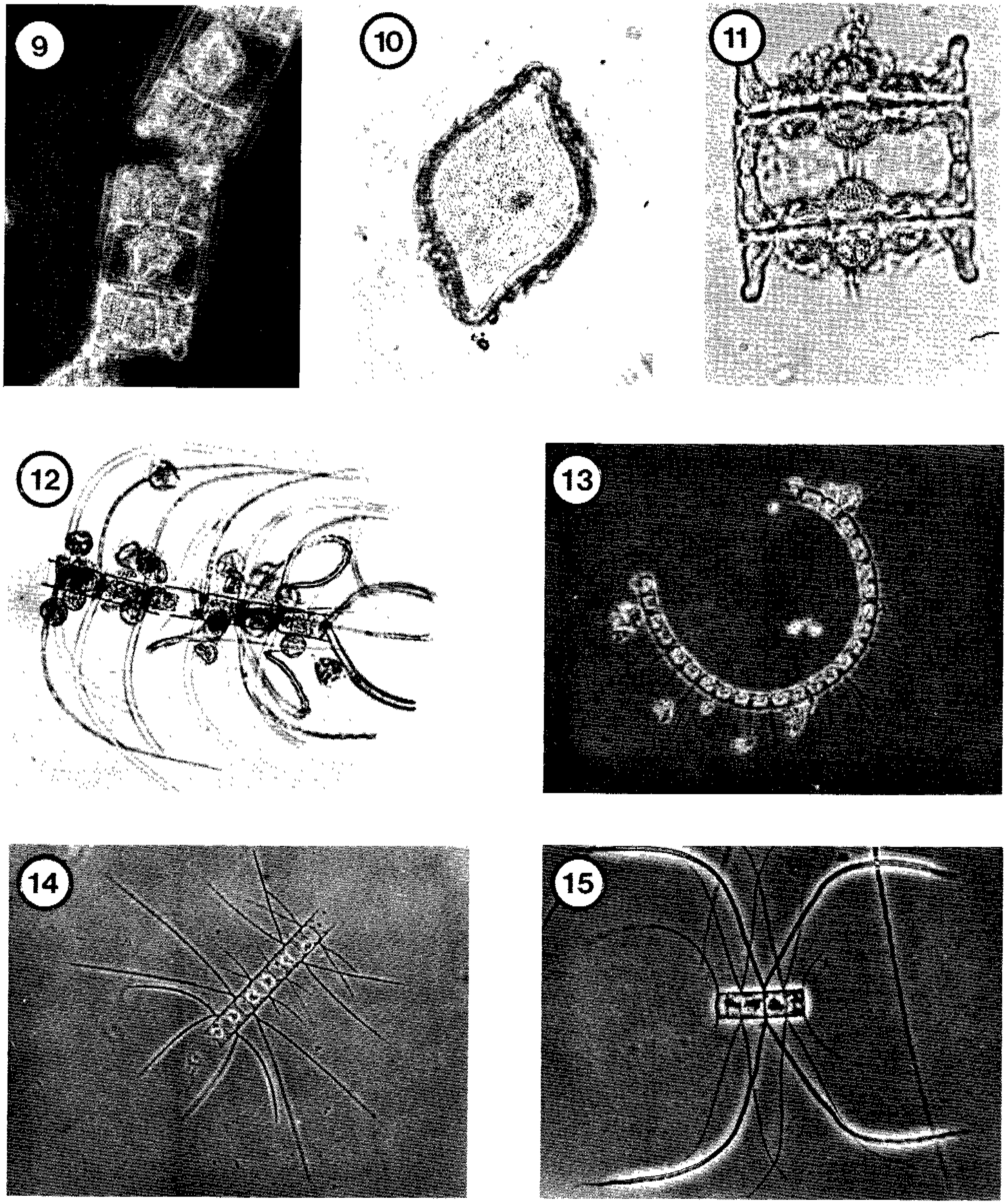
Figure 11. *Biddulphia tuomeyi* (Bailey) Roper. Width: 75 μm.

Figure 12. *Chaetoceros coarctatus* Lauder with attached contractile-stalked ciliates. Width without setae: 31.5 μm.

Figure 13. *Chaetoceros curvisetus* Cleve. Width without setae: 12 μm.

Figure 14. *Chaetoceros decipiens* Cleve. Width without setae: 13 μm.

Figure 15. *Chaetoceros diversus* Cleve. Width without setae: 10 μm.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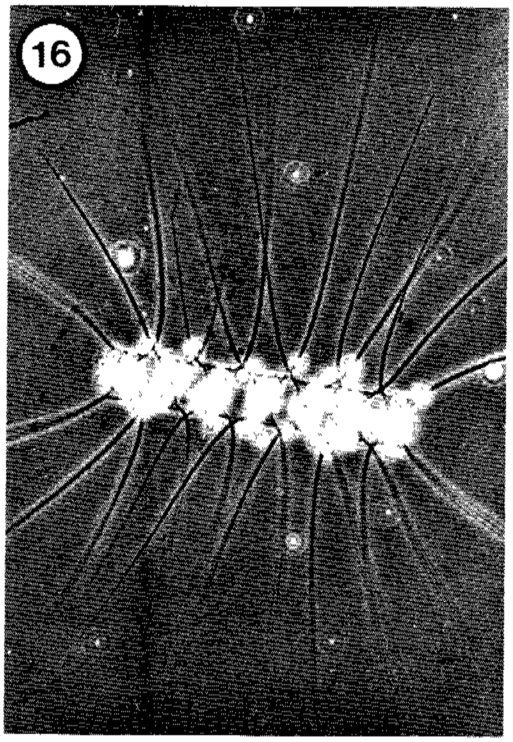
## PLATE IV.

Figure 16. *Chaetoceros didymus* Ehrenberg var. *didymus*. Width without setae: 11.5 µm.

Figure 17. *Chaetoceros lorenzianus* Grunow. Width without setae: 14 µm.

Figure 18. *Chaetoceros messanensis* Castracane. Width without setae: 19 µm.

Figure 19. *Climacodium frauenfeldianum* Grunow. Width: 91.5 µm.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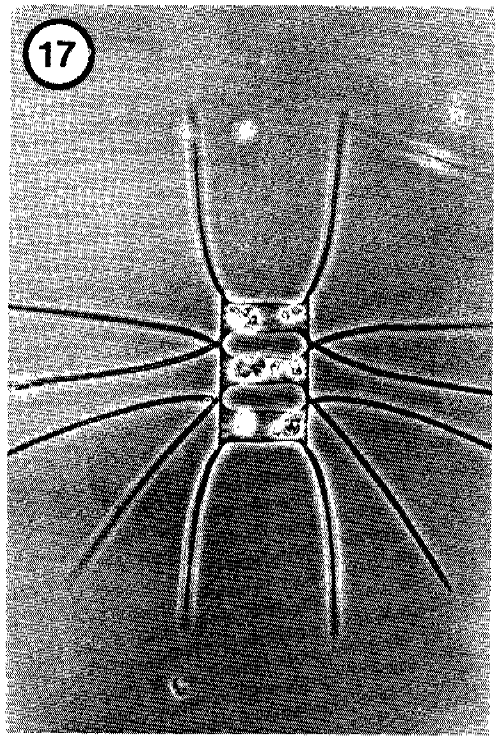
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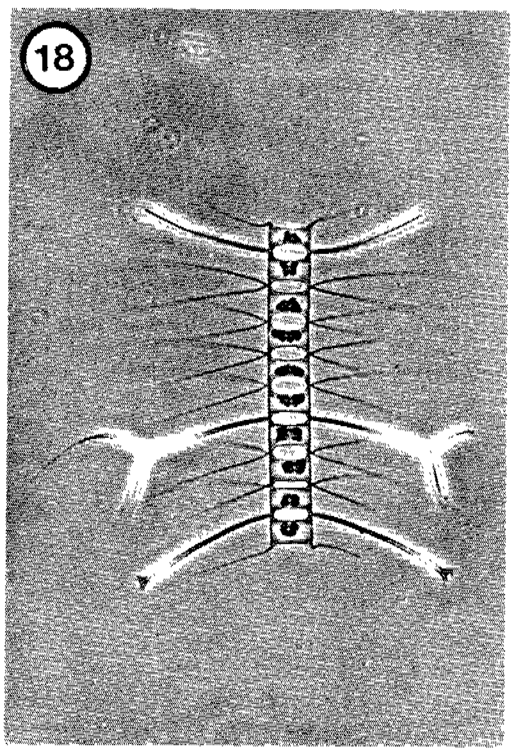
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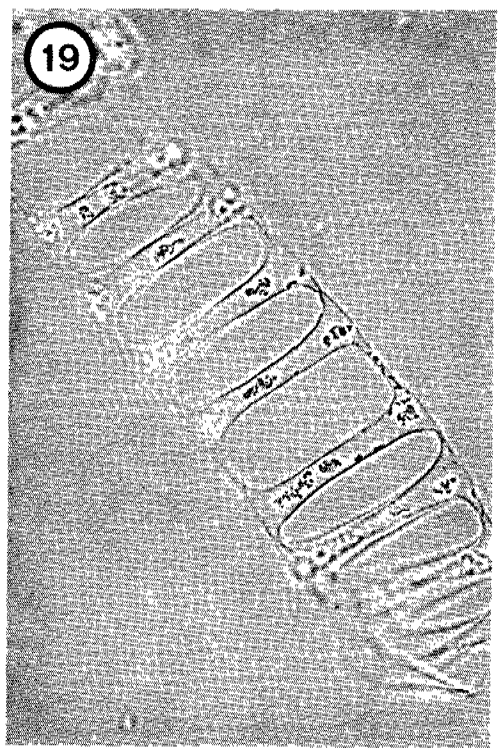
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## PLATE V

Figure 20. *Corethron criophilum* Castracane (= *C. hystrix*). Width: 13.4 μm.

Figure 21. *Coscinodiscus centralis* Ehrenberg. Diameter: 150 μm.

Figure 22. *Coscinodiscus wailesii* Gran & Angst. Diameter: 278 μm.

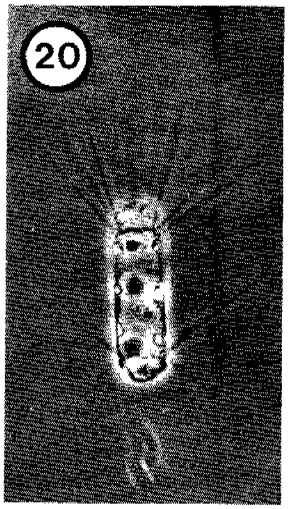
Figure 23. *Ditylum brightwelli* (West) Grunow. Body width: 42 μm, body length: 150 μm, length with spines: 282μm.

Figure 24. *Lithodesmium intricatum* Grunow.

Figure 25. *Eupodiscus radiatus* Bailey. Diameter: 119 μm.

Figure 26. *Grammatophora marina* (Lyngbye) Kützing. Cell length: 73 μm.

Figure 27. *Guinardia flaccida* (Castracane) Peragallo. Cell length: 45 μm.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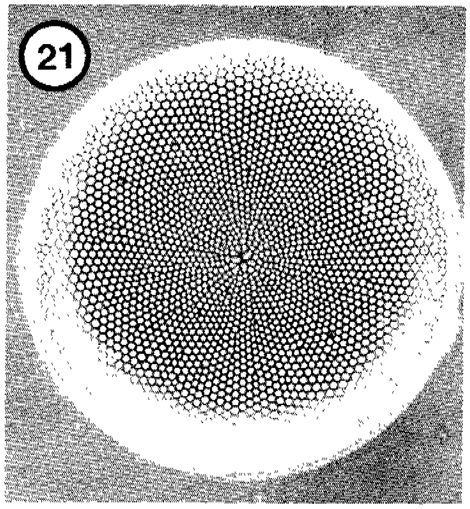
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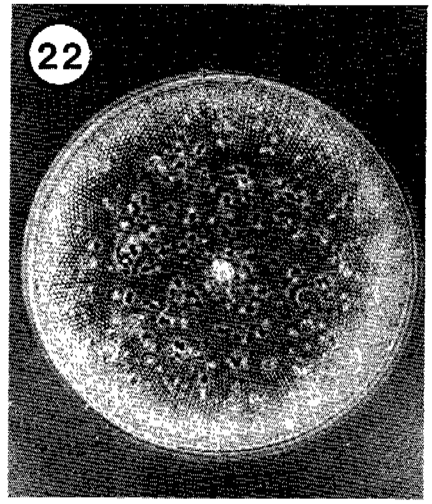
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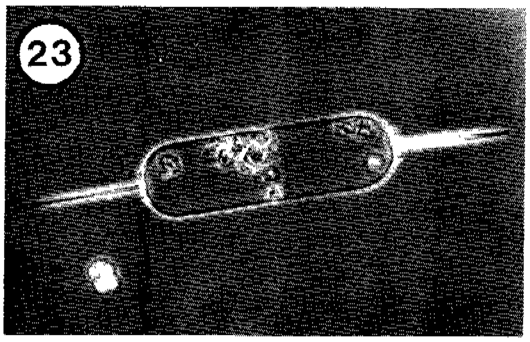
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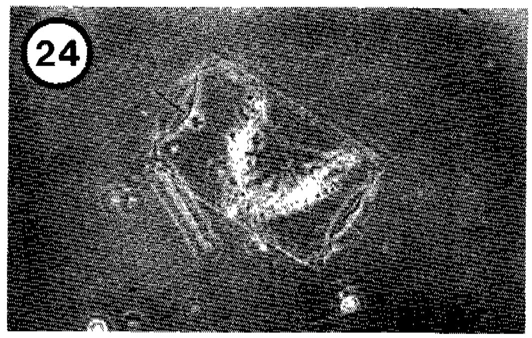
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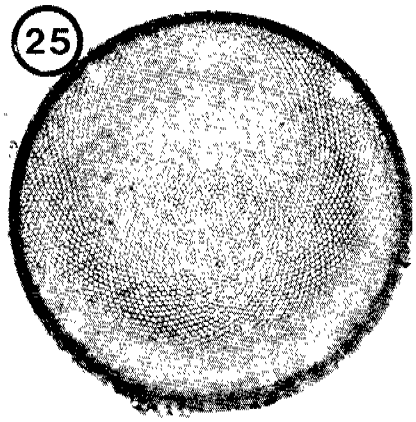
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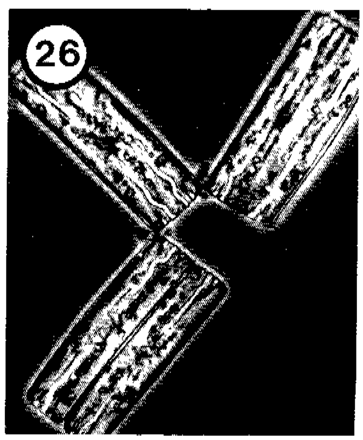
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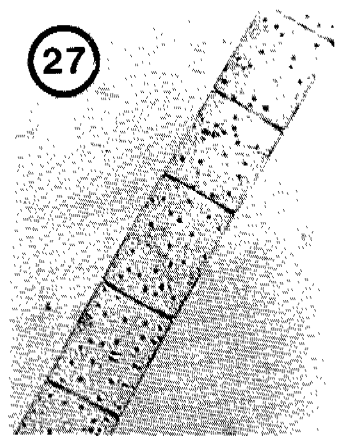
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## PLATE VI

Figure 28. *Hemiaulus hauckii* Grunow. Width: 17.4 μm.

Figure 29. *Hemiaulus membranaceus* Cleve. Width: 20.4 μm.

Figure 30. *Palmeriana hardmanianus* Greville (= *Hemidiscus hardmanianus*). Length: 354 μm.

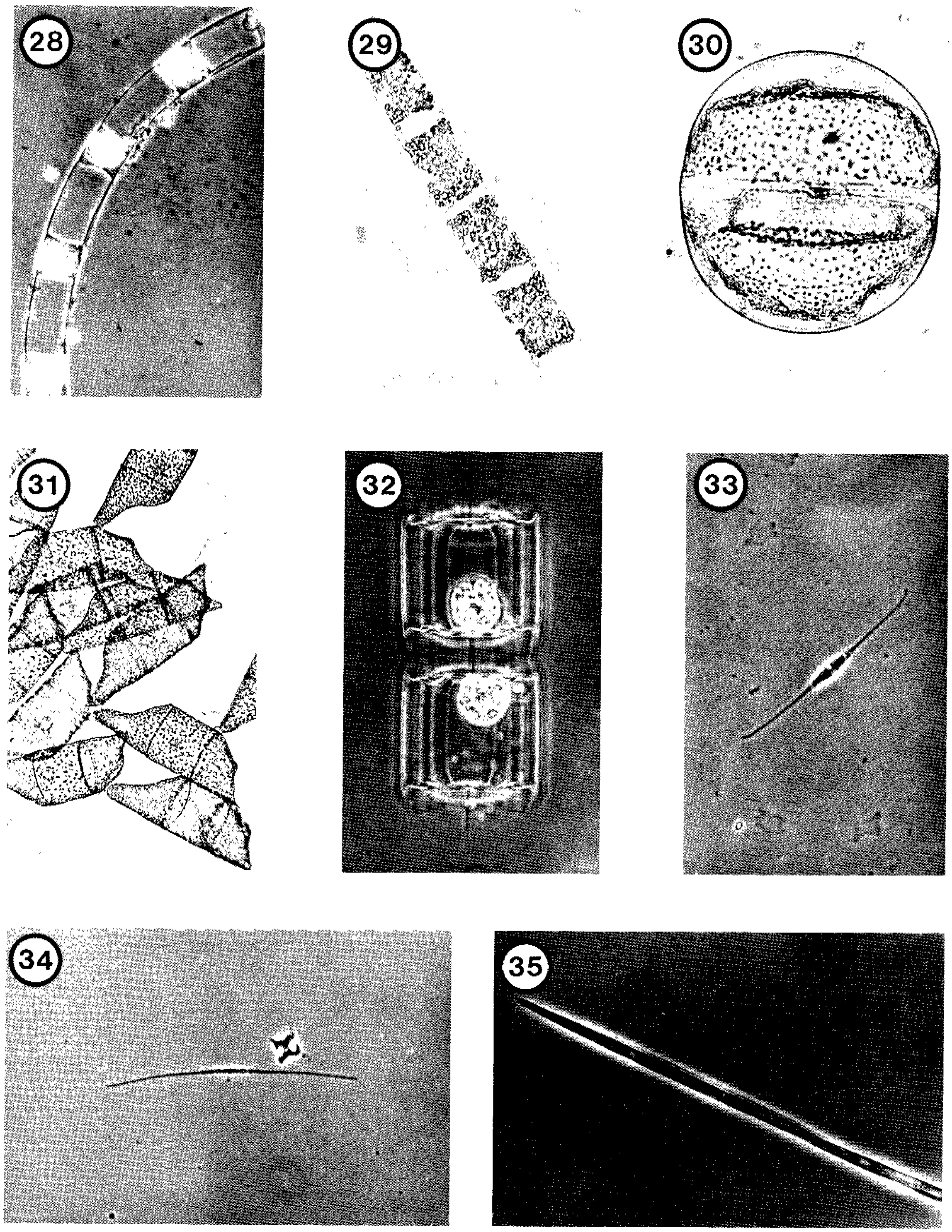
Figure 31. *Isthmia enervis* Ehrenberg. Width: 212 μm.

Figure 32. *Lithodesmium undulatum* Ehrenberg. Width: 60 μm.

Figure 33. *Nitzschia closterium* (Ehrenberg) W. Smith. Length: 49 μm.

Figure 34. *Nitzschia longissima* (Brébisson) Ralfs. Length: 132 μm.

Figure 35. *Nitzschia pungens* var. *atlantica* Cleve. Cell length: 134 μm, width: 10 μm.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## PLATE VII

Figure 36. *Paralia sulcata* (Ehrenberg) Cleve. Diameter: 33 μm.

Figure 37. *Planktoniella sol* (Wallich) Shütt. Diameter 135 μm.

Figure 38. *Rhabdonema adriaticum* Kützing. Cell width: 66.7 μm, length: 83 μm.

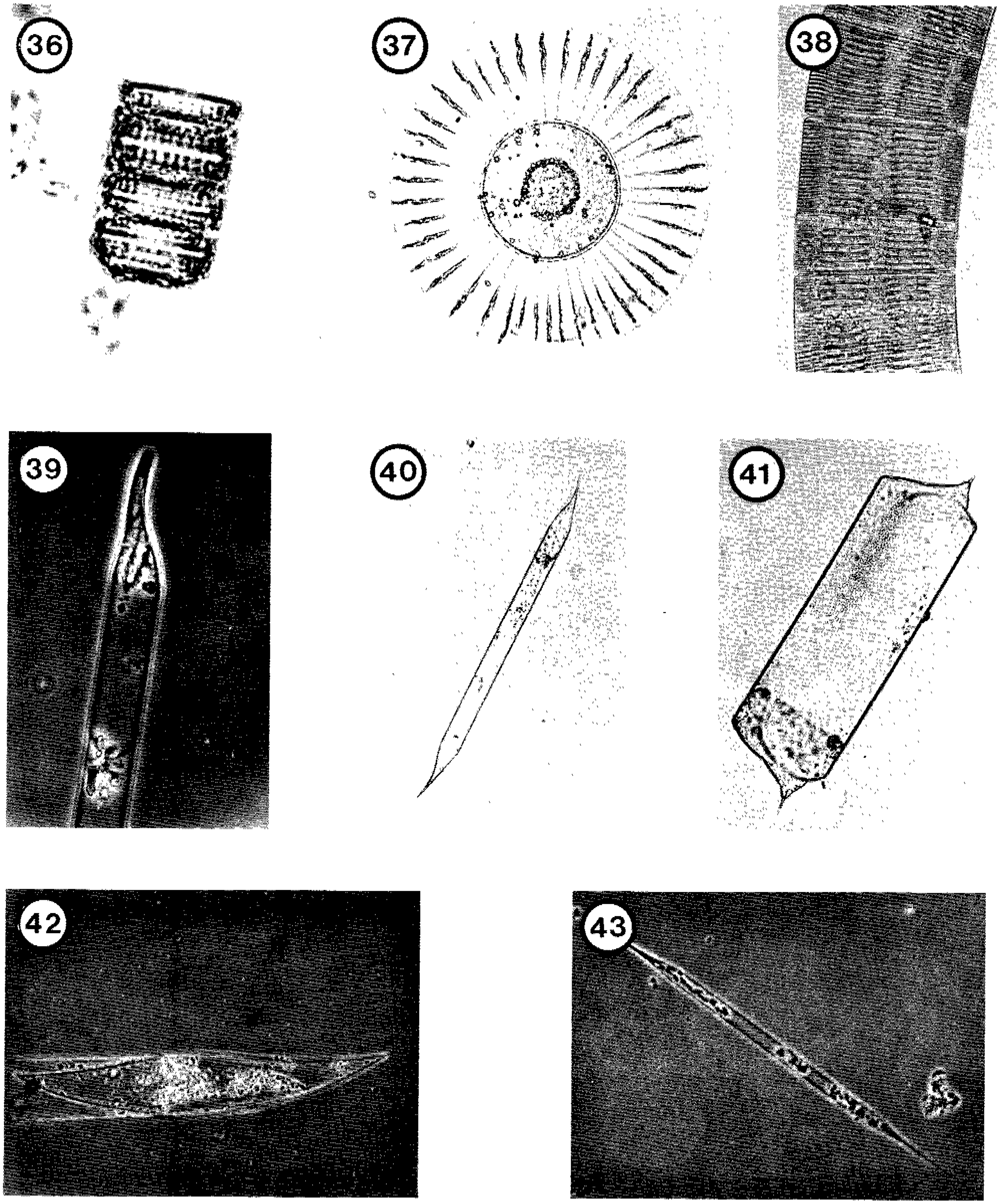
Figure 39. *Rhizosolenia alata* Brightwell. Width: 16 μm.

Figure 40. *Rhizosolenia calcar-avis* Schultze. Width: 36 μm.

Figure 41. *Rhizosolenia castracanei* Peragallo. Width: 274 μm.

Figure 42. *Rhizosolenia robusta* Norman. Length: 929 μm.

Figure 43. *Rhizosolenia setigera* Brightwell. Length: 327 μm.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## PLATE VIII

Figure 44. *Rhizosolenia stolterfothii* Peragallo. Width: 24 $\mu$m.

Figure 45. *Rhizosolenia styliformis* Brightwell. Width: 68 $\mu$m.

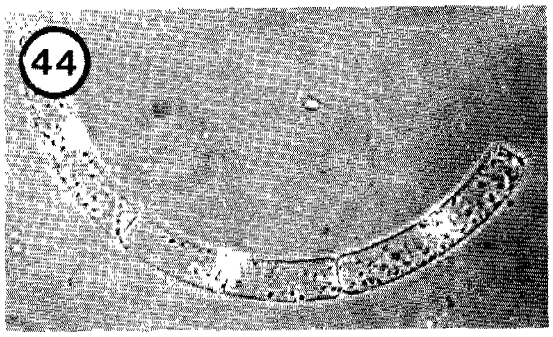
Figure 46. *Skeletonema costatum* (Greville) Cleve. Width: 19 $\mu$m.

Figure 47. *Stephanopyxis palmeriana* (Greville) Grunow. Width: 53.4 $\mu$m.

Figure 48a. *Thalassionema nitzschiodes* Grunow. Cell length: 21 $\mu$m, width: 4.5 $\mu$m.

Figure 48b. *Thalassionema nitzschiodes* Grunow. Cell length: 63 $\mu$m, width: 4 $\mu$m.

Figure 49. *Thalassiothrix frauenfeldii* Grunow. Cell length: 207.6 $\mu$m.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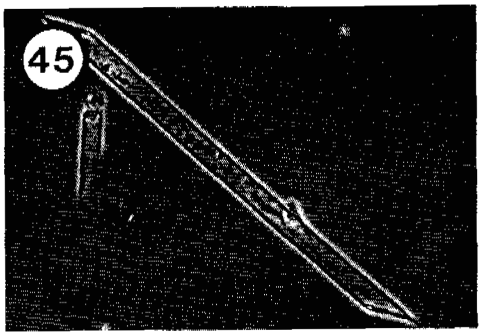
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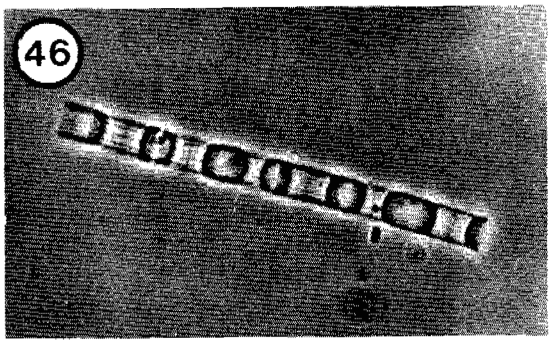
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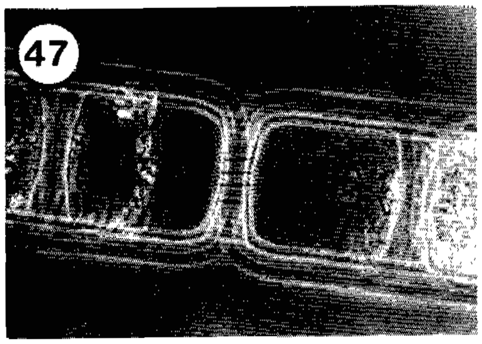
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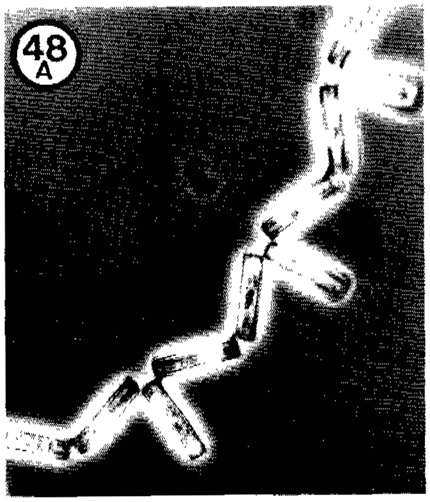
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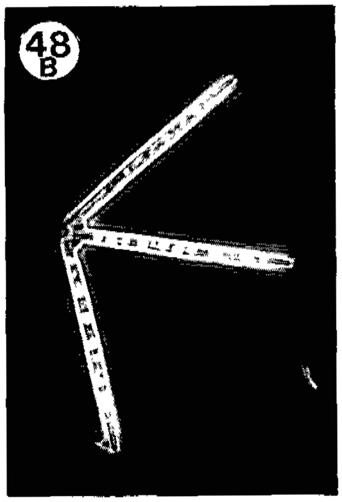
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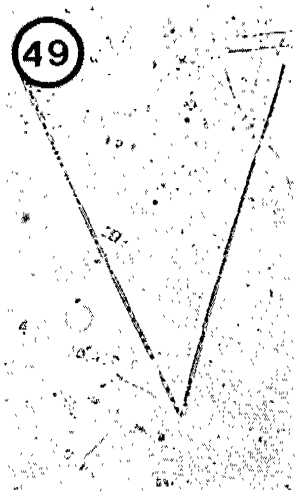
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## PLATE IX

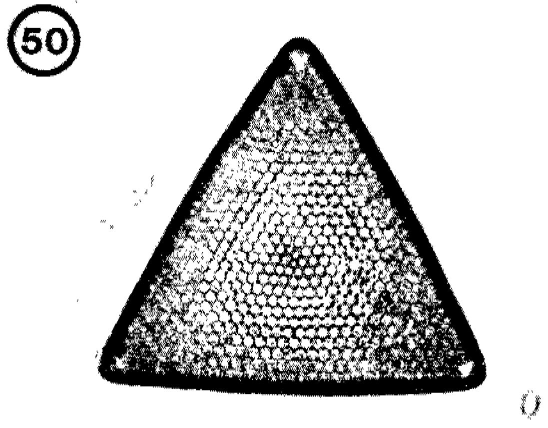
Figure 50. *Triceratium favus* Ehrenberg. Diameter: 112 $\mu$m.

Figure 51a. *Triceratium* sp. cf. *formosum* f. *pentagonales*. Diameter: 148 $\mu$m.

Figure 51b. *Triceratium* sp. cf. *formosum* f. *pentagonales*.

Figure 52. Unidentified centric diatom. Length: 210 $\mu$m, width: 112 $\mu$m.

Figure 53. Unidentified centric diatom. Cell length: 182 $\mu$m, width: 84 $\mu$m.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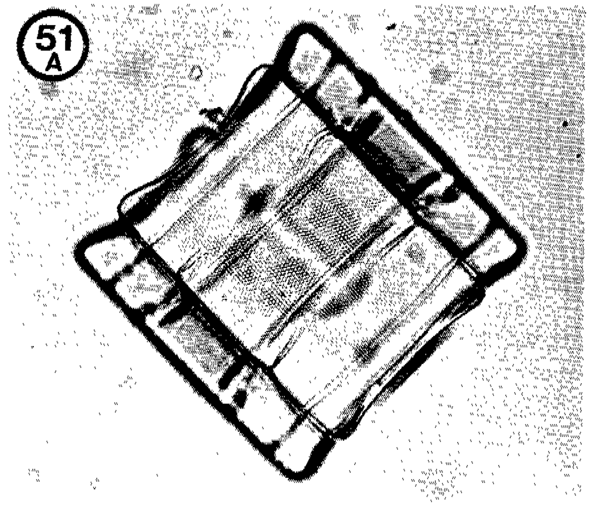
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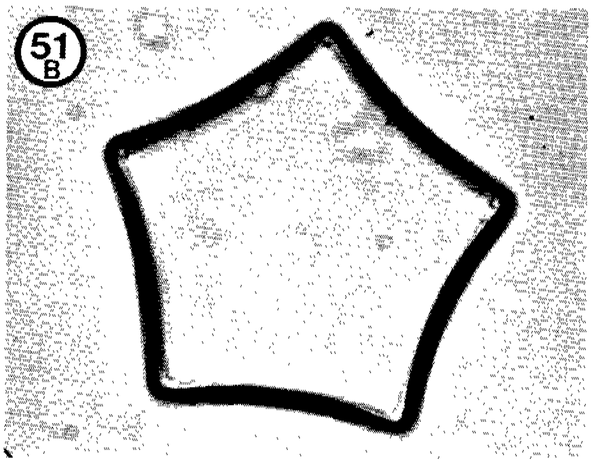
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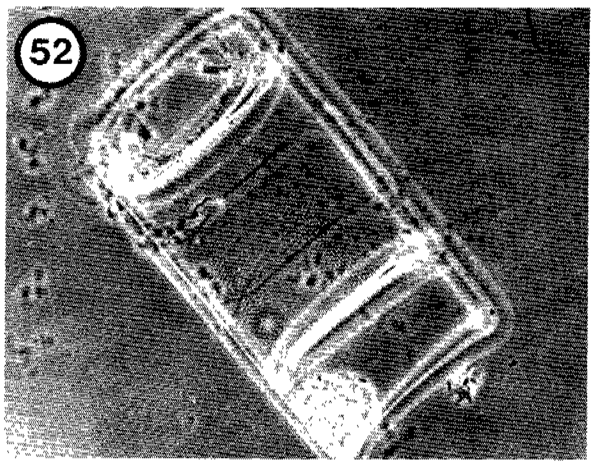
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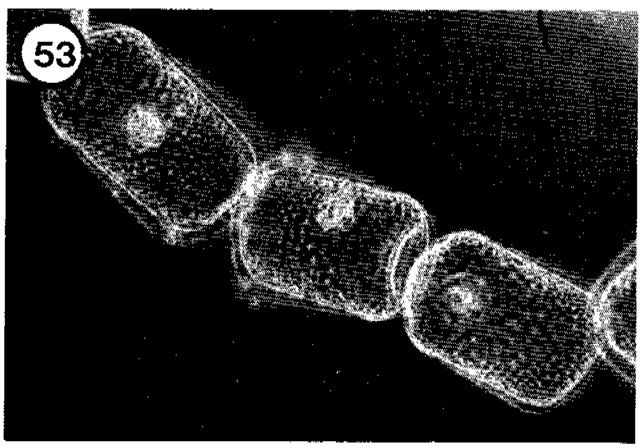
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## PLATE X

Figure 54. *Amphisolenia bidentata* Schröder. Length: 773 $\mu$m.

Figure 55. *Amphisolenia bifurcata* Murray & Whitting. Length: 971 $\mu$m.

Figure 56. *Amphisolenia* sp. cf. *lemmermanii* Kofoid. Length: 420 $\mu$m.

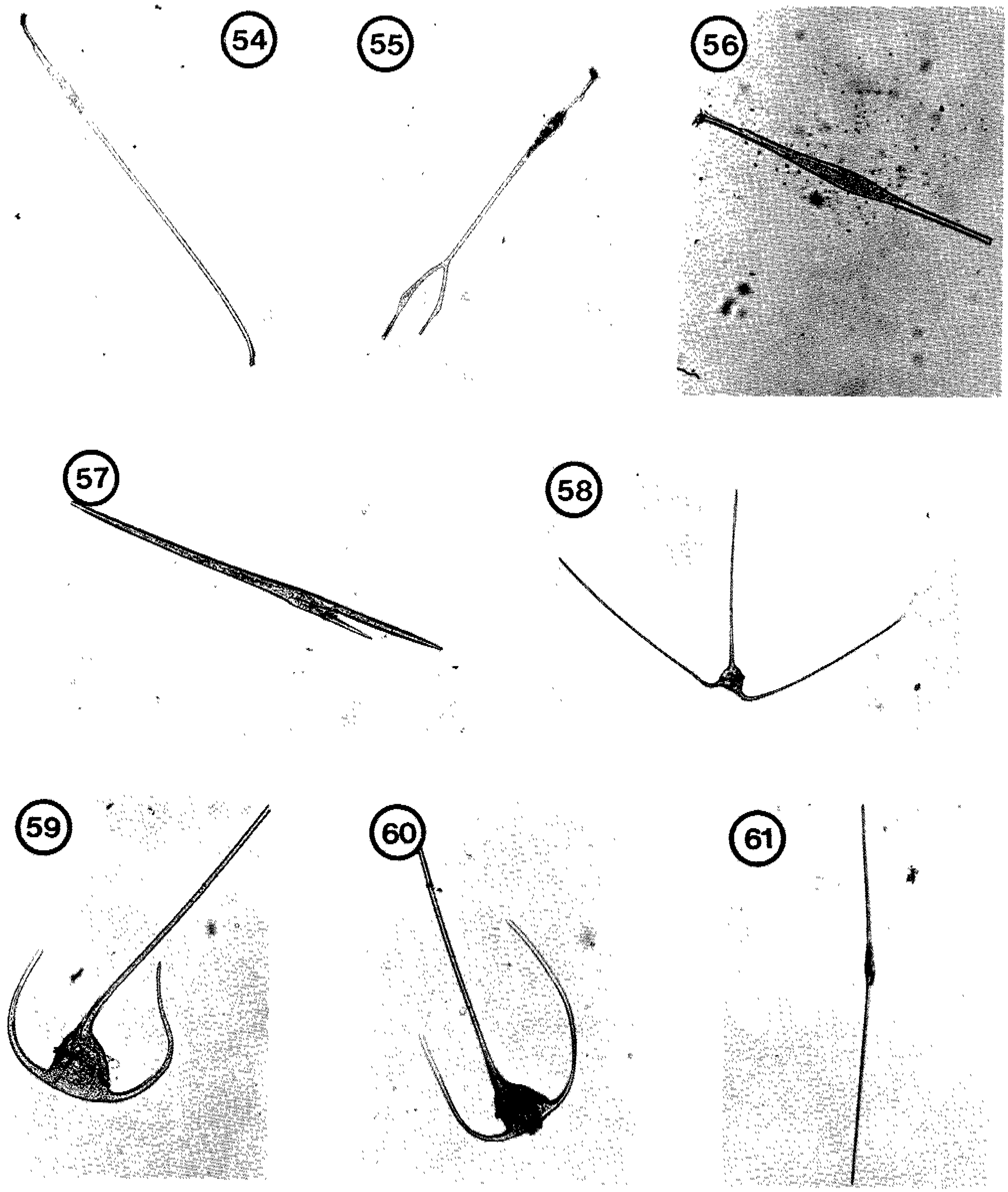
Figure 57. *Ceratium belone* Cleve. Length: 815 $\mu$m.

Figure 58. *Ceratium carriense* Gourret var. *carriense*. Body width: 72 $\mu$m.

Figure 59. *Ceratium contortum* (Gourret) Cleve var. *contortum*. Body width: 73 $\mu$m.

Figure 60. *Ceratium contortum* var. *karstenii* (Pavillard) Sournia.

Figure 61. *Ceratium extensum* (Gourret) Cleve. Length: 1075 $\mu$m.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## PLATE XI

Figure 62. *Ceratium furca* (Ehrenberg) Claparède & Lachman. Length: 285 $\mu$m.

Figure 63. *Ceratium fusus* (Ehrenberg) Dujardin. Length: 378 $\mu$m.

Figure 64. *Ceratium hexacanthum* Gourret var. *hexacanthum*.

Figure 65. *Ceratium hircus* Schröder (= *Ceratium furca* var. *hircus*). Length: 129 $\mu$m.

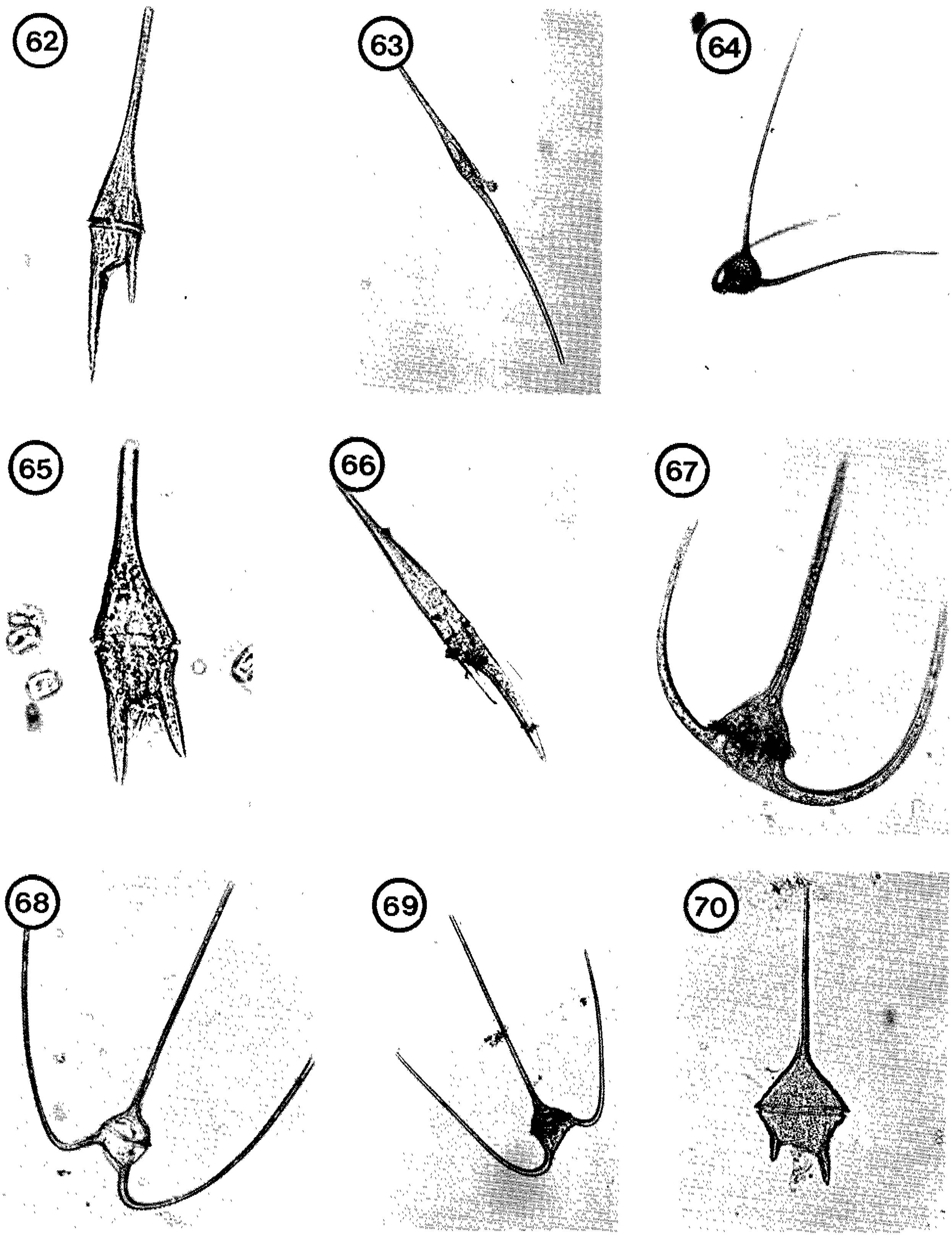
Figure 66. *Ceratium incisum* (Karsten) Jörgensen. Length: 371 $\mu$m.

Figure 67. *Ceratium lunula* (Schimper & Karsten) Jörgensen. Body width: 98 $\mu$m.

Figure 68. *Ceratium macroceros* (Ehrenberg) Vanhöffen var. *macroceros*. Body width: 51 $\mu$m.

Figure 69. *Ceratium massiliense* (Gourret) Karsten. Body width: 54 $\mu$m.

Figure 70. *Ceratium pentagonum* Gourret. Length: 150 $\mu$m.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## PLATE XII

Figure 71. *Ceratium ranipes* var. *palmatum* (Schröder) Cleve. Apical horn length: 182 µm.

Figure 72. *Ceratium trichoceros* (Ehrenberg) Kofoid. Length: 291 µm.

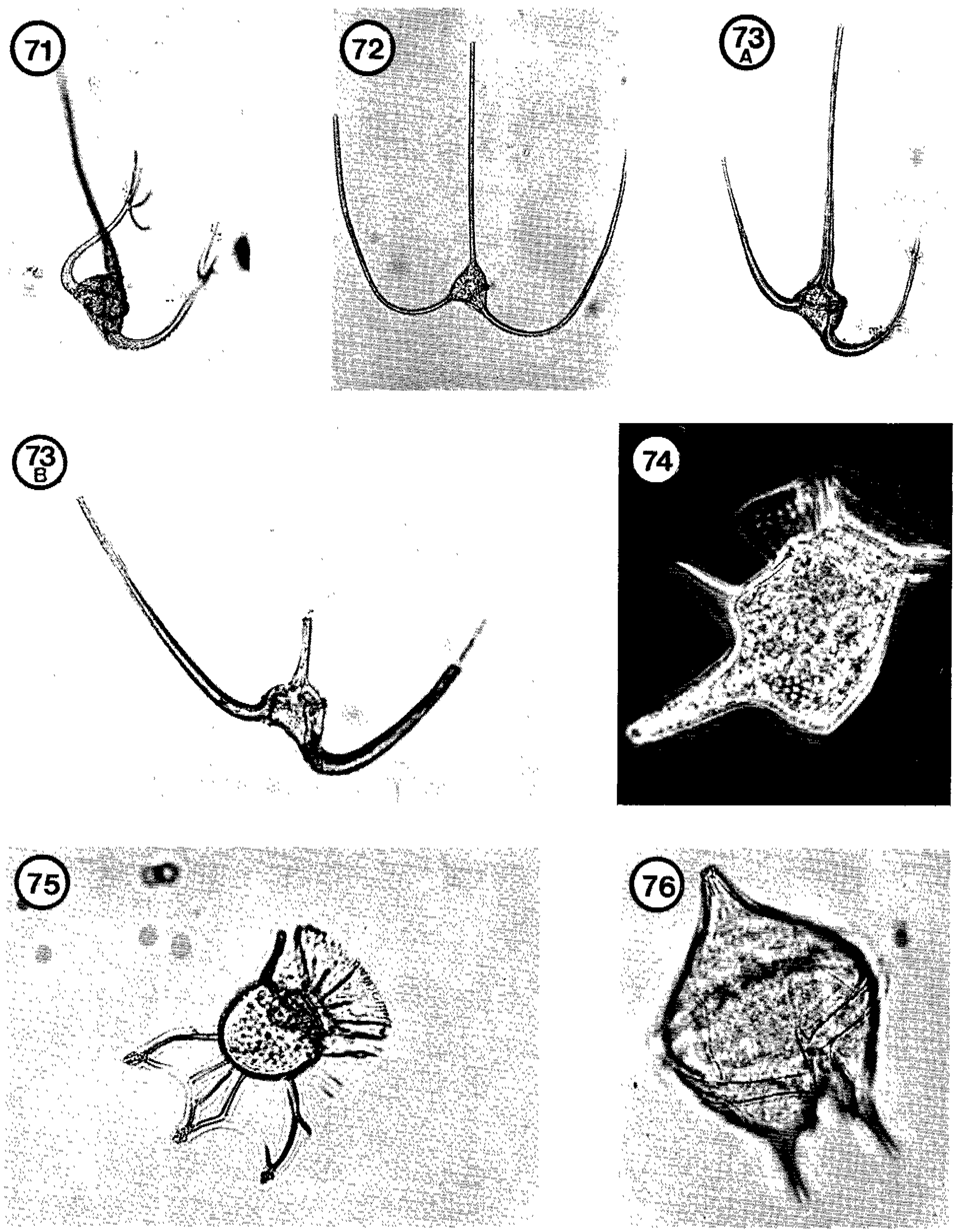
Figure 73a. *Ceratium vultur* Cleve var. *vultur*. Body width: 64 µm.

Figure 73b. *Ceratium vultur* Cleve var. *vultur*.

Figure 74. *Dinophysis caudata* S. Kent.

Figure 75. *Ornithocercus magnificus* Stein.

Figure 76. *Protoperdinium claudicans* (Paulsen) Balech. Length: 102 µm.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## PLATE XIII

Figure 77. *Protoperdinium conicum* (Gran) Balech. Length: 74 μm.

Figure 78. *Protoperidinium oceanicum* (Vanhöffen) Balech. Length: 121 μm.

Figure 79. *Prorocentrum gracile* Schütt. Length: 56 μm.

Figure 80. *Pyrocystis fusiformis* Wyville-Thomson & Blackman. f. *fusiformis*. Length: 215 μm.

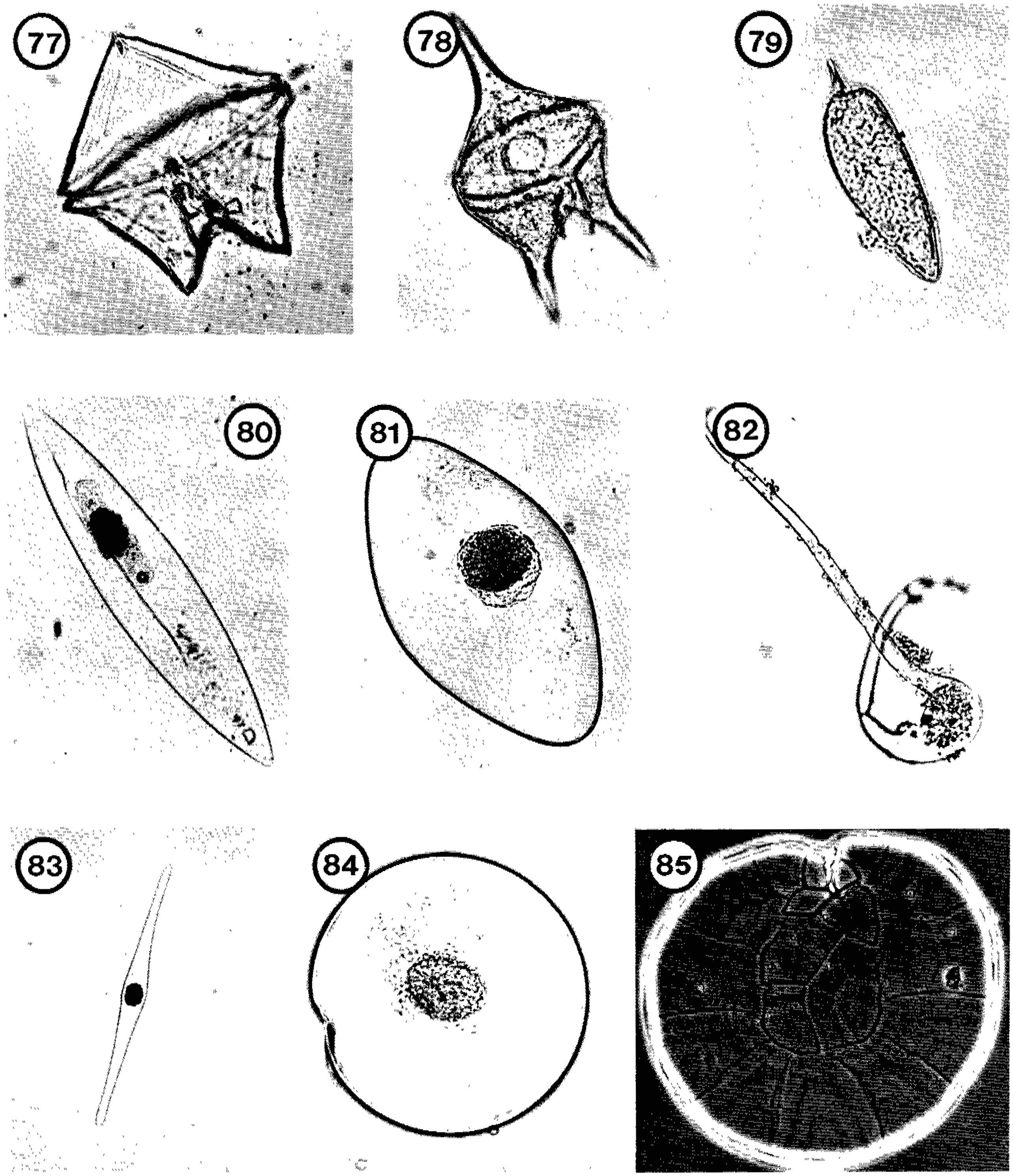
Figure 81. *Pyrocystis fusiformis* f. *biconica* Kofoid. Length: 187 μm.

Figure 82. *Pyrocystis hamulus* var. *inaequalus* Schröder. Length: 200 μm.

Figure 83. *Pyrocystis lancelata* Schröder. Length: 150 μm.

Figure 84. *Pyrocystis noctiluca* J. Murray & Schütt. Diameter: 261 μm.

Figure 85. *Pyrophacus steinii* (Schiller) Wall & Dale. Width: 93 μm.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# VIII. Zooplankton, 1971-1973

## ABSTRACT

Walker, L.M., B. M. Glass, and B. S. Roberts. 1979. Nearshore Marine Ecology at Hutchinson Island, Florida: 1971-1974. VIII. Zooplankton, 1971-1973. Fla. Mar. Res. Publ. No. 34. Pp. 62-98. Two years of plankton samples from five nearshore stations off Hutchinson Island, Florida were examined for zooplankton diversity, abundance and seasonality. Adult copepods, particularly calanoids, were the numerically dominant zooplankton group. Other numerically dominant groups were copepod larvae, tintinnids, echinoid larvae, ophiuroid larvae and urochordates. Abundance estimates for total zooplankton were moderate ($\bar{x} = 3{,}843/m^3$) compared to other Florida bays, temperate bays, Bermuda, the Gulf Stream and the Sargasso Sea. The net northerly flow along the coast in this area contributes to this moderate abundance and the transitory nature of the community. Total zooplankton and copepods generally increased in numbers during winter through mid-summer and decreased between late summer and fall. Other holo- and meroplankton groups showed some variation in seasonality. Certain copepods and chaetognaths are suggested as indicators of oceanic or estuarine influences at Hutchinson Island. The number and diversity of these indicators suggest definite oceanic intrusion in winter and oceanic and estuarine influence in summer. These data are presented as a part of a baseline study to characterize the nearshore waters off Hutchinson Island prior to the operation of the Florida Power and Light Company's St. Lucie Power Plant Unit #1.

## INTRODUCTION

Zooplankton samples were collected as part of an integral sampling program to obtain baseline data prior to operation of a nuclear power plant (St. Lucie Unit #1). This study documents diversity and abundance of zooplankton populations off Hutchinson Island, an area which has not been extensively studied.

Only two other studies have sampled coastal waters near Hutchinson Island. A few zooplankton groups were documented from the 1953-54 R/V *T. N. Gill* cruises in coastal and offshore waters from Cape Hatteras to Jupiter Inlet. The groups studied were the calanoid genera *Acrocalanus* and *Candacia* (Fleminger and Bowman, 1956; Bowman, 1958), chaetognaths (Pierce and Wass, 1962), the sergestoid shrimp genus *Lucifer* (Bowman and McCain, 1967) and calanoid copepods (Bowman, 1971). Grice (1957) studied copepods of west Florida coastal waters but included three stations in the immediate vicinity of Ft. Pierce Inlet on Florida's east coast. Other researchers have examined inshore and shelf waters off Florida's east coast but the sampling transects did not include our area.

## METHODS AND MATERIALS

A total of 91 single tow samples were collected at five stations in nearshore waters off Hutchinson Island (Figure 1). Collections were bimonthly during the first year (September 1971 through August 1972) and monthly the second year (September 1972 through August 1973). Exceptions occurred in December 1972 when Station I was not sampled and in June 1973 when Stations I and II were sampled twice (June 2 and 20). Samples were taken with a plankton net (0.5 m opening, 202 $\mu$m mesh, 5:1 length) equipped with a flowmeter to record volume of seawater sampled. Oblique tows were taken during the day in a circular pattern and 50-150 m$^3$ of seawater was filtered. For details on station locations, area descriptions and field collection procedures, see Gallagher and Hollinger (1977).

Samples were preserved in 5% buffered formalin-seawater in quart (960 ml) jars. The sample was inverted several times to ensure random distribution of organisms. Several aliquots (5-15 ml depending on zooplankton composition and density) were taken with a wide-mouthed pipette and each was placed in a 9 x 9 cm plastic counting tray with a grid of 36 squares. Each aliquot was examined and all taxa listed. Another aliquot was taken for counts and two rows perpendicular to each other (10 squares) were selected via a random numbers table. All organisms within the squares were counted. Five to 15 or more squares were counted depending on zooplankton density. At least 100 organisms of the most abundant taxon were counted and 200 to 1000 total organisms were counted. Exuviae and obviously decayed organisms were not counted. The number of organisms recorded was multiplied by area and volume conversion factors to give the total number in the tow. Results were reported in numbers/m$^3$ for each taxon. If a taxon was observed in the first aliquots but not in the count aliquot, it was listed as "present" and represented as "0" in all calculations. When two or three aliquots were taken for quantitive analysis, the number/m$^3$ is an average of all aliquots. The number of samples or subsamples necessary for statistical analyses was not calculated since it would change with each collection and each sample. An error of $\pm$ 20% is possible using these techniques. Rationale of the program is explained by Walker and Steidinger (1979).

## RESULTS & DISCUSSION

Taxa have been divided into two ecological groups: holoplankton and meroplankton. The holoplankton group includes tychoplankton. Fish eggs and larvae were included in the meroplankton. The groupings under the two major headings are listed in order of decreasing abundance, except for Chaetognatha (listed second instead of third).

Abundance and frequency of each taxon were calculated. These data and results from other studies were used to determine distribution, seasonality, dominance within a sample and to suggest biological indicators. Any sampling technique incorporates some bias. Therefore, comparisons of abundance between groups of small organisms, such as tintinnids, which may pass through medium to coarse mesh nets (Reeve, 1970), and groups containing large mesozooplankton may neither be accurate nor warranted. Consequently, the numerical data are used in broad comparisons to indicate trends.

Abbreviations used are: OTR = observed temperature range, OSR = observed salinity range, OCR = observed count range, $\overline{X}$TC = mean of total count, and OCC = sampling months of occurrence. Although a hyphen indicates "through," samples were only collected every other month from September 1971 through August 1972. The "0" occurrences were not included in mean determinations.

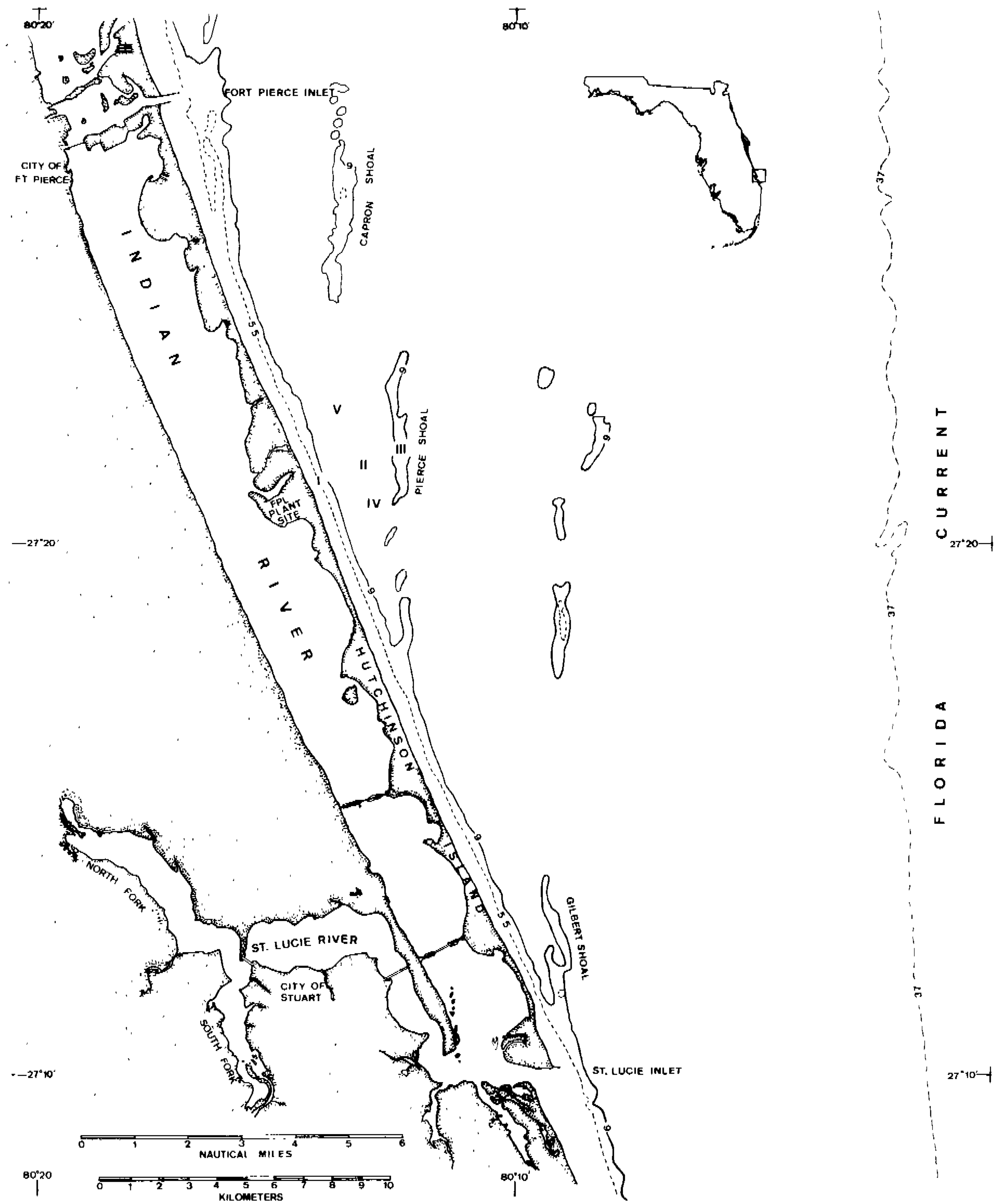


Figure 1. Study area, showing station locations.

## ANNOTATED TAXA LIST HOLOPLANKTON

### COPEPODA

CALANOIDA

*Acartia*

*Acartia* was the second most frequently occurring copepod genus and third in copepod abundance. It was recorded in 99.0% of all samples. Three species were recorded at Hutchinson Island.

*Acartia bermudensis* was recorded in all but four months of the sampling period (62.6% of samples). Highest counts occurred in March 1972 and January-February 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5 ‰, OCR: 6-1,821/$m^3$, $\overline{X}$TC: 304.1/$m^3$, OCC: September 1971-March, May, August 1973.

Esterly (1911) first described *Acartia bermudensis* from enclosed Bermuda waters. Herman and Beers (1969) also found this species in a Bermuda sound. Owre and Foyo (1972) recorded it at one station near the mouth of the Amazon River. This species occurs in the Florida Current off Miami (Owre and Foyo, 1967) and in Biscayne Bay (Reeve, 1970).

*Acartia danae* was "present" at Station II in May 1973. OTR: 22.8-24.1°C, OSR: 36.6-37.7‰.

In Florida waters, *Acartia danae* was reported from Biscayne Bay (Reeve, 1970), the Florida Current (Owre and Foyo, 1967) and the eastern Gulf of Mexico (King, 1950). It occurs in the western North Atlantic off New England (Wilson, 1932a; Grice and Hart, 1962), off Bermuda (Wilson, 1936; Deevey, 1971), in the eastern Caribbean (Owre and Foyo, 1964) and in the Venezuela basin (Legaré, 1961b, 1964; Björnberg, 1971).

*Acartia spinata* was identified in 48.4% of all samples. Highest counts occurred from June through July 1973. OTR: 20.5-30.1°C, OSR: 34.0-38.5‰, OCR: 17-948/$m^3$, $\overline{X}$TC: 188.1/$m^3$, OCC: January, May-July, November 1972; January-August 1973.

Near Ft. Pierce, *Acartia spinata* is most abundant in summer (Grice, 1957). This species occurs in neritic and Florida Current waters off Miami (Davis, 1950; Owre and Foyo, 1967). Woodmansee (1958) concludes that *A. spinata* is transient in Biscayne Bay. It is recorded from Bermuda waters (Esterly, 1911; Herman and Beers, 1969) where Clarke (1934) considers it an offshore species. Björnberg (1971) states it is unique to the Caribbean, Gulf of Mexico and Florida Current.

*Calanopia*

*Calanopia americana* was recorded in 8.8% of all samples. OTR: 22.8-29.6°C, OSR: 34.0-38.0‰, OCR: 29-39/$m^3$, $\overline{X}$TC: 34.0/$m^3$, OCC: May 1972; January, June-July 1973.

*Calanopia americana* occurs in estuarine, neritic and oceanic waters. Records include the Gulf of Mexico (Davis, 1950; King, 1950; Fleminger, 1956; Park, 1970), St. Andrew Bay (Hopkins, 1966), southeastern Florida waters including the Florida Current (Davis, 1950; Woodmansee, 1958; Reeve, 1964; Owre and Foyo, 1967; Bowman, 1971) and Caribbean waters (Fish, 1962; Park, 1970; Owre and Foyo, 1964, 1972). It ranges from Bermuda to Brazil (Owre and Foyo, 1967, 1972). Clarke (1934) suggests that *C. americana* is benthic in Bermuda waters and migrates into the plankton.

*Calocalanus*

*Calocalanus pavo* occurred sporadically over the sampling period (27.5% of samples). Highest numbers occurred in January 1972 and February 1973. OTR: 20.7-28.4°C, OSR: 33.0-38.5‰, OCR: 3-90/$m^3$, $\overline{X}$TC: 19.6/$m^3$, OCC: January, May-July, November-December 1972; January-April, June-July 1973.

*Calocalanus pavo* occurs in the Florida Current (Davis, 1950; Owre and Foyo, 1967) and in oceanic waters along the southeastern Atlantic coast (Bowman, 1971). It ranges from the Woods Hole region to Brazil including the Gulf of Mexico (Wilson, 1932a, 1936; King, 1950; Fish, 1962; Grice and Hart, 1962; Owre and Foyo, 1967, 1972; Park, 1970). It is a common epiplanktonic species in the Caribbean and occurs in the upper 300 meters although it often concentrates in the upper 50 meters (Cervigon, 1962; Owre and Foyo, 1964, 1967, 1972; Park, 1970; Björnberg, 1971). Roehr and Moore (1965) reported a reverse diurnal migration of *C. pavo* in the Florida Current off Miami.

*Candacia*

*Candacia curta* and *C. pachydactyla* were identified at Hutchinson Island. *Candacia curta* occurred in three samples (3.3%). OTR: 22.4-26.3°C, OSR: 34.0-38.2‰, OCR: 19/$m^3$, $\overline{X}$TC: 19/$m^3$, OCC: November 1972; June 1973.

Owre and Foyo (1967) found several specimens in the Florida Current. It is also recorded from the Gulf of Mexico (Fleminger and Bowman, 1956), the eastern Caribbean (Owre and Foyo, 1964) and off Venezuela (Legaré, 1961b, 1964; Cervigon, 1962).

*Candacia pachydactyla* was found in low numbers during winter and spring (19.0% of samples). OTR: 20.6-26.3°C, OSR: 33.0-38.5‰, OCR: 4-64/$m^3$, $\overline{X}$TC: 24.8/$m^3$, OCC: January-March, November 1972; January-February, April 1973.

*Candacia pachydactyla* is found in the Florida Current (Davis, 1950; Owre and Foyo, 1967), Gulf of Mexico (King, 1950) and the Caribbean (Legaré, 1961b, 1964; Cervigon, 1962; Grice and Hart, 1962; Owre and Foyo, 1964, 1972; Park, 1970). It occurs year-round near Barbados but is most abundant from January to June (Fish, 1962; Lewis and Fish, 1969). It ranges from Woods Hole to Brazil (Wilson, 1932a; Owre and Foyo, 1972) and is principally an epipelagic species although it has been found as deep as 1500 meters (Owre and Foyo, 1967, 1972; Park, 1970).

*Centropages*

*Centropages furcatus* and *C. violaceus* were recorded at Hutchinson Island. *Centropages furcatus* was recorded in low numbers in 54.9% of all samples and was most abundant in summer and fall. OTR: 21.0-32.0°C, OSR: 33.0-38.0‰, OCR: 3-47/m$^3$, $\bar{X}$TC: 14.8/m$^3$, OCC: September-November 1971; March-December 1972; January, March-August 1973.

This species is common in neritic waters of the Gulf of Mexico (Davis, 1950; King, 1950; Fleminger, 1956), near the Florida Current (Owre and Foyo, 1967) and along the southeastern Atlantic coast (Bowman, 1971). It ranges from Long Island to Brazil (Owre and Foyo, 1967, 1972; Lewis and Fish, 1969). *Centropages furcatus* generally occurs in the upper 100 meters (Zoppi, 1961b; Owre and Foyo, 1967, 1972); however, a single specimen was recorded from 1316 meters in the eastern Caribbean (Owre and Foyo, 1964).

*Centropages violaceus* was "present" in one sample in February 1973. OTR: 20.7-21.9°C, OSR: 37.5‰.

*Centropages violaceus* is associated with oceanic waters in the Caribbean (Björnberg, 1971; Owre and Foyo, 1972). Records include the Florida Current (Owre and Foyo, 1967), off Venezuela (Cervigon, 1962; Legaré, 1964; de la Cruz, 1971), off the northeastern coast of South America (Owre and Foyo, 1972) and the Sargasso Sea (Deevey, 1971).

*Clausocalanus*

*Clausocalanus furcatus* occurred in 25.3% of all samples in low numbers. OTR: 20.6-32.0°C, OSR: 33.0-38.5‰, OCR: 4-21/m$^3$, $\bar{X}$TC: 12.8/m$^3$, OCC: November 1971; March-May, September, November 1972-February, April, August 1973.

*Clausocalanus furcatus* is a neritic and oceanic species, occurring in the Gulf of Mexico (Davis, 1950; Grice, 1960a, Park, 1970) and the Florida Current (Owre and Foyo, 1967). It is numerically important in the Gulf Stream to Long Island (Grice and Hart, 1962) and dominant in oceanic waters from Cape Hatteras to Hutchinson Island (Bowman, 1971). This species commonly occurs in the Caribbean (Owre and Foyo, 1964, 1971, 1972; Park, 1970), off Venezuela (Cervigon, 1962; Legaré, 1964) and off Bermuda (Esterly, 1911; Herman and Beers, 1969). Moore and Sander (1976) record *C. furcatus* as a dominant copepod off Barbados even though it is considered a sporadic breeder. It usually occurs in the upper 500 meters and may concentrate in the upper 100 meters (Owre and Foyo, 1964b; Park, 1970; Björnberg, 1971; Michel and Foyo, 1976).

*Euaugaptilus*

*Euaugaptilus hecticus* was "present" at Station II in March 1973. OTR: 21.8-23.1°C, OSR: 36.1‰.

Owre and Foyo (1967) found this species in the Florida Current and suggested that it may migrate diurnally. It occurs in the Caribbean (Owre and Foyo, 1964, 1972), off Bermuda (Moore, 1949), the Sargasso Sea (Deevey, 1971) and over the Cariaco Trench (Legaré, 1964). Moore and Sander (1977) recorded it at Barbados.

*Eucalanus*

Four species were recorded at Hutchinson Island.

*Eucalanus attenatus* was recorded in low numbers in 5.5% of all samples. OTR: 22.8-32.0°C, OSR: 33.0-36.1‰, OCR: 7-50/m$^3$, $\bar{X}$TC: 28.5/m$^3$, OCC: January, May, September 1972; April 1973.

*Eucalanus attenatus* occurs in offshore waters of the Gulf of Mexico (King, 1950; Fleminger, 1956) and in the Florida Current (Davis, 1950; Owre and Foyo, 1967). It has been recorded from neritic and oceanic waters between Florida and Long Island (Grice and Hart, 1962; Bowman, 1971). This species occurs throughout the Caribbean (Legaré, 1961b, 1964; Cervigon, 1962; Fish, 1962; Lewis and Fish, 1969; Park, 1970; de la Cruz, 1971; Owre and Foyo, 1972). It is abundant in the upper 300 meters of the open Caribbean (Björnberg, 1971). It ranges from the Gulf of St. Lawrence to Venezuela (Owre and Foyo, 1967).

*Eucalanus crassus* was identified in 5.5% of all samples. OTR: 24.8-29.5°C, OSR: 33.0-37.2‰, OCR: 3-5/m$^3$, $\bar{X}$TC: 4.0/m$^3$, OCC: January, September 1972; April, August 1973.

*Eucalanus crassus* occurs in the Florida Current (Owre and Foyo, 1967) and in the Caribbean (Legaré, 1964). It is reported from the Sargasso Sea (Grice and Hart, 1962; Deevey, 1971) and from oceanic waters between Cape Hatteras and Hutchinson Island (Bowman, 1971). This species ranges from the Gulf of St. Lawrence to Venezuela (Owre and Foyo, 1967).

*Eucalanus monachus* was recorded from all but two months of samples (70.3%). It was the most numerous *Eucalanus*. High counts occurred in November 1972, May 1973 and August 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-214/m$^3$, $\bar{X}$TC: 25.1/m$^3$, OCC: September-November 1971; March-September, November 1972-August 1973.

This species is reported from brackish areas of west Florida to the edge of the shelf (King, 1950; Hopkins, 1973). It occurs in the Florida Current (Owre and Foyo, 1967) and in oceanic waters from Cape Hatteras to Hutchinson Island (Bowman, 1971). Grice (1957) recorded *Eucalanus monachus* off Ft. Pierce in

June. It is common in parts of the Caribbean (Legaré, 1961b, 1964; Cervigon, 1962; Park, 1970; de la Cruz, 1971). It ranges from Woods Hole to Venezuela (Wilson, 1932a; Legaré, 1964).

*Eucalanus mucronatus* occurred at Stations III and V in May 1972. OTR: 22.8-24.2°C, OSR: 35.0-36.0‰, OCR: 19/m³, $\overline{X}$TC: 19/m³.

This uncommon calanoid has few records from the western North Atlantic. Wilson (1936) records it from Bermuda. It is reported from the Caribbean (Owre and Foyo, 1964; Moore and Sander, 1977) and the Florida Current (Owre and Foyo, 1967).

### *Euchaeta*

*Euchaeta marina* generally occurred in low numbers from winter through spring (18.7% of samples). Highest counts were in January 1972. OTR: 20.7-29.1°C, OSR: 33.0-38.5‰, OCR: 5-289/m³, $\overline{X}$TC: 159.0/m³, OCC: January, May, November 1972-February, April, July-August 1973.

*Euchaeta marina* occurs primarily in oceanic waters of the Gulf of Mexico (Davis, 1950; Fleminger, 1956), in the Florida Current (Davis, 1950; Owre and Foyo, 1967) and along the southeastern Atlantic Coast (Davis, 1950; Grice and Hart, 1962; Owre and Foyo, 1967; Bowman, 1971). Bowman (1971) considers this species an indicator of oceanic waters although it has been recorded from neritic and slope waters (Grice and Hart, 1962). Owre and Foyo (1967) note that *E. marina* was the second most abundant copepod offshore of Miami. This species also occurs throughout the Caribbean (Legaré, 1961b, 1964; Cervigon, 1962; Fish, 1962; Owre and Foyo, 1964, 1971, 1972; de la Cruz, 1971; Park, 1970). It ranges from the Gulf of St. Lawrence to off the Amazon River (Owre and Foyo, 1967, 1972). This species is epiplanktonic, often concentrating within the upper 25 to 100 meters, but ranging widely through the water column (Moore and O'Berry, 1957; Owre and Foyo, 1964, 1972; Björnberg, 1971; Park, 1975).

### *Haloptilus*

*Haloptilus longicornis* was "present" at Station II in March 1973. OTR: 21.8-23.1°C, OSR: 36.1‰.

This oceanic species is abundant in the Florida Current (Owre and Foyo, 1967). Records in the western North Atlantic include Wilson (1936), Moore (1949), Legaré (1961b, 1964), Grice and Hart (1962), de la Cruz (1971), Deevey (1971), Owre and Foyo (1972) and Moore and Sander (1977). Roehr and Moore (1965) documented a reverse migration in the Florida Current although Michel and Foyo (1976) found no regular migration in Caribbean populations.

### *Heterocope*

Specimens of *Heterocope* spp. were "present" in seven samples (7.7%). OTR: 21.9-28.2°C, OSR: 34.0-38.5‰, OCC: October, December 1972-March 1973.

King (1950) records this genus at one station in the eastern Gulf of Mexico. It is possible this unique genus has been overlooked as a copepodite.

### *Heterorhabdus*

*Heterorhabdus spinifrons* was "present" at Station II in March 1973. OTR: 21.8-23.1°C, OSR: 36.1‰.

This deep water form is recorded in the western North Atlantic from the Florida Current (Owre and Foyo, 1967), the Caribbean (Owre and Foyo, 1964, 1972; Legaré, 1964), Bermuda (Wilson, 1936; Moore, 1949), the Sargasso Sea (Deevey, 1971), and off the mouth of the Amazon River (Owre and Foyo, 1972). It also occurs in the eastern Gulf of Mexico (King, 1950).

### *Labidocera*

*Labidocera* was the fifth most frequently occurring genus and ranked fifth in copepod abundance. It was counted in 92.0% of the samples throughout the year at all stations. Two species were identified at Hutchinson Island.

*Labidocera acutifrons* was recorded twice, in January 1972 and May 1973 (3.3% of all samples). OTR: 23.3-25.2°C, OSR: 34.0-36.1‰, OCR: 6/m³, $\overline{X}$TC: 6/m³.

Fleminger (1957) describes *Labidocera acutifrons* as tropical-oceanic. Bowman (1971) reports it from a few oceanic stations between southern Florida and Cape Hatteras. This species may be an indicator of Gulf Stream surface water along the western Atlantic coast (Sherman and Schaner, 1968). It occurs in eastern Gulf of Mexico waters (King, 1950) and in the Florida Current (Owre and Foyo, 1967).

*Labidocera aestiva* was a common copepod at Hutchinson Island. It occurred in 91.0% of all samples. Highest counts occurred in May 1972 and January 1973. Copepodite stages occurred almost year-round. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-1,199/m³, $\overline{X}$TC: 117.4/m³, OCC: September 1971-August 1973.

*Labidocera aestiva* is a euryhaline, neritic species found in estuarine and shelf waters along the north and west coasts of the Gulf of Mexico (Davis, 1950; King, 1950; Fleminger, 1957) and along the Atlantic coast south of the Gulf of St. Lawrence (Sutcliffe, 1950; Grice and Hart, 1962; Owre and Foyo, 1967; Jacobs, 1968; Bowman, 1971). Owre and Foyo (1967) reported this species from the Florida Current and Björnberg (1971) considers it characteristic of inshore Caribbean waters. Hopkins (1966) recorded it year-round from St.

Andrew Bay. Bowman (1971) described *L. aestiva* and another abundant copepod, *Acartia tonsa*, as a "coastal association".

*Lucicutia*

*Lucicutia flavicornis* was identified in 3.3% of all samples. OTR: 21.3-25.1°C, OSR: 35.5-37.7‰, OCR: 19/$m^3$, $\overline{X}$TC: 19/$m^3$, OCC: March 1972; March, June 1973.

This oceanic species is reported over the outer shelf off west Florida (King, 1950) and commonly occurs in the Florida Current (Owre and Foyo, 1967). It is abundant in the Sargasso Sea (Grice and Hart, 1962), in oceanic waters off the southeastern coastal states (Bowman, 1971) and in the Caribbean (Legaré, 1961b, 1964; Cervigon, 1962; Owre and Foyo, 1964, 1971; Park, 1970; de la Cruz, 1971). This species ranges from Long Island to neritic waters off the Amazon River (Owre and Foyo, 1967, 1972). It may migrate extensively to depths of 4350 meters but is usually concentrated in the upper 500 meters (Owre and Foyo, 1964b, 1967, 1972; Roehr and Moore, 1965; Park, 1970; Deevey and Brooks, 1971; Michel and Foyo, 1976).

*Paracalanus*

*Paracalanus* spp. occurred in every sample and were more abundant than any other zooplankton taxon. The cyclopoid genus *Oithona*, was also present in every sample, but *Paracalanus* was 8.7 times more abundant. Low counts were in the fall. Highest densities were in May 1972. High numbers also occurred in January 1972 and May-June 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 6-8,862/$m^3$, $\overline{X}$TC: 1,085.2/$m^3$, OCC: September 1971-August 1973.

Although *Paracalanus aculeatus*, *P. crassirostris* and *P.* sp. cf. *parvus* were identified from Hutchinson Island samples, they were not routinely counted. The number of samples precluded dissection necessary for specific discrimination.

*Paracalanus* is a dominant year-round resident in Biscayne Bay that at times may be more abundant than *Acartia* or *Labidocera* (Woodmansee, 1958; Reeve, 1964, 1970; Bader and Roessler, 1972). Grice (1956) ranked *Paracalanus* as third among copepod genera in Alligator Harbor (northwest Florida) and Legaré (1964) ranked it second off Venezuela.

*Paracalanus aculeatus* is most abundant in oceanic waters but also occurs in shelf waters (Sutcliffe, 1950; Owre and Foyo, 1967; Björnberg, 1971; Bowman, 1971). Grice (1957) recorded it near Hutchinson Island and attributed its presence to the proximity of oceanic Gulf Stream water. Records include the Gulf of Mexico (Davis, 1950; Fleminger, 1956; Grice, 1960a), oceanic waters between Cape Hatteras and the Florida Straits (Bowman, 1971), the Caribbean Sea (Owre and Foyo, 1971; Michel and Foyo, 1976) and off Jamaica (Moore and Sander, 1976). This species ranges from New York to the Amazon River area (Grice and Hart, 1962; Deevey, 1971; Owre and Foyo, 1972). It is epiplanktonic and concentrates in the upper 50 meters although specimens have been recorded from 4350 meters (Zoppi, 1961b; Owre and Foyo, 1964, 1972; Björnberg, 1971; Michel and Foyo, 1976).

*Paracalanus crassirostris* is characteristic of estuarine and neritic waters and is abundant in coastal waters of the eastern Gulf of Mexico (Grice, 1956, 1960a), in St. Andrew Bay (Hopkins, 1966) and the Anclote River estuary (Weiss and Hopkins, 1972). This species has occurred in a small number of samples in Biscayne Bay (Reeve, 1970) and along the Florida east coast (Bowman, 1971). It has been reported from inshore Caribbean waters, particularly mangrove areas (Suarez-Caabro, 1959; Björnberg, 1971). It ranges from Long Island Sound (Deevey, 1956) to Venezuela (Björnberg, 1971).

Grice (1957) reported *Paracalanus* sp. cf. *parvus* as very abundant at inshore stations near Hutchinson Island. *Paracalanus parvus* is abundant in estuarine, neritic and oceanic waters of the western North Atlantic (Wilson, 1932a; Sutcliffe, 1950; Woodmansee, 1958; Deevey, 1960, 1971; Cronin et al., 1962; Grice and Hart, 1962; Martin, 1965; Jacobs, 1968; Wheeler, 1970). Records for the Gulf of Mexico include King (1950), Fleminger (1956), Grice (1957) and Perry and Christmas (1973). It occurs in neritic and oceanic Caribbean waters (Park, 1970; Björnberg, 1971) and ranges in the western North Atlantic from the Canadian Arctic (Shih et al., 1971) to the Amazon River area (Owre and Foyo, 1972). It is an epiplanktonic species and usually concentrates in the upper 300 meters (Wilson, 1932b; Zoppi, 1961b; Park, 1970; Björnberg, 1971).

*Pleuromamma*

*Pleuromamma gracilis* was "present" in two samples from May 1972 and March 1973. OTR: 21.8-24.2°C, OSR: 36.0-36.1‰.

Owre and Foyo (1967) considered this species a diurnal migrator in the Florida Current. Colton et al. (1962) collected several night tows with large numbers of *Pleuromamma gracilis*. This species occurs throughout the Caribbean (Legaré, 1961b; Owre and Foyo, 1964, 1972; Moore and Sander, 1977), in the Sargasso Sea (Grice and Hart, 1962; Deevey, 1971) and off Bermuda (Wilson, 1936).

*Pontellina*

*Pontellina plumata* was "present" at Station III in January 1972 and at Station II in March 1973. OTR:

21.8-25.2°C, OSR: 34.0-36.1‰.

This species is rare and occurs in western North Atlantic oceanic waters (Wilson, 1942; Moore, 1949; Owre and Foyo, 1964, 1971; Park, 1970; Bowman, 1971; Deevey, 1971). Owre and Foyo (1967) recorded it year-round in the Florida Current and King (1950) found it beyond the edge of the west Florida shelf. It ranges from the Gulf of St. Lawrence to the edge of the shelf off the Amazon River (Owre and Foyo, 1967, 1972). This species is epiplanktonic and may demonstrate a reverse vertical migration pattern (Owre and Foyo, 1964, 1967, 1972; Roehr and Moore, 1965; Park, 1970).

*Pseudodiaptomus*

*Pseudodiaptomus coronatus* was "present" at Stations II and III in March 1972. OTR: 21.0-21.5°C, OSR: 35.0-38.0‰.

Grice (1957) also reports *Pseudodiaptomus coronatus* near Hutchinson Island at an inshore station. This species is usually associated with brackish waters of estuaries and coastal embayments but is rarely numerically dominant (Wilson, 1932a, b; Davis and Williams, 1950; King, 1950; Sutcliffe, 1950; Fleminger, 1956; Woodmansee, 1958; Cronin et al., 1962; Hopkins, 1966; Herman et al., 1968; Jacobs, 1968). However, it is recorded from nearshore coastal waters where salinities ranged up to 34.2‰ (Davis, 1950; Grice, 1956, 1957, 1960a; Deevey, 1960; Bowman, 1971; Perry and Christmas, 1973). It is a diurnal migrator in shallow water (Grice, 1956; Bowman, 1971; Perry and Christmas, 1973).

*Rhincalanus*

*Rhincalanus cornutus* was recorded in low numbers in spring and winter (7.7% of samples). OTR: 21.8-26.3°C, OSR: 34.0-38.5‰, OCR: 4/m³, $\overline{X}$TC: 4/m³, OCC: January, December 1972; January-February, April 1973.

*Rhincalanus cornutus* frequently occurs in the Florida Current off Miami (Owre and Foyo, 1967). It is characteristic of oceanic waters between Cape Hatteras and the Florida Straits (Bowman, 1971). The Atlantic form of the species is a common copepod in the Caribbean Sea (Bowman, 1971; Owre and Foyo, 1971; Michel and Foyo, 1976). It ranges from the Gulf of St. Lawrence to neritic and oceanic areas just north of the Amazon River outflow (Owre and Foyo, 1967, 1972). This species ranges in depth from 0-3602 meters but is characteristic of water between 300-900 meters (Owre and Foyo, 1967, 1972; Michel and Foyo, 1976).

*Scolecithrix*

*Scolecithrix danae* was "present" in three samples (3.3%) from January and November 1972. OTR: 25.0-26.1°C, OSR: 33.0-35.0‰.

*Scolecithrix danae* is fairly common in oceanic waters from the Gulf of St. Lawrence to Brazil (Owre and Foyo, 1967, 1972). Records from the western North Atlantic include Davis (1950), Legaré (1961b, 1964), Colton et al. (1962), Grice and Hart (1962), Van Engel and Tan (1965), Lewis and Fish (1969) and de la Cruz (1971). Wilson (1936) and Moore (1949) reported *S. danae* off Bermuda and Deevey (1971) found it in the Sargasso Sea. This species is epiplanktonic, usually occurring in the upper 100 meters, but ranging to 2500 meters (Michel and Foyo, 1976).

*Temora*

*Temora* was the fourth most frequent genus (94.5% of all samples) and second in abundance. Two species were identified at Hutchinson Island.

*Temora stylifera* was recorded throughout the sampling period (59.3% of samples). Highest counts were in May-June 1973. OTR: 20.5-29.5°C, OSR: 33.0-38.5‰, OCR: 2-594/m³, $\overline{X}$TC: 100.6/m³, OCC: September 1971-January, May-September, November 1972; January-August 1973. *Temora stylifera* copepodites occurred in fall, spring and summer (17.6% of samples) with highest counts in June-July 1973.

Bowman (1971) reported significant numbers of *Temora stylifera* during all seasons, except fall, off Jupiter Inlet and offshore Hutchinson Island. Grice (1957, 1960a) also reported it near Hutchinson Island, in an area probably influenced by oceanic waters. This species is primarily oceanic in the western North Atlantic and records include Wilson (1932a), Moore (1949), Grice (1957), Deevey (1960, 1971), Grice and Hart (1962) and Bowman (1971). However, it occurs in neritic waters in lower numbers (Deevey, 1952a, b; Van Engel and Tan, 1965; Grice and Hart, 1962; Bowman, 1971). This species occurs in oceanic and neritic waters of the Gulf of Mexico (Fleminger, 1956; Grice, 1957, 1960a) and in low concentrations near estuaries (Hopkins, 1966; Perry and Christmas, 1973). It is found in the Caribbean (Suarez-Caabro, 1959; Legaré, 1961b, 1964; Cervigon, 1962; Fish, 1962; Cervigon and Marcano, 1965; Owre and Foyo, 1964, 1967, 1972; Park, 1970; Björnberg, 1971; de la Cruz, 1971). *Temora stylifera* ranges from Labrador (Shih et al., 1971) to off the Amazon River (Owre and Foyo, 1972). It usually occurs in the upper 300 meters but may concentrate in the upper 50 meters (Zoppi, 1961b; Owre and Foyo, 1964; Roehr and Moore, 1965; Park, 1970; Björnberg, 1971) and has been recorded to 1750 meters (Owre and Foyo, 1964).

*Temora turbinata* was always more abundant than *T. stylifera* except in May 1973. It occurred in collections from every month (91.2% of samples). Numbers were generally lower in spring and fall. OTR: 20.5-32.0°C, OSR: 33.0-38.5‰, OCR: 2-2,127/m³, $\overline{X}$TC: 242.4/m³, OCC: September 1971-August 1973. *Temora* *turbinata* copepodites were recorded in every month except September 1971 (59.3% of samples).

Grice (1957, 1960a) recorded *Temora turbinata* near Hutchinson Island and at many of his inshore stations in Florida waters. Owre and Foyo (1967) reported it in the Florida Current off Miami. This species occurs in neritic and oceanic waters along the east and west coasts of Florida as well as in localized estuarine situations which probably represent coastal intrusion (Davis, 1950; King, 1950; Fleminger, 1956; Grice, 1956; Woodmansee, 1958; Reeve, 1964, 1970; Hopkins, 1966; Perry and Christmas, 1973). It is widely distributed throughout the Caribbean region (Suarez-Caabro, 1959; Legaré, 1961b, 1964; Cervigon, 1962; Owre and Foyo, 1964, 1967, 1972; Cervigon and Marcano, 1965; Park, 1970; Björnberg, 1971; de la Cruz, 1971). It ranges from oceanic waters south of Georges Bank (Wilson, 1950; Deevey, 1960) to the Amazon River area (Owre and Foyo, 1972). It is epiplanktonic but has been recorded to 1750 meters (Wilson, 1950; Zoppi, 1961b; Owre and Foyo, 1964). Legaré (1964) ranked it the fourth most abundant species in the upper 500 meters over the Cariaco Trench.

*Undinula*

*Undinula vulgaris* was identified in 68.1% of all samples. Numbers were highest in winter and late summer although counts reached 151/$m^3$ in May 1973. OTR: 20.0-30.1°C, OSR: 33.0-38.5‰, OCR: 2-1,460/$m^3$, $\overline{X}$TC: 163.7/$m^3$, OCC: September 1971-July, November 1972-August 1973.

Grice (1957, 1960a) also recorded this species near Hutchinson Island and attributed its presence to intrusion of high salinity water. Bowman (1971) found significant concentrations in neritic waters near Hutchinson Island in winter, spring and summer. *Undinula vulgaris* occurs in neritic and oceanic waters along Florida's east and west coasts (Davis, 1950; Fleminger, 1956; Grice, 1957, 1960a). Its occurrence in estuaries is probably due to transport from coastal waters (Hopkins, 1966; Perry and Christmas, 1973). It is common in the open Gulf of Mexico (Fleminger, 1956) and in the Florida Current (Owre and Foyo, 1967). This species is found year-round in the Caribbean (Suarez-Caabro, 1959; Cervigon, 1962; Fish, 1962; Legaré, 1964; Owre and Foyo, 1964, 1971, 1972; Cervigon and Marcano, 1965; Björnberg, 1971; de la Cruz, 1971). It ranges from south of Nova Scotia (Shih et al., 1971) to northeastern South America (Owre and Foyo, 1972). It is epiplanktonic and concentrates in the upper 50 meters although it has been recorded to 1500 meters (Owre and Foyo, 1964, 1972; Roehr and Moore, 1965; Park, 1970).

CYCLOPOIDA

*Copilia*

*Copilia mirabilis* occurred in 14.3% of all samples. Highest numbers were in January 1972. OTR: 20.7-38.2°C, OSR: 33.0-38.5‰, OCR: 3-32/$m^3$, $\overline{X}$TC: 14.2/$m^3$, OCC: January, November 1972; January-February, April, June 1973.

*Copilia mirabilis* is often abundant in the Florida Current (Davis, 1950; Owre and Foyo, 1967). It occurs in the offshore shelf waters of the eastern Gulf of Mexico (King, 1950). This species is present year-round off Barbados but is most abundant from winter to summer (Fish, 1962) or from winter to early spring (Lewis and Fish, 1969). It ranges from the Woods Hole region to off Brazil (Wilson, 1932a; Owre and Foyo, 1972). This species usually concentrates in the upper 500 meters but has been recorded to 2385 meters (Owre and Foyo, 1964, 1972; Roehr and Moore, 1965).

*Corycaeus*

*Corycaeus* was the third most frequent copepod genus (97.8% of samples) and occurred in every month sampled. Peak numbers were recorded in January 1972, November 1972 and July-August 1973. OTR: 20.0-32.0°C, OSR: 30.0-38.5‰, OCR: 1-554/$m^3$, $\overline{X}$TC: 74.6/$m^3$, OCC: September 1971-August 1973. Species identifications were not attempted.

*Corycaeus* is frequently reported in eastern Gulf of Mexico waters (Davis, 1950; King, 1950) and in the Florida Current (Davis, 1950; Owre and Foyo, 1967). This genus is common along the Florida east coast (Davis, 1950) and also occurs in the Caribbean (Owre and Foyo, 1964). *Corycaeus* ranges from estuarine conditions (Hopkins, 1966) to oceanic waters (Deevey, 1971).

*Farranula*

Three species of *Farranula* were recorded at Hutchinson Island. *Farranula carinata* was similar in abundance and mean count to *F. rostrata*. *Farranula gracilis* was not as common.

*Farranula carinata* was recorded in lower numbers in fall; highest concentrations occurred in January-February 1973, April-May 1973 and July 1973. It was in 61.5% of all samples. OTR: 20.5-30.1°C, OSR: 33.0-38.5‰, OCR: 1-198/$m^3$, $\overline{X}$TC: 47.1/$m^3$, OCC: September 1971-January, November 1972-August 1973.

*Farranula carinata* is a common oceanic species in the Caribbean (Wilson, 1942; Owre and Foyo, 1964, 1971, 1972). It occurs in shelf waters of the Florida west coast (King, 1950), in the Florida Current (Owre and Foyo, 1967) and in nearshore waters off Miami (Gordon, 1942). It is also recorded along the eastern edge of the Gulf Stream north of Bermuda (Wilson, 1942). Fish (1962) recorded *F. carinata* (*Corycella carinata*) in early spring and fall off Barbados. It ranges from the Woods Hole region (Wilson, 1932a) to neritic waters off northeastern South America (Owre and Foyo, 1972). This species is epiplanktonic and concentrates in the upper 10 meters but has been recorded to 5200 meters (Owre and Foyo, 1964; Michel and Foyo, 1976).

*Farranula gracilis* was recorded in low numbers throughout the study. Highest counts were in July-August 1973. It occurred in 33.8% of all samples. OTR: 21.8-32.0°C, OSR: 34.0-38.5‰, OCR: 2-69/m³, $\overline{X}$TC: 15.4/m³, OCC: September 1971-January, May-September, November 1972; January-August 1973.

*Farranula gracilis* (sometimes as *Corycella gracilis*) occurs in the Florida Current (Owre and Foyo, 1967) and is reported in the Gulf Stream and nearby oceanic waters as far north as Long Island (Wilson, 1942; Grice and Hart, 1962). It is common off Barbados and Jamaica and is classified as a continuous breeder at both locations (Moore and Sander, 1976). Most *Farranula gracilis* concentrate in the upper 50 meters of oceanic Caribbean water but may range to 2500 meters (Owre and Foyo, 1964b; Michel and Foyo, 1976).

*Farranula rostrata* was identified in every month but October 1972 (72.5%). Highest counts were in November 1972 and May 1973. OTR: 20.5-32.0°C, OSR: 33.0-38.5‰, OCR: 1-211/m³, $\overline{X}$TC: 46.8/m³, OCC: September 1971-September, November 1972-August 1973.

This species is rare in the Florida Current off Miami and is recorded in the Gulf Stream north of Bermuda (Wilson, 1942; Owre and Foyo, 1967). Wilson (1942) reported *Farranula rostrata* throughout the Caribbean. It is recorded to 350 meters (Owre and Foyo, 1967).

*Lubbockia*

*Lubbockia squillimana* occurred in 13.2% of all samples. OTR: 20.9-29.1°C, OSR: 35.1-38.0‰, OCR: 3-27/m³, $\overline{X}$TC: 12.7/m³, OCC: May 1972, March-August 1973.

*Lubbockia squillimana* is reported in outer shelf waters along the Florida west coast (King, 1950), the Florida Current off Miami (Owre and Foyo, 1967), the oceanic eastern Caribbean (Owre and Foyo, 1964) and the Straits of Yucatan (Owre and Foyo, 1972). It occurs mostly in oceanic waters and ranges from Long Island to the northern coast of South America (Wilson, 1942; Owre and Foyo, 1972). This species concentrates in the upper 300 meters but is recorded to 1500 meters (Owre and Foyo, 1964, 1967, 1972).

*Oithona*

The genus *Oithona* occurred in 98.9% of the samples and ranked fourth in copepod abundance. *Oithona plumifera* and *O. setigera* were the only species identified during routine counting; all others were included under *Oithona* spp.

*Oithona* spp. was recorded in 91.2% of all samples. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-705/m³, $\overline{X}$TC: 109.2/m³, OCC: September 1971-August 1973.

*Oithona* commonly occurs in estuarine, neritic and oceanic environments (Grice, 1960b; Legaré, 1964; Owre and Foyo, 1967; Bader and Roessler, 1972). Legaré (1961b) ranked the genus second in abundance in the Gulf of Cariaco.

*Oithona plumifera* was counted in 53.8% of all samples. Counts were lowest in early spring and fall. OTR: 20.7-32.0°C, OSR: 33.0-38.5‰, OCR: 2-385/m³, $\overline{X}$TC: 38.5/m³, OCC: September 1971-September, November 1972-August 1973.

Grice (1957) reports this species near Hutchinson Island. It is characteristic of the open Gulf of Mexico, but may occur in inshore areas along Florida's northwest coast (Davis, 1950; King, 1950; Grice, 1960a, b; Hopkins, 1966). *Oithona plumifera* is abundant in the Florida Current (Owre and Foyo, 1967) and the Gulf Stream (Grice and Hart, 1962). Michel and Foyo (1976) suggested it may be the most abundant oceanic copepod in the Caribbean and adjacent areas. Colton et al. (1962) used this species as an indicator of oceanic intrusion of the Gulf Stream into the Gulf of Maine and Georges Bank area. This species is reported in neritic and oceanic water from the Gulf of Maine to the northeast coast of South America (Wilson, 1932a, 1942; Deevey, 1960, 1971; Grice and Hart, 1962; Owre and Foyo, 1964, 1967, 1972). It ranges to a depth of 1250 meters but concentrates in the upper 350 meters (Wilson, 1942; Owre and Foyo, 1964, 1967, 1972; Björnberg, 1971).

*Oithona setigera* was recorded in 44.0% of all samples. Counts were highest in winter. OTR: 20.7-32.0°C, OSR: 33.0-38.5‰, OCR: 2-129/m³, $\overline{X}$TC: 46.2/m³, OCC: September-November 1971; March-May, September, November 1972-July 1973.

*Oithona setigera* is common in the Florida Current (Owre and Foyo, 1967) and the Gulf Stream between Long Island and Bermuda and the Sargasso Sea (Grice and Hart, 1962) but is rare in the oceanic eastern Caribbean (Owre and Foyo, 1964). Grice (1957) recorded it at one station in the Gulf of Mexico. It ranges in depth to 5200 meters but concentrates in the upper 100-150 meters (Michel and Foyo, 1976).

*Oncaea*

This cyclopoid genus was found in 80.2% of all samples. *Oncaea mediterranea* and *O. venusta* were identified during routine counting, all others were included in *Oncaea* spp.

*Oncaea* spp. occurred in over half the samples (59.3%) with highest counts in winter. Counts were also high on June 20, 1973 at Stations I and II. OTR: 20.5-31.0°C, OSR: 33.0-38.5‰, OCR: 4-403/$m^3$, $\bar{X}$TC: 54.6/$m^3$, OCC: September 1971-September, November 1972-August 1973.

*Oncaea* occurs in estuaries (Hopkins, 1966), coastal waters, (Deevey, 1952a) and the open ocean (Deevey and Brooks, 1971). Seven species have been recorded in the Florida Current and oceanic Caribbean (Owre and Foyo, 1967; Ferrari, 1975). It is the third most common genus recorded in the Gulf of Cariaco (Legaré, 1961b). *Oncaea* are very abundant in the upper 50 meters (Deevey and Brooks, 1971).

*Oncaea mediterranea* densities were low in summer and fall. It was counted in 47.3% of all samples. OTR: 20.7-32.0°C, OSR: 33.0-38.5‰, OCR: 5-100/$m^3$, $\bar{X}$TC: 27.5/$m^3$, OCC: November 1971; January, May, September, November 1972-May, June-August 1973.

*Oncaea mediterranea* is a common copepod in the oceanic Caribbean region (Owre and Foyo, 1971; Moore and Sander, 1976). It is also recorded from the oceanic waters of the Gulf of Mexico, the Sargasso Sea, the Florida Current, the Caribbean Sea and neritic and oceanic waters off northeastern South America (Wilson, 1936; Moore, 1949; Grice, 1957; Legaré, 1961b, 1964; Owre and Foyo, 1967; Deevey, 1971; Michel and Foyo, 1976). *Oncaea mediterranea* usually occurs in the upper 250 meters, but may range to 3144 meters (Michel and Foyo, 1976).

*Oncaea venusta* was "present" in seven samples in January 1972 and April-May 1973. OTR: 23.6-26.1°C, OSR: 34.0-38.2‰.

Michel and Foyo (1976) found *Oncaea venusta* twice as abundant as *Oncaea mediterranea* in the oceanic Caribbean. Wilson (1936) reported it from Bermuda. *Oncaea venusta* also occurs in the Gulf of Mexico (King, 1950). This species ranges to 5200 meters but concentrates in the upper 100-150 meters (Michel and Foyo, 1976).

*Saphirella*

*Saphirella tropica* occurred in low numbers in 5.5% of all samples. OTR: 22.7-29.0°C, OSR: 35.5-37.7‰, OCR: 4/$m^3$, $\bar{X}$TC: 4/$m^3$, OCC: July, October 1972; March, May, July 1973.

*Saphirella tropica* is reported from the Florida Current (Owre and Foyo, 1967), the Caribbean (Owre and Foyo, 1972) and Barbados (Moore and Sander, 1977).

*Sapphirina*

Three oceanic species of *Sapphirina* occurred in very low numbers at Hutchinson Island.

*Sapphirina nigromaculata* was "present" in March (Station II), May (Station IV) and June (Station II) 1973 in 3.3% of all samples. OTR: 21.8-26.2°C, OSR: 36.1-38.2‰.

Owre and Foyo (1967) recorded low numbers of *S. nigromaculata* from the Florida Current. Low numbers are also reported from the Gulf of Mexico (King, 1950), Barbados (Fish, 1962; Lewis and Fish, 1969), Sargasso Sea (Deevey, 1971), Cariaco Gulf area (Legaré, 1961b). Legaré (1964) found this species the most common *Sapphirina* in the Cariaco Trench region.

*Sapphirina ovatolanceolata* was "present" in June 1972 (Station III) and February 1973 (Station II). OTR: 20.7-25.2°C, OSR: 34.0-37.5‰.

This species is recorded from the Barbados (Fish, 1962; Lewis and Fish, 1969; Moore and Sander, 1977) and the Florida Current (Owre and Foyo, 1967).

*Sapphirina stellata* was recorded only during April 1973 at all but Station IV. OTR: 25.0-26.3°C, OSR: 36.1-37.7‰, OCR: 4/$m^3$, $\bar{X}$TC: 4/$m^3$.

Records for the western North Atlantic include Owre and Foyo (1967) and Moore and Sander (1977).

HARPACTICOIDA
*Clytemnestra*

Copepodites of *Clytemnestra* occurred in low numbers in 24.2% of all samples. OTR: 20.5-28.3°C, OSR: 33.0-38.5‰, OCR: 3-24/$m^3$, $\bar{X}$TC: 10.7/$m^3$, OCC: January-March, July, October-December 1972; February-April, June 1973.

This genus is recorded from neritic and Florida Current waters (Davis, 1950; King, 1950; Owre and Foyo, 1967).

*Euterpina*

*Euterpina acutifrons* occurred in 89.0% of all samples and was the most common harpacticoid. Highest concentrations occurred in March 1972 and in February and March 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 4-184/$m^3$, $\bar{X}$TC: 44.8/$m^3$, OCC: September-November 1971; March 1972-August 1973.

*Euterpina acutifrons* is recorded from the Gulf of Mexico in inshore waters (Davis, 1950; King, 1950) and in estuaries (Grice, 1956; Hopkins, 1966; Perry and Christmas, 1973) as well as Biscayne Bay and coastal waters off Miami (King, 1950; Woodmansee, 1958). Deevey (1971) found it in oceanic waters. It occurs throughout the Caribbean (Legaré, 1961b, 1964; Björnberg, 1971; de la Cruz, 1971; Owre and Foyo, 1971). It ranges from Delaware Bay (Deevey, 1960) to neritic waters off the Amazon River (Owre and Foyo, 1972). The species occurs between 10 and 50 meters in the Gulf of Cariaco (Zoppi, 1961b).

*Macrosetella*

*Macrosetella gracilis* was identified in 25.3% of all samples. Highest abundance was in January 1972. Copepodites were "present" in November 1972 and January and August 1973. OTR: 21.0-29.1°C, OSR: 33.0-38.5‰, OCR: 3-128/m$^3$, $\overline{X}$TC: 20.9/m$^3$, OCC: January, November-December 1972; January-April, June-August 1973.

*Macrosetella gracilis* occurs in the eastern Gulf of Mexico from brackish conditions to outer shelf waters, in the Florida Current and in neritic waters along Florida's southeast coast (Davis, 1950; King, 1950; Owre and Foyo, 1967). It is a common Caribbean copepod (Wilson, 1942; Legaré, 1964; Owre and Foyo, 1964b, 1967, 1971, 1972; Björnberg, 1965, 1971; Michel and Foyo, 1976).

It is considered a tropical or temperate open water species (Wilson, 1932a, b; Davis, 1950) but it ranges from the Gulf of Maine to coastal waters off the Amazon River (Wilson, 1932a, b; Sutcliffe, 1950; Grice and Hart, 1962; Owre and Foyo, 1972). This species is most common at 300 meters but may concentrate between 200 and 700 meters and range to below 6200 meters (Moore and O'Berry, 1957; Owre and Foyo, 1964; Björnberg, 1965, 1971; Roehr and Moore, 1965; Michel and Foyo, 1976).

*Miracia*

*Miracia efferata* and *M. minor* were observed at Hutchinson Island in very low numbers.

*Miracia efferata* was recorded in five months (11.0% of samples). OTR: 21.9-26.3°C, OSR: 33.0-38.5‰, OCR: 12/m$^3$, $\overline{X}$TC: 12/m$^3$, OCC: January, November 1972; February-April 1973.

*Miracia efferata* is abundant in the Florida Current off Miami (Owre and Foyo, 1967) and ranges from the Woods Hole region (Wilson, 1932a) to the coast of northeastern South America (Owre and Foyo, 1972). It is the only copepod off Jamaica which exhibits periodicity in breeding behavior; it is benthic and only swarms to the surface during mating (Moore and Sander, 1976). However, other researchers (Wilson, 1932a, 1942, 1950; Owre and Foyo, 1964) consider it epiplanktonic.

*Miracia minor* was identified only once as "present" at Station II in March 1973. OTR: 21.8-23.1°C, OSR: 36.1‰.

This species occurs in the oceanic Caribbean (Owre and Foyo, 1964, 1967, 1972).

*Oculosetella*

*Oculosetella gracilis* was "present" in March-April 1973 (2.2% of samples). OTR: 23.0-26.1°C, OSR: 36.1-37.2‰.

Although *Oculosetella gracilis* is a rare species with oceanic affinities, it is recorded from the surf off Miami (Gordon, 1942) and from a neritic station off Florida's east coast (Davis, 1950). It also has been recorded from the open Gulf of Mexico off Florida's west coast (Davis, 1950; King, 1950), the Florida Current (Owre and Foyo, 1967), the oceanic Caribbean (Owre and Foyo, 1972) and the western North Atlantic to Woods Hole (Wilson, 1932a, 1942, 1950; Deevey, 1971). This species is usually epiplanktonic, but ranges to 1000 meters (Wilson, 1942, 1950; Owre and Foyo, 1972).

UNDETERMINED HARPACTICOIDA

Most of the undetermined forms were benthic and generally considered tychoplanktonic. They were found infrequently (12.1% of samples) and sporadically in very low concentrations. OTR: 23.1-32.0°C, OSR: 33.0-38.2‰, OCR: 2-11/m$^3$, $\overline{X}$TC: 6.3/m$^3$, OCC: November 1971; January, July, September 1972; January, April-May, July 1973.

## COPEPOD LARVAE

This category consisted of nauplii and all copepodites not identified to genus or species. They occurred in 96.7% of the samples. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-2,021/m$^3$, $\overline{X}$TC: 99.7/m$^3$, OCC: September 1971-August 1973. Highest concentrations occurred during September 1971 and July 1973. Minima were recorded in November 1971 and April 1973.

Nauplii dominate in nearshore waters along Florida's west coast in spring and winter, and along Florida's east coast in winter, spring and fall (Davis, 1950). Copepod nauplii and copepodites may be a dominant group in Biscayne Bay during any season (Smith et al., 1950; Woodmansee, 1958; Reeve, 1970). *Acartia* copepodites dominated the zooplankton in Biscayne Bay in October and December (Woodmansee, 1958). Summer and fall maxima of young copepods has been reported in neritic waters off Biscayne Bay (Reeve, 1964). Highest densities of nauplii in Beaufort Inlet were recorded from spring through fall, particularly in areas of higher temperature and salinity (Sutcliffe, 1950).

OTHER COPEPODA

Monstrilloid copepods were "present" at Station V in May 1972. OTR: 24.0-24.2°C, OSR: 36.0‰. Monstrilloids are recorded from Biscayne Bay (Davis, 1947, 1949) and from inshore waters off northwest Florida (King, 1950).

Caligoid copepods were "present" at Station II in August 1973. OTR: 25.6-28.1°C, OSR: 35.2-35.4‰. They are found in Florida Bay (Davis, 1950) and from offshore waters of eastern Venezuela (Legaré, 1961b). They are rare in the plankton.

CHAETOGNATHA
*Sagitta*

Five species of *Sagitta* were recorded at Hutchinson Island. *Sagitta inflata* (see Ghirardelli, 1968:279 corrected an orthographic error in the specific name.) and *S. helenae* formed 30.7% and 11.5%, respectively, of total *Sagitta* numbers. *Sagitta hispida* formed 5.9%. *Sagitta serratodentata* and *S. tenuis* occurred in low numbers. Immature *Sagitta* formed 49.7% of total *Sagitta* numbers and usually were more numerous than adult *Sagitta*. *Sagitta inflata* and *Sagitta* spp. (including *S. helenae*, *S. hispida*, *S. serratodentata*, *S. tenuis* and immature *Sagitta*) were the two categories used for computer analysis.

Immature *Sagitta* occurred throughout the sampling period (95.6% of samples); lowest counts were in fall. Highest counts were in October 1972 and March 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-339/$m^3$, $\overline{X}$TC: 57.1/$m^3$, OCC: September 1971-August 1973.

Immature *Sagitta* occur year-round in Biscayne Bay, peak in mid-winter and mid-summer (Woodmansee, 1958) and have averaged 3% of the total zooplankton. In St. Andrew Bay, immature forms (< 3 mm in length) comprised the greater portion of chaetognath biomass (Hopkins, 1966).

*Sagitta helenae* occurred in 29.7% of all samples with peak counts in January 1972 and August 1973. OTR: 20.0-28.7°C, OSR: 33.0-38.5‰, OCR: 3-321/$m^3$, $\overline{X}$TC: 69.7/$m^3$, OCC: September 1971; January-March, July, November 1972; January-February, April-May, August 1973.

*Sagitta helenae* is found in the western North Atlantic from nearshore waters to the shelf edge and is less tolerant of low salinities than *S. hispida* (Pierce, 1951, 1958; Bumpus and Pierce, 1955; Pierce and Wass, 1962; Hopkins, 1966). Pierce (1953) considers this species an indicator of shelf waters off Cape Hatteras. *Sagitta helenae* occurs in the Florida Current (Owre, 1960), in shelf waters from north of Cape Hatteras (Deevey, 1960; Grant, 1963a, b) through the Gulf of Mexico (Alvariño, 1965) and rarely, in bottom waters off the Bahamas (Owre, 1972). It has also been recorded from the Gulf of Cariaco (Legaré and Zoppi, 1961).

*Sagitta hispida* was recorded in 41.8% of all samples. It was absent or in very low numbers in fall and winter. High counts were recorded in spring and summer. OTR: 20.6-29.0°C, OSR: 34.0-38.5‰, OCR: 3-109/$m^3$, $\overline{X}$TC: 25.3/$m^3$, OCC: September-November 1971; March, July, November 1972-July 1973.

*Sagitta hispida* occurs in lower salinity waters along Florida's west coast (Pierce, 1951) and is the only chaetognath besides *S. tenuis* which penetrates into St. Andrew Bay (Hopkins, 1966). *Sagitta hispida* is usually associated with neritic waters within the 20 meter contour (Pierce, 1951, 1953; Bumpus and Pierce, 1955; Suarez-Caabro, 1959; Pierce and Wass, 1962; Reeve, 1970; Cosper and Reeve, 1970; Björnberg, 1971) but has been recorded in shelf water beyond 20 meters and in oceanic water (Suarez-Caabro and Madruga, 1960; Owre, 1960; Legaré and Zoppi, 1961; Lewis and Fish, 1969; Owre and Foyo, 1972). Two of the oceanic occurrences (Owre, 1960; Owre and Foyo, 1972) could represent entrainment from inshore waters. It occurs in nearshore waters off Barbados (Lewis and Fish, 1969; Moore and Sander, 1976) and off Bermuda (Herman and Beers, 1969). It ranges in the western North Atlantic from north of Cape Hatteras (Deevey, 1960; Grant 1963a, b) to Argentina and along the west coast to Africa (Alvariño, 1965). This species frequently occurs in sledge hauls in Bahamian waters and may be associated with the sediment (Owre, 1972).

*Sagitta inflata* occurred in 57.1% of all samples. High counts were in January 1972 and May and late June 1973. Counts were lowest in fall. OTR: 20.5-30.1°C, OSR: 33.0-38.5‰, OCR: 3-523/$m^3$, $\overline{X}$TC: 96.1/$m^3$, OCC: September 1971-May, November 1972; January-August 1973.

*Sagitta inflata* is widely distributed in neritic and oceanic waters of tropical-warm temperate regions (Tokioka, 1955; Grant, 1963b; Alvariño, 1965). It is a common species in the Gulf of Mexico and the Caribbean Sea (Pierce, 1951, 1954; Suarez-Caabro and Madruga, 1960; Legaré and Zoppi, 1961; Björnberg, 1971; Owre and Foyo, 1972; Michel and Foyo, 1976; Moore and Sander, 1976), ranging north to Cape Hatteras (Bumpus and Pierce, 1955). Hopkins (1966) reported it near the mouth of the St. Andrew Bay system. Pierce (1951) recorded populations in neritic waters along Florida's west coast year-round except during late summer and early fall. *Sagitta inflata* may be indicative of Gulf Stream intrusion in coastal waters north of Cape Hatteras to Nova Scotia (Pierce, 1953, 1958; Bumpus and Pierce, 1955; Deevey, 1960; Grice and Hart, 1962; Pierce and Wass, 1962; Grant, 1963a, b). It ranges from Nova Scotia (Shih et al., 1971) to neritic and oceanic waters near the Amazon River (Owre and Foyo, 1972). This species is epiplanktonic, usually concentrating in the upper 500 meters and migrating diurnally in the Florida Current (Owre, 1960).

*Sagitta serratodentata* occurred in low numbers in five of the months sampled (8.8%). It was recorded as "present" except at Station III in late June 1973. OTR: 22.4-29.6°C, OSR: 34.0-37.7‰, OCR: 57/m$^3$, $\overline{X}$TC: 57/m$^3$, OCC: November 1972; April-May, June-July 1973.

*Sagitta serratodentata* is an "oceanic, epiplanktonic species typical of tropical and temperate Atlantic and adjacent waters" and ranges between 50°N and 45°S (Alvariño, 1965). It is found in offshore shelf and oceanic waters from Jupiter Inlet to Cape Hatteras, Gulf of Mexico, the Florida Current and the Caribbean (Pierce, 1953, 1954; Bumpus and Pierce, 1955; Owre, 1960; Grice and Hart, 1962; Pierce and Wass, 1962; Michel and Foyo, 1976). This species peaks in summer and fall in the Florida Current off Miami (Owre, 1960) and is "present" year-round off Barbados and Jamaica (Moore and Sander, 1976).

*Sagitta tenuis* was recorded off Hutchinson Island in 15.4% of samples. Counts were highest in March. OTR: 20.0-28.3°C, OSR: 34.0-38.0‰, OCR: 9-77/m$^3$, $\overline{X}$TC: 24.5/m$^3$, OCC: March-July, October-December 1972.

*Sagitta tenuis* is a neritic species (Alvariño, 1965) which tolerates salinities from 10.9-39.7% (Owre and Foyo, 1972). It occurs commonly in St. Andrew Bay (Hopkins, 1966), in coastal waters of the eastern Gulf of Mexico (Pierce, 1951), but is rare in coastal waters off Miami (Owre, 1972). It inhabits shelf waters from the Florida Straits to Cape Hatteras (Pierce, 1953, 1958; Bumpus and Pierce, 1955; Pierce and Wass, 1962). This chaetognath ranges from south of Delaware Bay (Grant, 1963a) to neritic waters near the Amazon River (Owre and Foyo, 1972).

### *Krohnitta*

*Krohnitta pacifica* was recorded in November 1971 and February 1973 (3.3% of samples). OTR: 20.7-27.0°C, OSR: 35.0-38.5‰, OCR: 2/m$^3$, $\overline{X}$TC: 2/m$^3$.

Owre (1960) found this oceanic, cosmopolitan species common in the Florida Current off Miami. It is associated with the Gulf Stream as far north as North Carolina (Pierce, 1953) although it occasionally strays into coastal waters (Bumpus and Pierce, 1955; Pierce, 1958; Grice and Hart, 1962). It is common throughout the Caribbean (Legaré and Zoppi, 1961; Owre and Foyo, 1972; Michel and Foyo, 1976) and also occurs in low numbers in the Gulf of Mexico (Pierce, 1954) and the Sargasso Sea (Grice and Hart, 1962; Deevey, 1971).

## OTHER MAJOR HOLOPLANKTON

### LARVACEA

Larvaceans were second to copepods in total abundance. They formed 13.8% of the total zooplankton. Other studies in Florida waters have shown that larvaceans are important plankters (Woodmansee, 1958; Reeve, 1964; Hopkins, 1966; Bader and Roessler, 1972; Roberts, 1974). The percent composition of zooplankton off Jamaica (Moore and Sander, 1976) was similar to that off Hutchinson Island. Two genera, *Oikopleura* and *Fritillaria*, were identified at Hutchinson Island.

*Oikopleura* spp. occurred in 97.8% of the Hutchinson Island samples and formed 91.9% of all larvaceans. This genus was present year-round and was the most frequent, abundant non-copepod zooplankton genus. Counts were highest in winter and summer. OTC: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 4-3,942/m$^3$, $\overline{X}$TC: 532.0/m$^3$, OCC: September 1971-August 1973. Björnberg (1971) reported six species from the Caribbean and Gulf of Mexico.

*Fritillaria* spp. occurred in 39.6% of the samples. Maximum populations occurred in February 1973 coincidentally with high densities for *Oikopleura*. Minor peaks occurred in January and July 1972. OTR: 20.7-30.1°C, OSR: 33.0-38.5‰, OCR: 3-1,091/m$^3$, $\overline{X}$TC: 130.1/m$^3$, OCC: January, May-November 1972; January-July 1973. Björnberg (1971) reported four species from the Caribbean and Gulf of Mexico.

### TINTINNIDA

Tintinnids occurred in 47.3% of the samples. OTR: 20.7-32.0°C, OSR: 33.0-38.5‰, OCR: 1-6,674/m$^3$, $\overline{X}$TC: 246.8/m$^3$, OCC: September 1971-April 1973; August 1973.

Tintinnids can dominate the plankton in and around Biscayne Bay (Smith et al., 1950). Davis (1950) consistently found tintinnids in Florida east coast samples as well as in many west coast samples. In the Gulf of Mexico, tintinnids range from brackish river water to oceanic water (King, 1950; Hopkins, 1966; Balech, 1967; Cosper, 1972) but are frequently more dominant in bay and coastal waters (King, 1950).

### THECOSOMATA

Unidentified thecosomes occurred in 47.3% of all samples. Maxima occurred in May and July 1973. They were absent or in low numbers in fall. OTR: 20.5-30.1°C, OSR: 34.0-38.5‰, OCR: 5-739/m$^3$, $\overline{X}$TC: 69.9/m$^3$, OCC: September 1971; May, November 1972-August 1973.

*Creseis acicula* was present in 28.6% of the Hutchinson Island samples. OTR: 20.5-32.0°C, OSR: 33.0-38.2‰, OCR: 4-263/m$^3$, $\overline{X}$TC: 58.4/m$^3$, OCC: September 1971-June, September, November 1972; March-August 1973. Juveniles were recorded in September 1972.

This species is more often associated with neritic waters than any other thecosome (Haagensen, 1976). It is reported in St. Andrew Bay (Hopkins, 1966) and off the coast of South America (Owre and Foyo, 1972). It is a common species in the Florida Current (Wormelle, 1962). *Creseis acicula* ranges in the Atlantic from Newfoundland to Argentina (Van der Spoel, 1967).

*Creseis virgula* was present in 29.7% of the samples. Numbers were highest in September and July 1973; numbers were generally lowest in fall and winter. OTR: 20.7-29.6°C, OSR: 34.0-38.5‰, OCR: 3-74/$m^3$, $\overline{X}$TC: 25.2/$m^3$, OCC: September 1971; January, May, November 1972-July 1973.

Like *Creseis acicula*, *C. virgula* is common in the Florida Current (Wormelle, 1962). Chen and Hillman (1970) considered a form of *C. virgula* an indicator of Gulf Stream water off Cape Hatteras. The same form is documented in a study of the relationship of West Florida Shelf waters and the Loop Current (Austin, 1971). *Creseis virgula* ranges in the Atlantic from Nova Scotia to Argentina (Van der Spoel, 1967).

## CLADOCERA

Unidentified cladocerans occurred in 6.6% of the samples. OTR: 20.7-24.5°C, OSR: 34.0-37.5‰, OCR: 5-251/$m^3$, $\overline{X}$TC: 61.8/$m^3$, OCC: May 1972; January-February 1973.

In St. Andrew Bay, cladoceran densities were highest in June, August and January, averaging 1.8% of the total zooplankton year-round (Hopkins, 1966). They occur in enclosed and shelf waters along Florida's west coast and in neritic and Gulf Stream waters off Miami (Davis, 1950).

*Evadne* spp. occurred in 37.4% of the samples. Maxima occurred in July of 1972 and 1973. OTR: 22.8-32.0°C, OSR: 33.0-38.0‰, OCR: 2-523/$m^3$, $\overline{X}$TC: 83.3/$m^3$, OCC: November 1971; July-November 1972; April-August 1973.

Hopkins (1966) reported *Evadne* in greatest abundance from June to October with a peak in August in St. Andrew Bay. *Evadne* spp. along Florida's west coast range from estuarine waters to the edge of the shelf (King, 1950). *Evadne* spp. often occur after a phytoplankton maximum in pelagic waters of the Caribbean Sea (Margalef, 1971). *Evadne tergestina* peaks during summer months off Barbados during times of freshwater influence (Moore and Sander, 1976).

*Penilia* spp. was recorded once at Hutchinson Island (1.1%). OTR: 29.4-29.5°C, OSR: 36.0-37.0‰, OCR: 3/$m^3$, $\overline{X}$TC: 3/$m^3$, OCC: September 1972.

*Penilia* is present throughout St. Andrew Bay but is more abundant during warm months (Hopkins, 1966). *Penilia* spp. behaves similarly to *Evadne* spp. in open surface waters of the Caribbean (Margalef, 1971).

## OSTRACODA

Ostracods occurred in 35.2% of the samples. Maxima occurred in January 1972 and March 1973. Numbers were low in summer and fall. OTR: 20.7-32.0°C, OSR: 33.0-38.2‰, OCR: 2-653/$m^3$, $\overline{X}$TC: 124.2/$m^3$, OCC: January, May, September, November 1972; January-August 1973. The holoplanktonic *Conchoecia* spp. were identified on several occasions.

Ostracods are primarily benthic and may be swept into the plankton by turbulence (Fish, 1925; Hulings and Gray, 1971). Ostracods occur year-round in coastal and oceanic waters from Cape Canaveral to Cape Hatteras (Roberts, 1974). Sutcliffe (1950) stated that ostracods are rare in Beaufort Inlet and over the shelf. Oceanic ostracods are recorded off Barbados (Deevey, 1970; Moore and Sander, 1976) and Jamaica (Moore and Sander, 1976).

## FORAMINIFERA

Foraminiferans occurred in 83.5% of all samples. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-455/$m^3$, $\overline{X}$TC: 30.5/$m^3$, OCC: September 1971-August 1973. *Globigerina* spp. were recorded at Hutchinson Island but not routinely counted.

Foraminiferans have constituted 19.5% of total plankton in the surf zone off Miami Beach (Davis, 1950). Forams dominate in the northeastern Gulf of Mexico off Florida, and Davis (1950) considered most of them to be tychopelagic forms. He reported pelagic *Globigerina* in low concentrations from offshore Gulf of Mexico and Florida Current waters. King (1950) also found forams in low abundance in Gulf waters off Florida. Forams are recorded from the Caribbean, Straits of Florida, off the coast of Venezuela and may be useful indicators of water masses (Legaré, 1961b; Jones, 1968; Austin, 1971).

## THALIACEA

Thaliaceans (salpids and doliolids) were collected sporadically during the sampling period. Salpids occurred in spring and summer in 12.1% of samples. OTR: 22.8-26.0°C, OSR: 35.0-38.0‰, OCR: 17-314/$m^3$, $\overline{X}$TC: 89.7/$m^3$, OCC: May 1972; May-June 1973. Doliolids were recorded in all seasons (19.8% of samples). Highest counts were in winter and spring. OTR: 20.7-28.4°C, OSR: 33.0-38.5‰, OCR: 1-54/$m^3$, $\overline{X}$TC: 21.1/$m^3$, OCC: January, May, November 1972; January-February, April-June, August 1973.

Thaliaceans are reported from outer St. Andrew Bay, open shelf waters off the Florida west coast and open neritic and Florida Current waters off the east coast (Davis, 1950; King, 1950; Hopkins, 1966). Björnberg (1971) and Owre and Foyo (1972) discussed their distribution in the Caribbean.

### *LUCIFER*

*Lucifer faxoni* occurred in 47.3% of the samples. Highest counts were recorded in January 1972 and August 1973. OTR: 20.0-30.1°C, OSR: 33.0-38.2‰, OCR: 1-281/$m^3$, $\overline{X}$TC: 34.4/$m^3$, OCC: November 1971-July, November 1972; January-August 1973.

*Lucifer faxoni* occurs primarily in coastal waters off the Florida Straits to Cape Hatteras (Bowman and McCain, 1967) but also in the Gulf Stream and the oceanic waters of the central North Atlantic. Cruise (1971) demonstrated a neritic-oceanic separation between *L. faxoni* and *L. typus* in the eastern Gulf of Mexico. *Lucifer faxoni* has been suggested as an indicator of eastern Gulf waters and *L. typus* of Loop Current water. *Lucifer faxoni* occurs in St. Andrew Bay (Hopkins, 1966) year-round, in Biscayne Bay from mid-October to mid-February (Woodmansee, 1958) and in North Carolina estuaries, where greatest abundance was recorded from April to October (Williams, 1969). In the latter two cases, it was transient from outside neritic waters. This species ranges from Nova Scotia to Rio de Janeiro (Williams, 1969).

### SIPHONOPHORA

Siphonophores occurred in 59.3% of the samples. Greatest concentrations were recorded in January 1972. Numbers were lowest in fall and summer. OTR: 20.0-29.6°C, OSR: 33.0-38.5‰, OCR: 1-90/$m^3$, $\overline{X}$TC: 17.2/$m^3$, OCC: September 1971-July 1972; October 1972-May 1973; July-August 1973.

Siphonophores are characteristic of oceanic waters but may also occur in neritic waters (Grice and Hart, 1962). Hopkins (1966) recorded them from St. Andrew Bay. Siphonophores are reported in nearshore and offshore regions of the Gulf of Mexico (Davis, 1950; King, 1950; Vasiliev, 1974), the Florida Current (Davis, 1950; Moore, 1953; Bsharah, 1957) and inshore waters of the Florida east coast (Davis, 1950). They are fairly common in the Gulf of Cariaco (Legaré, 1961b) and are abundant, particularly from July through September, in waters entering the Caribbean off Barbados (Lewis and Fish, 1969).

## MINOR HOLOPLANKTON

### AMPHIPODA

Amphipods were recorded in 27.5% of the samples. Most amphipods were in the pelagic sub-order Hyperiidea. They occurred sporadically year-round and were most frequent at Stations II and V. Numbers were highest in winter and spring. OTR: 20.5-32.0°C, OSR: 33.0-38.5‰, OCR: 2-151/$m^3$, $\overline{X}$TC: 27.9/$m^3$, OCC: January, May-October 1972; January-February, May-August 1973.

Amphipods are found in collections from coastal waters out to the Florida Current from Cape Canaveral to Cape Hatteras (Roberts, 1974). The genus *Hyperia* has been recorded from the Florida Current by Yang (1960).

Some amphipods are parasitic or semi-parasitic on scyphozoan medusae (Bowman et al., 1963; Bowman and Gruner, 1973). Therefore, some specimens from Hutchinson Island may have drifted into the area on host medusae and others may be benthic migrators. Vertical migration of benthic amphipods is well known and has been documented in nocturnal surface samples of inlets, sounds and estuaries of North Carolina (Williams and Bynum, 1972).

### ISOPODA

Isopods occurred in 39.6% of the samples. They were more frequent but were less abundant than amphipods. Maximum densities occurred in January 1972 at Stations III and IV. Highest frequency was at Station V. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 3-50/$m^3$, $\overline{X}$TC: 12/$m^3$, OCC: September 1971-August 1973.

Most of the isopods in Hutchinson Island plankton samples are probably parasitic forms or adults swept from the bottom by turbulence. However, *Eurydice* spp. were recorded in several months. This genus contains holoplanktonic species (Davis, 1955). OTR: 22.8-32.0°C, OSR: 33.0-36.0‰, OCR: 5-50/$m^3$, $\overline{X}$TC: 23.5/$m^3$, OCC: September 1971-January, May, September 1972; August 1973.

Parasitic isopods have been recorded in Florida waters (Davis, 1950). Pelagic isopods have been collected sporadically in estuaries, inlets and coastal-oceanic waters (Sutcliffe, 1950; Hopkins, 1966; Roberts, 1974).

### CUMACEA

Cumaceans were "present" at Station I in July 1973. OTR: 28.6-28.7°C, OSR: 35.6-35.7‰.

Cumaceans are tychoplanktonic. Davis (1950) records cumaceans from a few plankton samples from the Gulf of Mexico and waters off the Florida east coast.

### EUPHAUSIACEA

Euphausiids were recorded in 6.6% of the samples. OTR: 23.2-30.1°C, OSR: 35.0-38.0‰, OCR: 10-69/$m^3$, $\overline{X}$TC: 29.7/$m^3$, OCC: May, July 1972; July 1973.

Euphausiids maxima in spring and summer are recorded for the Florida Current (Lewis, 1954, 1955) and off Barbados (Lewis and Fish, 1969). Euphausiids increase in abundance in outer shelf and slope waters from Cape Canaveral to Cape Hatteras (Roberts, 1974). Legaré (1961a) reported five species from enclosed waters of the Gulf of Cariaco. This group is primarily oceanic and ranges through all depths (Fish, 1925; Leavitt, 1938). Presence of deep water species could indicate upwelling. They are indicators of oceanic water masses in the Pacific (Lasker and Theilacker, 1965).

## HYDROZOA

Free floating hydroids occurred in 9.9% of the samples They were observed in low concentrations in late summer and late spring. OTR: 21.5-29.5°C, OSR: 34.0-37.0‰, OCR: 3-10/m³, $\overline{X}$TC: 6.4/m³, OCC: November 1971; March, September-December 1972; August 1973. Hydroids in our samples were probably torn loose from the substrate in the area. Small anthozoans were "present" at Station IV in November 1972 probably due to turbulence.

## NEMATODA

Nematodes occurred in 4.4% of the samples and were recorded in fall and winter of 1972. OTR: 21.0-32.2°C, OSR: 34.0-38.5‰, OCR: 5-25/m³, $\overline{X}$TC: 15/m³, OCC: September, December 1972; February 1973.

Nematodes are recorded from the Florida Current and in samples from landlocked to neritic waters. They were common in one inlet sample in southeastern Florida (Davis, 1950). Almost all nematodes are tychopelagic (Davis, 1950); therefore, those in Hutchinson Island samples were probably swept into the plankton by turbulence.

## MYSIDACEA

Mysids occurred in 5.5% of the samples. OTR: 21.8-28.5°C, OSR: 34.0-38.5‰, OCR: 4-10/m³, $\overline{X}$TC: 6.3/m³, OCC: September 1971; January, April 1973.

Mysids may be equal to or more abundant than copepods in estuaries along the United States coast (Cronin et al., 1962; Hopkins, 1966; Björnberg, 1971; Roberts, 1974). A diverse mysid fauna has been reported in shallow waters of the Bahamas and southern Florida (Brattegard, 1969, 1970).

The diurnal bottom habit of mysids may account for the low counts at Hutchinson Island. Hopkins (1966) discusses the relation of benthic habit to capture method. Several mysid species found between Nova Scotia and the Florida Keys are "benthic" (Wigley and Burns, 1971). Vertical migration patterns have been studied in the Gulf of Mexico and the Caribbean (Björnberg, 1971) and from inlets, sounds and estuaries of North Carolina (Williams, 1972).

## *PYROSOMA* SPP.

These tropical colonial urochordates occurred in 2.2% of the samples. They were recorded at Station V in May and June 1973. OTR: 20.5-25.6°C, OSR: 35.0-37.0‰, OCR: 12/m³, $\overline{X}$TC: 12/m³. The colonies were mostly intact and quite small.

## GYMNOSOMATA

Gymnosomatous pteropods occurred in 3.3% of the samples. OTR: 20.0-26.0°C, OSR: 35.0-38.0‰, OCR: 4-5/m³, $\overline{X}$TC: 4.5/m³, OCC: March, May 1972. Previous records from Florida waters include Davis (1950) and Hopkins (1966).

## SIPUNCULIDA ?

Tentatively identified sipunculids occurred in 2.2% of the samples. OTR: 22.8-28.5°C, OSR: 36.0-36.6‰, OCR: 5/m³, $\overline{X}$TC: 5/m³, OCC: September 1971; May 1973. They were probably swept into the plankton by turbulence.

## PLATYHELMINTHES

A free-living (turbellarian) flatworm was "present" at Station I in January 1973 (1.1% of all samples). OTR: 22.4-22.6°C, OSR: 35.0‰.

King (1950) recorded one form which ranges from brackish to offshore waters along Florida's west coast. Other references for Florida waters include Davis (1950) and Davis and Williams (1950). A few turbellarian forms are planktonic, but many live in the benthos of the marine littoral or sublittoral and could be swept into the plankton.

## ACARINA

A water mite was "present" (1.1% of samples) at Station I in October 1972. OTR: 28.0-28.2°C, OSR: 35.5-36.5‰. This was probably a benthic form swept into the plankton by turbulence. Acarids are not truly planktonic (Davis, 1950).

## *TOMOPTERIS*

This pelagic polychaete occurred in 6.0% of the samples. OTR: 22.4-28.6°C, OSR: 33.0-37.7‰, OCR: 2/m³, $\overline{X}$TC: 2/m³, OCC: January, May 1972; January, March-April, July 1973.

A single species of *Tomopteris* infrequently occurs during fall and spring in St. Andrew Bay (Hopkins, 1966). Pelagic polychaetes have been documented sporadically in Gulf of Mexico and Caribbean waters (Perkins and Savage, 1975).

## MEROPLANKTON

### ECHINODERM LARVAE

Echinoderm larvae comprised approximately 8.9% of all zooplankton off Hutchinson Island. They are a minor larval group (biomass) in St. Andrew Bay and peak in warmer months (Hopkins, 1966). They also have been recorded from spring to fall in the Anclote Anchorage area (Weiss and Hopkins, 1972). Sutcliffe (1950) found them in late summer and early fall at Beaufort Inlet. High densities of echinoderm larvae are documented over the inner shelf between Cape Hatteras and Jupiter Inlet (Roberts, 1974).

#### ECHINOID LARVAE

Echinoid larvae were the third most abundant zooplankton group (after Copepoda and Larvacea). This category included, for computer analysis, echinopluteus and a few echinoid post-larvae. Echinopluteus constituted 63.3% of the echinoderm larvae. They were present in 51.6% of the samples. Major peaks occurred from January to February and in May 1973. Echinoplutei dominated the zooplankton during January and February at Stations I and II and May at Station V. OTR: 20.5-32.0°C, OSR: 33.0-38.5‰, OCR: 2-12,086/$m^3$, $\overline{X}$TC: 448.9/$m^3$, OCC: November 1971, July-November 1972, January-March, May-August 1973.

Perry and Christmas (1973) collected low concentrations from the highest salinity zone of Mississippi Sound in September and October. In Biscayne Bay, echinoid larvae occur irregularly year-round and peaked in August (Woodmansee, 1958) and Reeve (1964, 1970) reports them at Bear Cut. Echinoid larvae are common in west and east coast neritic waters of Florida and are present in the Florida Current (Davis, 1950).

Echinoid post-larvae occurred in 6.6% of the samples. OTR: 22.4-30.1°C, OSR: 34.0-37.2‰, OCR: 9-12/$m^3$, $\overline{X}$TC: 10.5/$m^3$, OCC: November 1971; January, April, August 1973.

Juvenile sea urchins have been significant in surface waters of the highest salinity zone of Mississippi Sound (Perry and Christmas, 1973).

#### OPHIUROID LARVAE

Ophiuroid larvae were the fourth most abundant non-copepod group. Ophiopluteus and post larval ophiuroids were combined for computer analyses.

Ophioplutei formed 35.9% of echinoderm larvae and occurred in 56.0% of all samples. Highest counts were in September 1971, September-October 1972, July-August 1973. OTR: 20.6-32.0°C, OSR: 33.0-38.5‰, OCR: 2-2,163/$m^3$, $\overline{X}$TC: 233.2/$m^3$, OCC: September 1971-February, May-August 1973.

Ophioplutei occur in neritic waters along Florida's west coast and in estuarine and neritic waters along the east coast (Davis, 1950). In Mississippi Sound, they comprise the majority of echinoderm larvae and both early and late stages peak in August (Perry and Christmas, 1973).

Post-larval ophiuroids occurred in 2.2% of the samples at Hutchinson Island. They were "present" in September 1971. Concentrations of 7/$m^3$ were recorded in December 1972. OTR: 22.0-26.3°C, OSR: 34.0-35.0‰.

#### ASTEROID LARVAE

Asteroid larvae, both bipinnaria and brachiolaria, occurred in 14.3% of the samples. Post larval-asteroids were included with asteroid larval stages for computer analyses.

Asteroid larvae were recorded in spring and summer 1973 at Stations IV and V. OTR: 20.5-28.2°C, OSR: 35.0-37.7‰, OCR: 6-87/$m^3$, $\overline{X}$TC: 39.3/$m^3$, OCC: May-June, August 1973.

Asteroid larvae are common in neritic waters off Florida's southeast coast (Davis, 1950). They occurred in high concentrations at one station in St. Andrew Bay during June (Hopkins, 1966).

Post-larvae occurred in 11.0% of all samples. Highest numbers occurred in February 1973. OTR: 20.7-28.4°C, OSR: 34.0-38.5‰, OCR: 2-44/$m^3$, $\overline{X}$TC: 14/$m^3$, OCC: March, October-November 1972, January-February, August 1973.

#### HOLOTHUROID LARVAE

Holothuroid larvae occurred at Station III in November 1971 (1.1% of all samples). OTR: 26.8-27.0°C, OSR: 35.0‰, OCR: 17/$m^3$, $\overline{X}$TC: 17/$m^3$.

### MOLLUSK LARVAE

Mollusk larvae as a group were nearly equal in abundance to echinoid larvae and represented 5.4% of the total zooplankton.

#### GASTROPOD LARVAE

Gastropod veligers were the third most frequent and abundant non-copepod group. They were recorded in 93.4% of the samples, formed 77.8% of the mollusk veligers and occurred in every month sampled. Populations were highest in summer. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 3-3,606/$m^3$, $\overline{X}$TC: 183.0/$m^3$, OCC: September 1971-August 1973. *Echinospira* larvae were present at Hutchinson Island but were not included in routine counting.

Gastropod larvae are common year-round in St. Andrew Bay and are most abundant from summer to fall (Hopkins, 1966). They are also abundant in Biscayne Bay (Woodmansee, 1958; Lackey and Lackey, 1972), peaking in spring, summer and fall (Reeve, 1970), in Mississippi Sound, peaking in spring and summer (Perry and Christmas, 1973) and in Beaufort Inlet during colder months (Sutcliffe, 1950).

### PELECYPOD LARVAE

Bivalve veligers were approximately one third as abundant as gastropod larvae. They occurred in 85.7% of the samples and were recorded year-round. High concentrations occurred in spring and summer. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-545/m³, $\overline{X}$TC: 613/m³, OCC: September 1971-August 1973.

Pelecypod larvae peak in spring and summer in Mississippi Sound (Perry and Christmas, 1973). In St. Andrew Bay, they occur year-round, with highest concentrations in late spring to fall, and are similar in abundance to gastropod veligers (Hopkins, 1966). They outnumber gastropod veligers in the Anclote Anchorage (Weiss and Hopkins, 1972). Pelecypod larvae are a significant part of the total zooplankton in Biscayne Bay, with highest concentrations in August to October (Woodmansee, 1958). In Beaufront Inlet, they peak in late spring, summer and fall (Sutcliffe, 1950).

## DECAPOD LARVAE

### RETANTIAN LARVAE

This was the second most frequent non-copepod group. It was recorded in 95.6% of the samples. It was comprised primarily of brachyuran larvae (zoea and megalopae), then porcellanid zoeae, and hermit crab glaucothöe. This group comprised 44.4% of the decapod larvae and was present in equal frequency at all stations year-round. Counts were generally greatest in spring and summer. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-482/m³, $\overline{X}$TC: 68.3/m³, OCC: September 1971-August 1973.

Brachyuran larvae are abundant in late spring and summer in Mississippi Sound (Perry and Christmas, 1973) and usually comprise the majority of decapod larvae in Biscayne Bay where they peak in September and early spring (Woodmansee, 1958). Roberts (1974) reviewed information on brachyuran larvae between Cape Canaveral and Cape Hatteras and notes year-round occurrences with peaks in warmer months (particularly late summer to early autumn off North Carolina). Brachyuran larvae occur off Barbados in surface waters at the entrance to the Caribbean and peak from February to March and from September to November (Lewis and Fish, 1969). Brachyuran megalopae migrate to the surface at night in study areas along the southeast United States coast (Williams, 1971; Roberts, 1974). This phenomenon may explain concentrations found in our diel collections.

### UNDETERMINED DECAPOD LARVAE

This was an artificial grouping which included mostly zoeae that could not be placed into caridean, anomuran or other groups. These larvae represented 35.0% of the total decapod larvae and occurred in 89.0% of the samples. They were present year-round and were recorded at all stations. High counts occurred in January 1972 and from May to July 1973. Highest concentrations were recorded in January 1972. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-1,534/m³, $\overline{X}$TC: 64.6/m³, OCC: September 1971-August 1973.

The January maxima did not coincide with larval decapod maxima in other areas (Sutcliffe, 1950; Reeve, 1964; Hopkins, 1966; Weiss and Hopkins, 1972; Perry and Christmas, 1973; Roberts, 1974). However, Reeve (1970) has observed a caridean larvae peak in winter for inshore Biscayne Bay samples and a distinct low for decapod larvae in summer. Woodmansee (1958) records spring and fall peaks in Biscayne Bay. Definite winter peaks also occur off Barbados (Lewis and Fish, 1969). Some caridean juvenile forms may migrate from the sediments into the water column at night (Roberts, 1974).

### NATANTIAN LARVAE AND UNDETERMINED NATANTIANS

Decapods, except *Lucifer faxoni* adults, which could definitely be placed in the suborder Natantia (cf. Barnes, 1974) were included here. This group comprised 20.5% of the decapod larvae. The majority were larval stages of Penaeidae including large numbers of *Lucifer* larvae (protozoeal or slightly later stages). Natantian larvae occurred in 37.4% of the samples. Peaks occurred in May and from July to August 1973. OTR: 20.9-32.0°C, OSR: 33.0-38.2‰, OCR: 4-398/m³, $\overline{X}$TC: 84.5/m³, OCC: September 1971; September 1972; May-August 1973.

Penaeidean larvae have early to late summer or fall maxima between Cape Canaveral and Cape Hatteras (Williams, 1969; Roberts, 1974).

Undetermined natantians were recorded eight times and concentrations ranged from "present" to 13/m³. OTR: 21.8-32.0°C, OSR: 33.0-37.2‰, OCR: 3-13/m³, $\overline{X}$TC: 5.1/m³, OCC: November 1971; January, September 1972; January, May 1973.

They may have been post-larval or adult natantian shrimp which were temporarily in the plankton (Williams, 1969; Perry and Christmas, 1973).

## CIRRIPEDE LARVAE

### CIRRIPEDE NAUPLII

Barnacle nauplii occurred in 81.3% of the samples and were recorded year-round. Peaks occurred in fall and summer with small peaks in winter. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-966/m³, $\overline{X}$TC: 105.2/m³, OCC: September 1971-August 1973. Highest concentrations were usually recorded at Station I.

Cirripede nauplii occur year-round, except January, in the Anclote Anchorage area (Weiss and Hopkins, 1972). Nauplii are more abundant in spring and summer in Mississippi Sound (Perry and Christmas, 1973). Woodmansee (1958) and Reeve (1970) found them rare or unimportant in Biscayne Bay studies. However, nauplii are significant members of the zooplankton at an entrance into north Biscayne Bay and peak numbers in September and from January to February correspond with known settlement times for barnacles in that area (Reeve, 1964).

### CIRRIPEDE CYPRIS

Cyprids occurred in 54.9% of the samples and were less abundant than naupliar stages. Maximum abundance was in January 1972, and from May to July 1973, and generally coincided with peaks in nauplii populations. However, in May and June 1973, cirripede cyprids outnumbered nauplii. Counts were lowest in fall and early spring. OTR: 21.8-32.0°C, OSR: 33.0-38.2‰, OCR: 2-194/m$^3$, $\overline{X}$TC: 30.7/m$^3$, OCC: September 1971-November 1972; January-August 1973.

Cypris larvae are usually a minor element in the plankton, probably because they settle rapidly (Davis, 1950; Woodmansee, 1958; Reeve, 1964; Perry and Christmas, 1973).

### POLYCHAETE LARVAE

Polychaete larvae occurred in 84.6% of the samples. Two specimens were identified as typhloscolecid pelagic polychaetes (Thomas Perkins, Marine Research Laboratory, personal communication). All other specimens appeared to be larval stages of benthic polychaetes representing several families. Polychaete larvae formed only 0.7% of the zooplankton. Highest counts were recorded in February and May 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-317/m$^3$, $\overline{X}$TC: 42.1/m$^3$, OCC: September 1971-November 1972; January-August 1973.

Polychaete larvae are the second most important contributors to larval biomass in St. Andrew Bay (Hopkins, 1966). They are numerically important in Biscayne Bay, with maxima recorded in September (Reeve, 1964, 1970). They formed the third most common zooplankton group and averaged 380/m$^3$ in Beaufort Inlet (Sutcliffe, 1950).

### FISH EGGS AND LARVAE

Fish eggs and larvae constituted 0.6% of the total zooplankton. They occurred in 90.1% of the samples. Counts were lowest in fall. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 1-590/m$^3$, $\overline{X}$TC: 39.0/m$^3$, OCC: September 1971-November 1972; January-August 1973.

Roberts (1974) recorded eggs and larvae at most stations between Cape Canaveral and Cape Hatteras. He observed a seaward decrease in the number of eggs, and larval counts were always less than 2% of the total zooplankton.

### MEDUSAE

Most medusae were hydromedusae. They occurred in 63.7% of the samples. Frequency of occurrence at each station was similar. Highest counts occurred in May and August 1973. OTR: 20.0-32.0°C, OSR: 33.0-38.5‰, OCR: 2-208/m$^3$, $\overline{X}$TC: 30.6/m$^3$, OCC: September 1971-November 1972; January-August 1973. At least two specimens were tentatively identified as Trachymedusae which are oceanic forms without a fixed hydroid stage (Russell, 1953) and are technically holoplankton.

Low concentrations of medusae are recorded off the Florida west coast to the shelf edge (Davis, 1950; King, 1950) and in the Gulf of Cariaco (Legaré, 1961b). Davis (1950) also reported them in waters off Florida's east coast. Medusae occur in variable numbers at different Biscayne Bay locations (Davis, 1950; Woodmansee, 1958; Reeve, 1964, 1970). Comparisons of 717 individual holoplanktonic or meroplanktonic "Hydromedusae" were used to determine neritic influence near Bermuda (Moore, 1949). Medusae in neritic waters of eastern Venezuela are relatively diverse but numerically important (Zoppi, 1961a).

## MINOR MEROPLANKTON

### PHORONIDS

The majority were actinotroch larvae, although a few specimens may have been partially metamorphosed adults which had not settled or had been swept into the plankton. They occurred in 28.6% of the samples. Highest counts occurred in October 1972 and May 1973. OTR: 22.0-30.1°C, OSR: 33.0-38.0‰, OCR: 2-54/m$^3$, $\overline{X}$TC: 22/m$^3$, OCC: May 1972-January, May, July-August 1973.

They occur sporadically in enclosed and neritic waters of Florida (Davis, 1950).

### CYPHONAUTES LARVAE

Cyphonautes larvae occurred sporadically year-round in 27.5% of the samples. OTR: 21.9-32.0°C, OSR: 34.0-38.2‰, OCR: 3-40/m$^3$, $\overline{X}$TC: 16.6/m$^3$, OCC: September, November 1971, July-October 1972, January-August 1973. An undetermined bryozoan was "present" at Station I in September 1972. It was probably an adult branching species swept loose by turbulence.

Cyphonautes larvae are common off the Florida west coast and in the Florida Current and neritic waters off Miami (Davis, 1950). Cyphonautes larvae are recorded from a northern inlet in Biscayne Bay (Reeve, 1970).

## LANCELET LARVAE

Cephalochordate larvae occurred in 9.9% of the samples. Highest concentrations were at Station II in February 1973. The February peak and the summer and fall occurrences correspond with data of Futch and Dwinell (1977) indicating some early spring spawning and summer to early fall recruitment in the Hutchinson Island study area. OTR: 20.7-32.0°C, OSR: 33.0-37.5‰, OCR: 2-44/m³, $\bar{X}$TC: 19.2/m³, OCC: September-October 1972; February, July-August 1973.

Davis (1950) records lancelet larvae from offshore samples over the West Florida shelf and lancelets occur sporadically just inside St. Andrew Bay (Hopkins, 1966). Very low concentrations are reported in coastal and offshore waters from Cape Canaveral to Cape Hatteras and occur primarily in spring, summer and fall (Roberts, 1974).

## STOMATOPOD LARVAE

Antizoea occurred in 17.6% of the samples from spring to early fall. OTR: 21.0-29.1°C, OSR: 35.0-38.2‰, OCR: 5-48/m³, $\bar{X}$TC: 17.7/m³, OCC: September 1971; March-July 1972; June-August 1973.

Antizoea represented 4% of the plankton abundance in one sample from nearshore waters off Miami Beach and occurred less frequently than pseudozoea in enclosed Florida east coast waters and the Florida Current (Davis, 1950).

Pseudozoea larvae were observed in 9.9% of the samples. Their abundance was about one third that of antizoea. They were recorded from spring through fall. OTR: 21.1-29.6°C, OSR: 34.0-37.7‰, OCR: 3-27/m³, $\bar{X}$TC: 10.0/m³, OCC: November 1972, May-August 1973.

Pseudozoea are found in nearshore Gulf of Mexico waters and in enclosed, neritic and Florida Current waters off Florida's southeast coast (Davis, 1950).

## ASCIDIAN LARVAE

Larvae of benthic tunicates occurred in 7.7% of the samples. OTR: 22.4-32.0°C, OSR: 35.0-38.2‰, OCR: 7-10/m³, $\bar{X}$TC: 8.3/m³, OCC: September-October 1972, March, June 1973.

## BRACHIOPOD LARVAE

Brachiopod larvae occurred in 5.5% of the samples. They occurred in low concentrations in only four months. OTR: 25.0-30.1°C, OSR: 34.0-35.8‰, OCR: 3-19/m³, $\bar{X}$TC: 9.0/m³, OCC: January, November 1972, July-August 1973. Brachiopod larvae are common in inshore coastal waters off west Florida and present in low concentrations in neritic waters off Miami (Davis, 1950).

## PLANULA LARVAE

Planula larvae occurred in 5.5% of all samples. OTR: 23.0-26.1°C, OSR: 36.1-38.2‰, OCR: 3-8/m³, $\bar{X}$TC: 5.0/m³, OCC: March-April 1973.

## UNDETERMINED LARVAE

Unidentified larvae were "present" in 8.8% of the samples. OTR: 21.5-29.5°C, OSR: 33.0-38.0‰, OCC: November 1971-March, July-September 1972; January 1973.

## UNDETERMINED NAUPLII

Unidentified naupliar stages of crustaceans occurred in 3.3% of the samples. OTR: 24.8-28.4°C, OSR: 34.0-38.0‰, OCR: 25-50/m³, $\bar{X}$TC: 37.5/m³, OCC: January, July 1972; August 1973.

## UNDETERMINED EGGS

Unidentified eggs were observed in 15.4% of samples and occurred in low numbers except for September 1971 when they formed a significant portion of the zooplankton (415/m³) in Station V samples. OTR: 23.1-28.7°C, OSR: 33.0-36.6‰, OCR: 6-415/m³, $\bar{X}$TC: 59.2/m³, OCC: September, November 1971; March, August 1973.

# DISCUSSION

Zooplankton was divided into 14 groups for analyses and discussion (Figures 2-6). Criteria for establishing categories included phylogenetic association, abundance, planktonic residency and possible use as biological indicators. Holoplankton categories are calanoids, cyclopoids, harpacticoids, chaetognaths, urochordates (larvaceans, thaliaceans and *Pyrosoma* spp.), *Lucifer faxoni*, cnidarians (siphonophores, medusae and planula larvae) and "other holoplankton" (primarily copepod larvae, tintinnids, *Evadne* and forams). Meroplankton categories are echinoid larvae, ophiuroid larvae, mollusk larvae, decapod larvae, polychaete larvae and "other meroplankton" (primarily cirripede larvae and fish eggs and larvae).

## DOMINANCE AND ABUNDANCE

Holoplankton abundance was usually greater than meroplankton (Figure 7). Low holoplankton-meroplankton ratios occurred during periods of relative decreases in total zooplankton at most stations from July to November (Figures 8 and 9). In most samples, low ratios may be attributed to decreases in holoplankton, primarily copepods, rather than in-

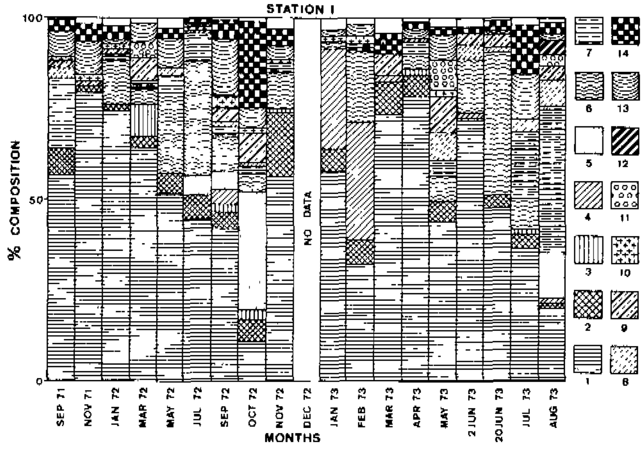


Figure 2. Percent composition of selected zooplankton categories at Station I. 1) calanoids; 2) cyclopoids; 3) harpacticoids; 4) echinoid larvae; 5) ophiuroid larvae; 6) urochordates; 7) mollusk larvae; 8) decapod larvae; 9) chaetognaths; 10) polychaete larvae; 11) cnidarians; 12) *Lucifer*; 13) other holoplankton; 14) other meroplankton.

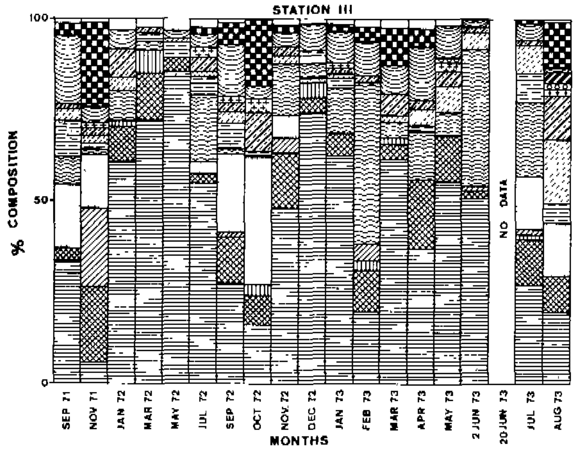


Figure 4. Percent composition of selected zooplankton categories at Station III. (See Figure 2 for Key.)

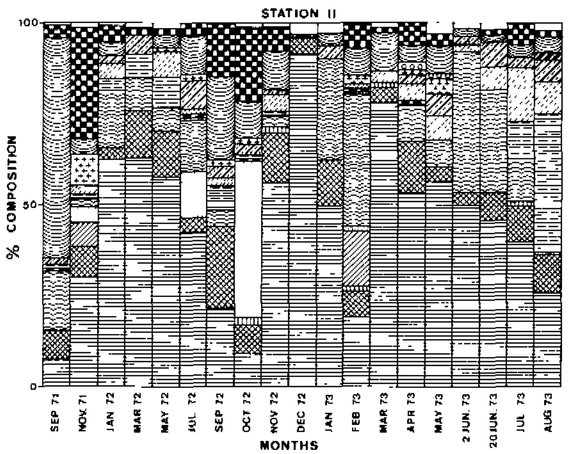


Figure 3. Percent composition of selected zooplankton categories at Station II. (See Figure 2 for Key.)

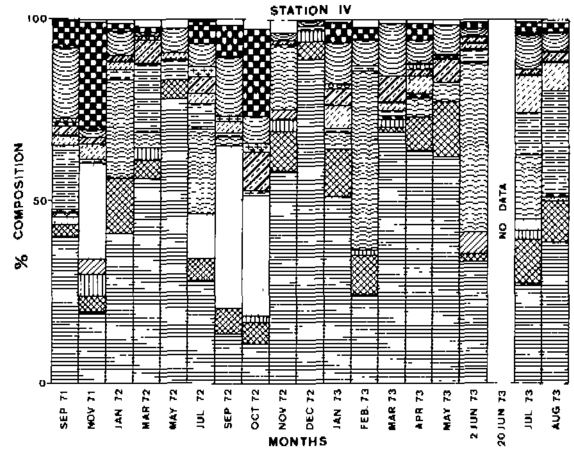


Figure 5. Percent composition of selected zooplankton categories at Station IV. (See Figure 2 for Key.)

creases in meroplankton. Copepods contributed substantially to total zooplankton abundance in most of the samples (Figure 8 and 9). Differences between stations occurred but overall stations were generally similar. Therefore, station results will be discussed both collectively and individually.

The numerical abundance (individuals/m$^3$) for each station and month is given in Tables 1-5. Station V had the largest number of individuals followed by Stations I, II, IV, and III. Abundance of each category was converted to percent of zooplankton in each sample and is represented by histograms (Figures 2-6). Percent abundance was used to compare categories within a sample and to observe relationships between stations. It seldom coincided with actual numerical abundance. For example, the largest percent abundance (91.7%) for calanoids occurred at Station II in December 1972 and represented 3,257 individuals/m$^3$. The largest numerical abundance of calanoids was 10,252/m$^3$ at Station III in May 1972 which comprised 85.9% of the sample. Most comparisons in this discussion are concerned with overall relationships and will be based on percent abundance unless otherwise specified. Cross-referencing Tables 1-5 and Figures 2-6 allows comparison of numerical and percent abundance.

Adult copepods were the dominant zooplankton group and comprised greater than 50% of the zooplankton in eight of the eighteen months sampled (Figures 2-6, Tables 1-5). They frequently were the most

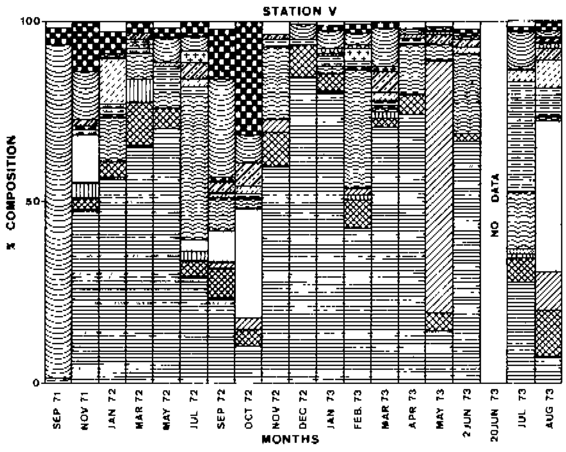


Figure 6. Percent composition of selected zooplankton categories at Station V. (See Figure 2 for Key.)

abundant group even when they comprised less than 50% of a sample. Calanoids were definitely the most numerous group, and low concentrations of zooplankton were generally due to decreased calanoid populations. Cyclopoids were usually present, but in much lower concentrations than calanoids except for five samples in August, September and November 1973. Harpacticoids were the least abundant and not always present.

The ten most abundant copepod genera in numerically decreasing order were *Paracalanus*, *Temora*, *Acartia*, *Oithona*, *Labidocera*, *Undinula*, *Corycaeus*, *Farranula*, *Euterpina*, and *Oncaea*. *Paracalanus*, *Acartia* and *Oithona* have also been predominant in several Florida bays (Grice, 1956; Hopkins, 1966, 1977; Reeve, 1970) and Bermuda (Herman and Beers, 1969). In Biscayne Bay (Reeve, 1970) the order of numerical abundance (*Acartia*, *Paracalanus*, *Temora*, *Labidocera* and *Oithona*) was similar to Hutchinson Island. The most abundant copepods recorded at Barbados and Jamaica, however, were *Clausocalanus*, *Paracalanus*, *Acartia*, *Undinula* and *Farranula* (Moore and Sander, 1976).

Other zooplankton that dominated numerically were copepod larvae (Station II, September 1971), tintinnids (Station V, September 1971), echinoid larvae (Station V, May 1973), ophiuroid larvae and urochordates. Ophiuroids were most abundant six times; four in October 1972. Greatest numerical abundance of ophiuroid larvae occurred at Station V in August 1973 when they were also the most abundant group. Urochordates were the largest group in five samples; three in February 1973. Oikopleura spp. were always the primary tunicates but *Fritillaria* spp. comprised 44% of the urochordates at Station IV in February 1973.

The fourteen categories ranked according to percent of total abundance (349,689 recorded individuals/m$^3$) are as follows: calanoids, 45.1%; urochordates, 14.0%; "other holoplankton", 8.0%; cyclopoids, 6.8%; echinoids, 5.7%; mollusk larvae, 5.4%; "other meroplankton", 3.5%; decapod larvae, 3.3%; ophiuroid larvae, 3.2%; chaetognaths, 2.6%; harpacticoids, 0.8%; polychaete larvae, 0.7%; cnidarians, 0.7%; *Lucifer faxoni*, 0.2%.

Total copepod abundance (including copepod larvae) ranged from 85 to 10,867/m$^3$ per sample ($\bar{x}$ = 3,952/m$^3$). Total abundance is lower than recorded in Florida bays (Grice, 1956; Hopkins, 1966, 1977) and offshore waters of Florida's west coast (Grice, 1957). Total abundance at Hutchinson Island is also less than copepod populations in the temperate bays of Block Island Sound (Deevey, 1952b) and Beaufort Inlet (Sutcliffe, 1950). The range is much greater than those reported by Deevey (1971) for the Sargasso Sea (87-106/m$^3$) and Grice and Hart (1962) for the Gulf Stream between Long Island and Bermuda (89-147/m$^3$). Exact comparison is difficult, however, because zooplankton studies vary in collection methods, e.g., net mesh size and sampling times (day-night).

Total zooplankton abundance ranged from 102-17,349/m$^3$ per sample ($\bar{x}$ = 3,843/m$^3$). This range at Hutchinson Island is less than recorded for Florida bays (Grice, 1956; Hopkins, 1966, 1977) and for temperate bays such as Beaufort Inlet (Sutcliffe, 1950). Additionally, zooplankton abundance has ranged from 3,600-109,400/m$^3$ at Long Island Sound (Jeffries and Johnson, 1973) and from 4,680-33,480/m$^3$ in Block Island Sound (Deevey, 1952b). Hutchinson Island zooplankton was more abundant than for Biscayne Bay (Reeve, 1964), Bermuda (Herman and Beers, 1969), the Sargasso Sea (Deevey, 1971), and the Gulf Stream between Bermuda and Long Island (Grice and Hart, 1962). Sharp decreases in Hutchinson Island zooplankton standing stock were noted after maxima which is similar to occurrences off Bermuda (Herman and Beers, 1969).

## SEASONALITY

Seasonalities have been inferred for Hutchinson Island zooplankton although sampling frequency does not permit definitive conclusions. Actual highs and lows for groups and species were possibly missed or underestimated. However, similarities are observable between the two years which may indicate yearly seasonal changes (Figures 8 and 9).

Total zooplankton for all stations generally increased during winter through mid-summer and decreased between late summer and fall. Fluctuations occur during the period of increased populations, but the lows still represent greater numbers than recorded for the seasonal low period. Major peaks occurred in January and May 1972 and February, May, June and July 1973. An exception to the general increase in zooplankton during winter through mid-summer occurred at most stations in March and April 1973 when standing stock decreased below late summer and fall

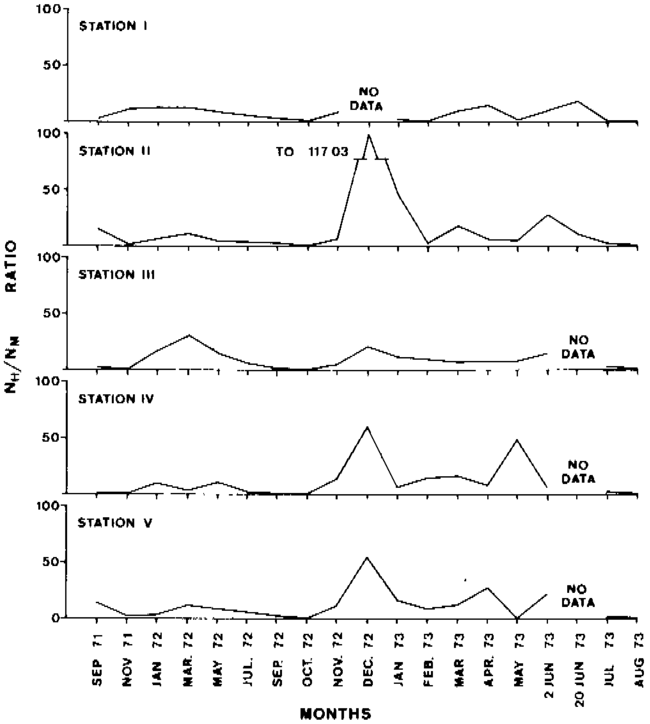


Figure 7. Ratio of holoplankton to meroplankton numerical abundance at Stations I through V.

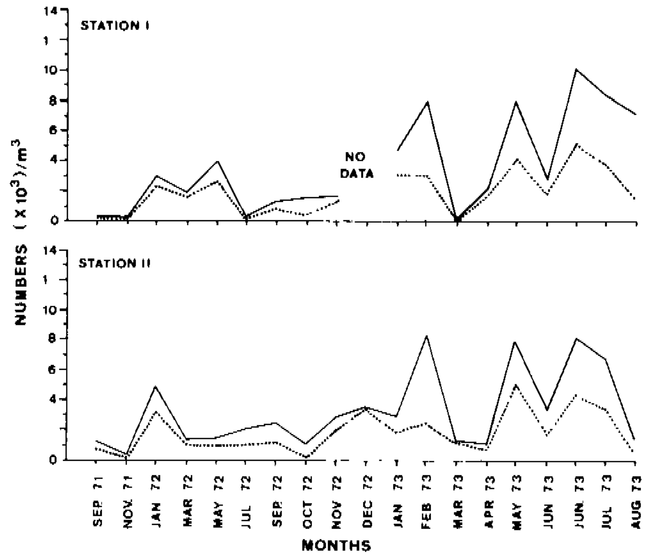


Figure 8. Total zooplankton abundance and total copepod abundance at Stations I and II.

minima. A decrease in March 1972 also occurred but numerical abundance was not as low as 1973. Two exceptions during the late summer-fall lows were the major peaks at Station V in September 1971 and November 1972.

Zooplankton abundance peaks for mid-summer and late spring through mid-summer also have been established for Bermuda with localized variations (Herman and Beers, 1969). These authors report an early fall peak for waters receiving oceanic exchange from the Sargasso Sea but numbers decline in the following months. Hopkins (1966) recorded high winter and summer densities in the St. Andrew Bay System but he also observed an increase in fall and a decline in spring. Zooplankton concentrations in Biscayne Bay, determined by volume rather than by numbers, were highest in fall and are antipodal to those described for Hutchinson Island zooplankton (Woodmansee, 1958).

Copepod seasonality was reflected in total zooplankton peaks. Copepods also mirrored zooplankton seasonality in the St. Andrew Bay System (Hopkins, 1966) and in Bermuda, particularly in waters which experienced oceanic exchange (Herman and Beers, 1969). Both studies also note fall peaks. Reeve (1970) did not discuss zooplankton as a whole for Biscayne Bay so relationships between copepods and zooplankton abundance cannot be determined. However, copepod seasonality was different from those recorded for Hutchinson Island and Bermuda. Reeve (1970) mentioned spring and fall increases and described fall peaks in zooplankton numbers as a characteristic factor of Biscayne Bay ecology. A fall maximum for copepod volume also has been reported by Woodmansee (1958). Copepod seasonality is different for each locality. No related pattern was observed for any two study areas, although Hutchinson Island seems more similar to Bermuda where maxima occur in all seasons but especially from winter to summer.

Seasonal trends of other zooplankton categories are tentative and were characterized by very low concentrations or absence to higher numbers in one or two months per year at one or more stations. Some of the groups which followed the winter, spring and summer maxima of total zooplankton at Hutchinson Island were chaetognaths, decapod larvae, polychaete larvae, mollusk larvae and cnidarians. Echinoid larvae were most abundant in winter and summer. Tintinnids and *Evadne* spp. ("other holoplankton") were among the few zooplankters which peaked in the fall at Hutchinson Island. Chaetognaths in Biscayne Bay (Reeve, 1970) are the only group for which seasonal trends are the same as at Hutchinson Island. Woodmansee (1958) noted only winter and summer maxima of immature *Sagitta* in Biscayne Bay and chaetognaths have been recorded during winter, summer and fall in the St. Andrew Bay Sytem (Hopkins, 1966). Fall is frequently a period of maximum abundance for decapod larvae, polychaete larvae, mollusk larvae, cnidarians and echinoderm larvae in Biscayne Bay (Woodmansee, 1958; Reeve, 1970), St. Andrew Bay (Hopkins, 1966) or Bermuda (Herman and Beers, 1969), although spring and/or summer peaks are also recorded for these groups. Mollusks peak in winter at Biscayne Bay

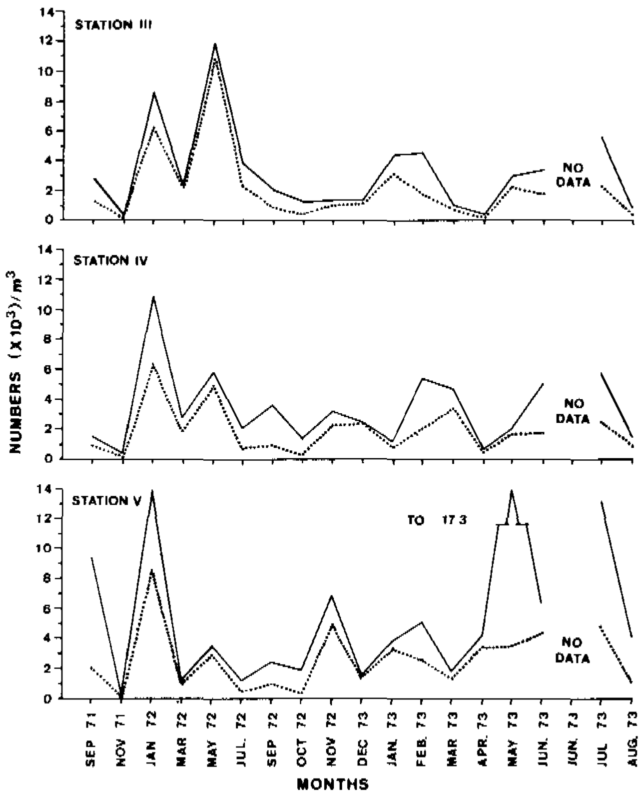


Figure 9. Total zooplankton abundance and total copepod abundance at Stations III through V.

(Woodmansee, 1958) while cnidarians exhibit a winter maxima in St. Andrew Bay (Hopkins, 1966).

True seasonality and relationships between benthic and pelagic communities are difficult to determine since: 1) meroplankton stages are transitory and their presence may be attributable to transport mechanisms, 2) larvae should be identified to species since different species of benthic invertebrates may reproduce seasonally or year-round in warm waters (Moore, 1972) and 3) larger nets may not capture larvae or may underestimate abundance. At Hutchinson Island, only occurrences of larval lancelets coincided with recruitment times reported by Futch and Dwinell (1977) for benthic populations.

Overall zooplankton seasonality in Hutchinson Island nearshore waters does not mimic other Florida or Bermuda waters, but high zooplankton abundance in warmer months was most common and variations were more noticeable in cooler months. Deviations should be expected because of differences in sampling procedures, gear and the influence of environmental factors.

## DISTRIBUTION

Worldwide distribution for copepod and chaetognath species was listed using the following references: Brady (1883), Scott (1909), Wilson (1932a, 1942), Farran (1936), Bowman (1957) and Alvariño (1965). Fifty copepod species (32 calanoids, 13 cyclopoids and 5 harpacticoids) were identified at Hutchinson Island. Forty-two are considered cosmopolitan in tropical or tropical-temperate waters. Five copepods have restricted distributions. *Acartia bermudensis* has only been reported from Bermuda, Florida east coast waters and off the Amazon River. *Acartia spinata* is limited to the Caribbean, Gulf of Mexico and Gulf Stream waters. *Calanopia americana* is primarily tropical and occurs only in the Atlantic. *Pseudodiaptomus coronatus* occurs in estuarine and coastal waters from Nova Scotia to the Mississippi Delta. *Labidocera aestiva* has been reported from the northern Gulf of Mexico, the Florida Current off Miami and from estuarine and neritic waters from the Gulf of St. Lawrence to Ft. Pierce Inlet. Available data is insufficient to establish distributions for three other copepod species identified at Hutchinson Island.

*Sagitta inflata* and *Krohnitta pacifica* are the only oceanic, cosmopolitan chaetognaths in our study area. The other four are limited to the Atlantic Ocean. *Sagitta serratodentata* is oceanic in tropical and temperate waters. The rest are neritic in the "tropico-equatorial Atlantic" and range from Delaware Bay to the coast of South America and occur off the west African coast.

All copepod species, except *Sapphirina ovatolanceolata*, identified at Hutchinson Island are considered members of Caribbean fauna (Wilson, 1942; Legaré, 1961b, 1964; Owre and Foyo, 1964, 1971, 1972; Björnberg, 1971; Michel and Foyo, 1976). This fauna is ostensibly supplied to the Caribbean by the North and South Equatorial Currents and may be transported to Florida's east coast by the Yucatan and Florida Currents (Björnberg, 1971; Park, 1975). Recent drift bottle studies confirm current transport through the Caribbean to the Florida east coast (Brucks, 1971; Duncan et al., 1977; Metcalf et al., 1977). Zooplankton components at Hutchinson Island could also have originated in the Gulf of Mexico (Owre, 1960). Williams et al. (1977) documented drift bottle transport from the eastern Gulf of Mexico to the east coast of Florida.

Almost all of the copepods and chaetognaths at Hutchinson Island are epiplanktonic. Several species concentrate within the upper 50 or 100 meters. *Heterorhabdus spinifrons*, *Rhincalanus cornutus*, *Macrosetella gracilis* and perhaps *Lubbockia squillimana* show affinities for depths below 500 m but may migrate diurnally or seasonally and be numerous in upper layers at certain times of the year.

## BIOLOGICAL INDICATORS

Many planktonic species can be used as indicators of water mass origin and interaction (Bary, 1959; Raymont, 1963; Austin, 1971). Austin (1971) has listed various "criteria" for selection of indicator species.

TABLE 1. TOTAL NUMBERS/m³ OF SELECTED ZOOPLANKTON GROUPS BY MONTH, STATION I.

| | Calanoids | Cyclopoids | Harpacticoids | Echinoid larvae | Ophiuroid larvae | Urochordates | Mollusk larvae | Decapod larvae | Chaetognaths | Polychaete larvae | Cnidarians | *Lucifer faxoni* | Other holo-plankton | Other mero-plankton |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 71 | 145 | 18 | 0 | 0 | 0 | 0 | 49 | 8 | 5 | 3 | 0 | 0 | 18 | 10 |
| Nov 71 | 198 | 4 | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 23 | 12 |
| Jan 72 | 2287 | 59 | 0 | 0 | 12 | 373 | 59 | 12 | 47 | 35 | 23 | 0 | 47 | 116 |
| Mar 72 | 1275 | 62 | 184 | 0 | 0 | 86 | 43 | 7 | 122 | 0 | 86 | 0 | 112 | 4 |
| May 72 | 2074 | 235 | 21 | 0 | 0 | 887 | 193 | 85 | 32 | 32 | 0 | 11 | 321 | 118 |
| Jul 72 | 169 | 25 | 0 | 0 | 21 | 119 | 29 | 0 | 4 | 4 | 0 | 0 | 4 | 4 |
| Sep 72 | 554 | 61 | 30 | 58 | 63 | 132 | 33 | 21 | 51 | 41 | 8 | 0 | 209 | 67 |
| Oct 72 | 185 | 90 | 42 | 0 | 540 | 87 | 33 | 22 | 131 | 23 | 2 | 0 | 88 | 385 |
| Nov 72 | 1004 | 316 | 20 | 16 | 4 | 179 | 41 | 13 | 7 | 22 | 11 | 0 | 71 | 81 |
| Dec 72 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Jan 73 | 2774 | 298 | 27 | 1315 | 2 | 95 | 27 | 2 | 34 | 80 | 17 | 5 | 81 | 31 |
| Feb 73 | 2535 | 510 | 15 | 2565 | 15 | 1575 | 150 | 15 | 15 | 180 | 0 | 0 | 255 | 75 |
| Mar 73 | 75 | 9 | 0 | 2 | 0 | 0 | 1 | 0 | 6 | 0 | 1 | 1 | 1 | 6 |
| Apr 73 | 1684 | 130 | 37 | 0 | 0 | 87 | 65 | 9 | 25 | 9 | 3 | 0 | 62 | 46 |
| May 73 | 3471 | 456 | 54 | 40 | 27 | 577 | 335 | 616 | 804 | 134 | 657 | 13 | 548 | 108 |
| 2 Jun 73 | 1974 | 8 | 0 | 46 | 8 | 405 | 8 | 107 | 92 | 8 | 23 | 0 | 23 | 39 |
| 20 Jun 73 | 4813 | 369 | 0 | 0 | 0 | 3942 | 38 | 155 | 369 | 0 | 58 | 0 | 116 | 271 |
| Jul 73 | 3030 | 337 | 106 | 27 | 0 | 717 | 1515 | 302 | 62 | 71 | 0 | 18 | 1055 | 1126 |
| Aug 73 | 1426 | 120 | 24 | 112 | 890 | 64 | 2902 | 504 | 288 | 0 | 216 | 281 | 128 | 224 |

TABLE 2. TOTAL NUMBERS/m³ OF SELECTED ZOOPLANKTON GROUPS BY MONTH, STATION II.

| | Calanoids | Cyclopoids | Harpacticoids | Echinoid larvae | Ophiuroid larvae | Urochordates | Mollusk larvae | Decapod larvae | Chaetognaths | Polychaete larvae | Cnidarians | *Lucifer faxoni* | Other holo-plankton | Other mero-plankton |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 71 | 90 | 101 | 0 | 0 | 0 | 202 | 22 | 11 | 22 | 0 | 0 | 0 | 753 | 44 |
| Nov 71 | 123 | 36 | 0 | 27 | 18 | 9 | 6 | 9 | 0 | 36 | 3 | 0 | 18 | 125 |
| Jan 72 | 3071 | 163 | 0 | 0 | 13 | 781 | 152 | 201 | 101 | 0 | 0 | 38 | 189 | 227 |
| Mar 72 | 917 | 192 | 5 | 0 | 0 | 132 | 93 | 0 | 77 | 0 | 0 | 0 | 10 | 32 |
| May 72 | 875 | 196 | 0 | 0 | 0 | 96 | 132 | 105 | 13 | 18 | 0 | 9 | 53 | 26 |
| Jul 72 | 850 | 81 | 0 | 0 | 260 | 282 | 33 | 29 | 157 | 29 | 0 | 0 | 173 | 74 |
| Sep 72 | 544 | 563 | 18 | 0 | 0 | 110 | 159 | 55 | 73 | 43 | 12 | 0 | 575 | 355 |
| Oct 72 | 98 | 84 | 20 | 0 | 439 | 6 | 16 | 3 | 31 | 17 | 5 | 0 | 104 | 210 |
| Nov 72 | 1594 | 387 | 48 | 18 | 0 | 83 | 32 | 131 | 33 | 15 | 6 | 0 | 312 | 185 |
| Dec 72 | 3257 | 159 | 30 | 0 | 0 | 12 | 24 | 6 | 12 | 0 | 6 | 0 | 41 | 6 |
| Jan 73 | 1482 | 386 | 6 | 0 | 0 | 828 | 16 | 20 | 102 | 12 | 6 | 0 | 101 | 16 |
| Feb 73 | 1588 | 588 | 109 | 1262 | 109 | 3025 | 109 | 87 | 22 | 196 | 65 | 0 | 632 | 523 |
| Mar 73 | 1062 | 59 | 16 | 5 | 0 | 5 | 3 | 41 | 8 | 0 | 3 | 0 | 141 | 16 |
| Apr 73 | 588 | 155 | 4 | 0 | 0 | 106 | 15 | 49 | 26 | 15 | 23 | 0 | 54 | 68 |
| May 73 | 4521 | 329 | 25 | 38 | 25 | 559 | 76 | 545 | 457 | 317 | 127 | 13 | 622 | 241 |
| 2 Jun 73 | 1630 | 123 | 0 | 22 | 0 | 1282 | 0 | 67 | 78 | 0 | 0 | 0 | 68 | 22 |
| 20 Jun 73 | 3659 | 632 | 57 | 19 | 38 | 2299 | 57 | 498 | 555 | 19 | 38 | 0 | 171 | 95 |
| Jul 73 | 2654 | 663 | 72 | 60 | 0 | 796 | 675 | 976 | 193 | 0 | 12 | 12 | 216 | 385 |
| Aug 73 | 367 | 148 | 0 | 4 | 13 | 0 | 547 | 125 | 98 | 0 | 8 | 27 | 62 | 21 |

TABLE 3. TOTAL NUMBERS/m³ OF SELECTED ZOOPLANKTON GROUPS BY MONTH, STATION III.

| | Calanoids | Cyclopoids | Harpacticoids | Echinoid larvae | Ophiuroid larvae | Urochordates | Mollusk larvae | Decapod larvae | Chaetognaths | Polychaete larvae | Cnidarians | *Lucifer faxoni* | Other holo-plankton | Other mero-plankton |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 71 | 951 | 98 | 15 | 0 | 498 | 226 | 279 | 98 | 38 | 8 | 0 | 0 | 536 | 100 |
| Nov 71 | 19 | 69 | 0 | 71 | 49 | 5 | 5 | 7 | 7 | 5 | 2 | 0 | 14 | 76 |
| Jan 72 | 5164 | 834 | 128 | 0 | 0 | 706 | 64 | 321 | 674 | 0 | 64 | 0 | 448 | 64 |
| Mar 72 | 1804 | 315 | 157 | 0 | 0 | 64 | 54 | 15 | 40 | 0 | 5 | 0 | 20 | 5 |
| May 72 | 10252 | 454 | 73 | 0 | 0 | 88 | 497 | 146 | 73 | 15 | 15 | 0 | 264 | 58 |
| Jul 72 | 2137 | 170 | 0 | 0 | 123 | 722 | 189 | 57 | 151 | 104 | 0 | 0 | 152 | 75 |
| Sep 72 | 565 | 260 | 14 | 23 | 442 | 32 | 141 | 64 | 55 | 32 | 9 | 0 | 287 | 123 |
| Oct 72 | 212 | 108 | 40 | 0 | 477 | 5 | 21 | 0 | 139 | 52 | 2 | 0 | 48 | 243 |
| Nov 72 | 701 | 224 | 0 | 61 | 88 | 210 | 13 | 31 | 31 | 4 | 9 | 0 | 57 | 30 |
| Dec 72 | 1065 | 58 | 59 | 0 | 15 | 59 | 52 | 0 | 0 | 0 | 7 | 0 | 103 | 0 |
| Jan 73 | 2778 | 273 | 0 | 0 | 23 | 558 | 114 | 45 | 68 | 68 | 23 | 0 | 375 | 91 |
| Feb 73 | 929 | 530 | 130 | 212 | 0 | 2081 | 24 | 36 | 82 | 0 | 24 | 0 | 447 | 188 |
| Mar 73 | 628 | 42 | 19 | 4 | 0 | 45 | 8 | 19 | 60 | 0 | 8 | 0 | 80 | 102 |
| Apr 73 | 144 | 74 | 3 | 0 | 0 | 51 | 7 | 18 | 9 | 0 | 3 | 2 | 57 | 19 |
| May 73 | 1716 | 384 | 0 | 11 | 6 | 189 | 11 | 217 | 115 | 69 | 40 | 0 | 211 | 18 |
| 2 Jun 73 | 1733 | 68 | 0 | 38 | 0 | 1273 | 0 | 162 | 48 | 0 | 0 | 0 | 68 | 10 |
| 20 Jun 73 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Jul 73 | 1534 | 692 | 69 | 79 | 831 | 1168 | 445 | 445 | 59 | 0 | 0 | 0 | 257 | 70 |
| Aug 73 | 176 | 88 | 0 | 5 | 129 | 5 | 47 | 155 | 508 | 16 | 16 | 26 | 10 | 109 |

TABLE 4. TOTAL NUMBERS/m³ OF SELECTED ZOOPLANKTON GROUPS BY MONTH, STATION IV.

| | Calanoids | Cyclopoids | Harpacticoids | Echinoid larvae | Ophiuroid larvae | Urochordates | Mollusk larvae | Decapod larvae | Chaetognaths | Polychaete larvae | Cnidarians | *Lucifer faxoni* | Other holo-plankton | Other mero-plankton |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 71 | 632 | 54 | 0 | 0 | 33 | 16 | 294 | 43 | 44 | 16 | 16 | 0 | 304 | 115 |
| Nov 71 | 77 | 18 | 23 | 16 | 103 | 0 | 4 | 16 | 8 | 2 | 0 | 0 | 8 | 115 |
| Jan 72 | 4530 | 1662 | 0 | 0 | 0 | 2971 | 302 | 252 | 201 | 50 | 50 | 0 | 705 | 251 |
| Mar 72 | 1663 | 153 | 96 | 0 | 0 | 134 | 545 | 10 | 191 | 0 | 29 | 0 | 30 | 48 |
| May 72 | 4540 | 317 | 39 | 0 | 0 | 0 | 316 | 108 | 40 | 10 | 0 | 0 | 406 | 30 |
| Jul 72 | 600 | 130 | 0 | 0 | 260 | 500 | 150 | 60 | 100 | 60 | 10 | 0 | 140 | 130 |
| Sep 72 | 493 | 270 | 10 | 33 | 1633 | 93 | 42 | 112 | 28 | 60 | 0 | 0 | 591 | 312 |
| Oct 72 | 161 | 90 | 27 | 4 | 498 | 4 | 19 | 13 | 163 | 33 | 0 | 0 | 126 | 360 |
| Nov 72 | 1887 | 354 | 105 | 88 | 0 | 573 | 28 | 28 | 34 | 22 | 22 | 0 | 72 | 11 |
| Dec 72 | 2251 | 124 | 76 | 0 | 7 | 0 | 28 | 7 | 0 | 0 | 0 | 0 | 28 | 7 |
| Jan 73 | 654 | 167 | 9 | 0 | 0 | 58 | 15 | 79 | 58 | 6 | 15 | 3 | 146 | 9 |
| Feb 73 | 1336 | 588 | 73 | 25 | 25 | 2660 | 73 | 37 | 12 | 12 | 12 | 0 | 393 | 172 |
| Mar 73 | 3318 | 66 | 108 | 4 | 0 | 11 | 108 | 97 | 339 | 11 | 0 | 0 | 696 | 36 |
| Apr 73 | 464 | 67 | 7 | 0 | 0 | 39 | 8 | 36 | 14 | 0 | 11 | 0 | 47 | 33 |
| May 73 | 1329 | 323 | 0 | 0 | 0 | 117 | 0 | 15 | 139 | 22 | 0 | 0 | 177 | 7 |
| 2 Jun 73 | 1666 | 123 | 18 | 298 | 0 | 2332 | 176 | 88 | 88 | 18 | 18 | 0 | 106 | 71 |
| 20 Jun 73 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Jul 73 | 1593 | 710 | 133 | 47 | 171 | 1033 | 663 | 587 | 85 | 0 | 9 | 19 | 549 | 179 |
| Aug 73 | 618 | 181 | 0 | 0 | 17 | 11 | 461 | 124 | 45 | 0 | 6 | 11 | 68 | 45 |

TABLE 5. TOTAL NUMBERS/m³ OF SELECTED ZOOPLANKTON GROUPS BY MONTH, STATION V.

| | Calanoids | Cyclopoids | Harpacticoids | Echinoid larvae | Ophiuroid larvae | Urochordates | Mollusk larvae | Decapod larvae | Chaetognaths | Polychaete larvae | Cnidarians | *Lucifer faxoni* | Other holo-plankton | Other mero-plankton |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep 71 | 0 | 55 | 0 | 0 | 83 | 28 | 110 | 28 | 0 | 0 | 0 | 0 | 8695 | 443 |
| Nov 71 | 136 | 9 | 12 | 0 | 38 | 0 | 7 | 0 | 5 | 0 | 0 | 0 | 38 | 39 |
| Jan 72 | 7938 | 631 | 0 | 0 | 0 | 1714 | 541 | 1760 | 135 | 0 | 90 | 90 | 180 | 857 |
| Mar 72 | 844 | 156 | 80 | 0 | 0 | 90 | 52 | 5 | 24 | 0 | 0 | 0 | 0 | 38 |
| May 72 | 2462 | 202 | 19 | 0 | 0 | 176 | 215 | 44 | 19 | 6 | 0 | 19 | 245 | 94 |
| Jul 72 | 376 | 54 | 33 | 0 | 43 | 516 | 22 | 32 | 54 | 43 | 0 | 0 | 53 | 54 |
| Sep 72 | 574 | 203 | 14 | 42 | 217 | 217 | 21 | 35 | 77 | 28 | 7 | 0 | 658 | 336 |
| Oct. 72 | 205 | 91 | 0 | 61 | 600 | 54 | 23 | 46 | 129 | 0 | 0 | 0 | 159 | 622 |
| Nov 72 | 4185 | 673 | 40 | 238 | 0 | 1387 | 158 | 66 | 80 | 13 | 13 | 0 | 65 | 66 |
| Dec 72 | 1367 | 145 | 4 | 0 | 0 | 4 | 25 | 0 | 0 | 0 | 0 | 0 | 71 | 4 |
| Jan 73 | 3117 | 192 | 5 | 0 | 0 | 74 | 109 | 20 | 39 | 10 | 59 | 0 | 187 | 49 |
| Feb 73 | 2190 | 399 | 58 | 94 | 0 | 1673 | 117 | 12 | 35 | 176 | 59 | 0 | 164 | 129 |
| Mar 73 | 1308 | 46 | 31 | 4 | 0 | 19 | 35 | 43 | 108 | 23 | 0 | 0 | 201 | 31 |
| Apr 73 | 3155 | 230 | 22 | 0 | 0 | 579 | 67 | 52 | 37 | 0 | 7 | 0 | 67 | 30 |
| May 73 | 2524 | 841 | 13 | 12086 | 50 | 804 | 13 | 0 | 477 | 88 | 188 | 0 | 201 | 64 |
| 2 Jun 73 | 4330 | 99 | 12 | 50 | 0 | 1430 | 25 | 112 | 100 | 12 | 25 | 0 | 86 | 149 |
| 20 Jun 73 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Jul 73 | 3680 | 901 | 133 | 0 | 236 | 2069 | 4035 | 429 | 89 | 30 | 15 | 15 | 1420 | 177 |
| Aug 73 | 378 | 667 | 5 | 539 | 2163 | 54 | 397 | 393 | 157 | 20 | 78 | 74 | 109 | 125 |

Although there are many involved, the most important are ease of identification, taxonomic stability and well-known distribution for a certain water mass.

In nearshore Hutchinson Island waters there is a periodic intrusion of oceanic (Gulf Stream) water masses as well as outflow of estuarine waters from the Indian River (Walker and Steidinger, 1979; Walker, 1979). Some of the zooplankton species, especially copepods and chaetognaths, recorded at Hutchinson Island may be biological indicators of these water movements. The older literature on chaetognaths is well known (e.g., Raymont, 1963) and the work of E. L. Pierce in the western North Atlantic is referenced in this paper under the discussion of chaetognath species.

Copepods have been used as indicators of neritic-oceanic water mass interactions off the U.S. eastern coast by Bigelow (1924), Colton et al. (1962) and Sherman and Schaner (1968). Based on the literature, the following calanoid copepod species identified off Hutchinson Island are strongly associated with oceanic water, and their presence could be used to substantiate oceanic intrusion: *Candacia pachydactyla*, *Centropages violaceus*, *Eucalanus attenatus*, *Euchaeta marina*, *Haloptilus longicornis*, *Labidocera acutifrons*, *Lucicutia flavicornis*, *Pontellina plumata* and *Scolecithrix danae*. *Temora stylifera* appears widespread in distribution, but its affinity for oceanic water places it on this list, especially when large changes in abundance occur in comparison to its neritic relative, *Temora turbinata*. Other calanoids which might prove to be useful indicators, but require further information, are *Calocalanus pavo*, *Heterorhabdus spinifrons*, *Paracalanus aculeatus*, *Pleuromamma gracilis*, *Rhincalanus cornutus*, *Undinula vulgaris*, and, based on more limited data, *Eucalanus crassus* and *Candacia curta*. Moore and Sander (1976) noted that several of these species which are considered oceanic were recorded off Barbados and Jamaica in waters characterized as neritic.

The following cyclopoid and harpacticoid species may be useful as oceanic indicators at Hutchinson Island: *Copilia mirabilis*, *Farranula carinata*, *F. gracilis*, *Lubbockia squillimana*, *Macrosetella gracilis*, *Miracia minor*, *Oculosetella gracilis*, *Oithona setigera*, *Oncaea venusta*, *Saphirella tropica* and the three *Sapphirina* species. Among the chaetognaths, *Sagitta serratodentata* and *Krohnitta pacifica* are useful indicators of oceanic intrusion.

The calanoid copepod *Pseudodiaptomus coronatus* could be a reliable indicator of estuarine flow from the Indian River. *Labidocera aestiva* and *Paracalanus crassirostris* may also be useful estuarine indicators, especially if counts provide a basis for comparing changes in abundance. An increase in abundance, i.e. presence of higher numbers than usual, is undoubtedly a more useful parameter than simple presence or absence (Fasham and Angel, 1975).

At Hutchinson Island, abundance and diversity of the above indicators suggest definite oceanic intrusion in winter and estuarine and some oceanic influence in summer. Counts for most oceanic species were highest in winter. March-April 1973 showed strong oceanic influence. Twenty-two oceanic species, including three which occurred only during this period, were recorded in these two months. Nevertheless, counts were low for all these species.

## CONCLUSIONS

Species composition, abundance and seasonality characterize the zooplankton community off Hutchinson Island as tropical-subtropical with Caribbean affinities. Certain copepod and chaetognath indicator species demonstrate oceanic (Gulf Stream) and estuarine (Indian River) influence.

Abundance estimates for total zooplankton were moderate ($\bar{x}$ = 3,843/m$^3$) compared to other Florida bays, temperate bays, Bermuda, the Gulf Stream and the Sargasso Sea. The net northerly flow along the coast in this area may contribute to this moderate abundance. This transport may also contribute to the lack of correlation between many benthic populations and their larval planktonic forms. Nevertheless, the community represents a diverse assemblage of holo- and meroplanktonic species.

Although meroplankton dominated total zooplankton on several occasions, holoplankton, particularly calanoid copepods, were the usual predominant members of the zooplankton. Copepods, urochordates, echinoid larvae, mollusk larvae, ophiuroid larvae, chaetognaths and *Lucifer faxoni* are especially recognizable and should provide a means for monitoring the area for changes in species composition and abundance after power plant start-up.

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# IX. Diel Plankton, 1973-1974

## ABSTRACT

Walker, L. M. 1979. Nearshore Marine Ecology at Hutchinson Island, Florida: 1971-1974. IX. Diel Plankton, 1974. Fla. Mar. Res. Publ. No. 34. Pp. 99-117. One year of monthly diel samples from nearshore waters off Hutchinson Island, Florida were analyzed for physicochemical and plankton parameters. Physicochemical data varied little from the previous two years' patterns although several specific data points were higher and attributed to increased rainfall and runoff. Diel variations showed little significance. The dominant net phytoplankters were *Bellerochea horologicalis* and *Skeletonema costatum*, while the dominant zooplankters were calanoid copepods, *Paracalanus* and *Acartia*. Meroplankton formed about 29.5% of the total zooplankton and was dominated by ophioplutei. Seasonal trends in plankton abundance were similar to the previous two years' with the exception of an October zooplankton peak dominated by ophioplutei. Winter appeared to be a period of strong oceanic influence based on the occurrence of oceanic plankters. Diel phytoplankton counts were not significantly different; however, zooplankton counts were significantly different at one station. At the taxonomic level, day-night abundance differed significantly for *Calanopia americana*, *Sagitta helenae* and cumaceans. Other zooplankters showed nocturnal or diurnal trends as well. These data are presented as part of a "base-line" study in nearshore waters off Hutchinson Island, Florida prior to the operation of Florida Power and Light Company's St. Lucie Unit #1.

## INTRODUCTION

The diel study (1973-1974) extended an integral baseline survey (1971-1973) designed to characterize the nearshore environment off Hutchinson Island prior to nuclear power plant operation. The first two years' hydrographic, faunistic and floristic data indicated that the Hutchinson Island area is dynamic and moderately productive with estuarine and oceanic influences. The third year of sampling was conducted to assess diel variation in this environment and to determine whether diel differences, particularly in zooplankton composition and abundance, could affect impact evaluations.

## METHODS AND MATERIALS

Monthly diel samples were collected from September 1973 to August 1974, at three permanent stations (Figure 1) along a transect from the discharge port site. September samples were separated by less than 5 hours. Otherwise, day-night samples were taken about 12 hours apart on similar tidal cycles to reduce tidal influence (Worth and Hollinger, 1977). A plankton net (0.5 m opening, 202 $\mu$m mesh, 5:1 length), equipped with a flowmeter, was hauled obliquely in a wide circular pattern over each station for 5 minutes at the bottom and 5 minutes at the surface. Surface and bottom water samples were collected for basic inorganic nutrients ($NH_3$-N, $NO_3$-N, $NO_2$-N, $PO_4$-P, $SiO_2$-Si), total organic carbon, particulate load (inorganic and organic fractions) and pigments. Measurements were made of dissolved oxygen, temperature and salinity. Station descriptions and all field and laboratory procedures are detailed in Gallagher and Hollinger (1977) and Walker and Steidinger (1979).

Methods used for plankton collection and analyses incorporate those recommended by UNESCO (1968), Edmondson and Winberg (1971), Schlieper (1972) and Slack et al. (1973). Plankton samples were preserved in buffered 5% seawater formalin and organisms were identified and counted in aliquots ranging from 0.01 ml to 15 ml depending on specimen density and the group being counted. Zooplankton counting procedures using gridded petri dishes usually involved two random rows of five squares each, while whole aliquots were observed for phytoplankton. In each case at least 100 specimens of the dominant taxon(a) were counted (see Walker et al., 1979 and Tester and Steidinger, 1979 for details).

Water samples for inorganic nutrients were transported to the Marine Research Laboratory, Florida Department of Natural Resources in St. Petersburg for analyses. Ammonia-nitrogen was determined according to Solórzano (1969) and $NO_3$-N according to Kahn and Brezenski (1967). The methods outlined in Strickland and Parsons (1968) were used for $NO_2$-N, $PO_4$-P and $SiO_2$-Si. Beginning in December 1973 total organic carbon was estimated from total Kjeldahl nitrogen. Total particulate loads were determined according to Strickland and Parsons (1968). Total inorganic and organic fractions were determined by ashing. Chlorophyll *a* and phaeopigments were determined spectrophotometrically as outlined by Lorenzen (1967). Carotenoids at 480 nm were also determined (Strickland and Parsons, 1968).

Dissolved oxygen was determined with a Yellow Springs Instruments (Model 51A) oxygen meter. Temperature was determined with a thermistor on the oxygen meter. Salinity was obtained by titration according to Strickland and Parsons (1968).

The data were analyzed statistically, using a Hewlett-Packard 9821A. Shannon's diversity indices (Shannon and Weaver, 1963) and Morisita indices of sample affinity (Morisita, 1959) were determined for net phytoplankton species. These indices were not applied to zooplankton data due to varying taxonomic rank identifications. One-way and two-way analyses of variance with transformed data were used to determine any significant station or diel differences with the significance level at $P_{.05}$. Correlation coefficients were determined by station for day and night samples using the Spearman's rank correlation analysis (Steele and Torrie, 1960) with $P_{.05}$. September samples were not included in analyses of variance or Spearman's rank correlation analyses since the "day" samples were collected near or after sunset.

## RESULTS AND DISCUSSION

### PHYSICOCHEMICAL PARAMETERS

Seasonal patterns for temperature, salinity, dissolved oxygen, particulate load and nutrients differed little from the previous two years (see Worth and Hollinger, 1977, who presented data for all three years). Highest temperatures occurred in summer and fall, lowest in winter. Dissolved oxygen patterns were generally the inverse of temperature patterns. Salinities peaked in spring and summer although there was a noticeable increase in December.

Silicates and ortho-phosphate levels were highest following heavy rainfall and peaked in fall and spring. Nitrate-nitrogen and $NO_2$-N values were highest in fall. All three nitrogen species peaked in March-April, but $NO_3$-N and $NO_2$-N levels were generally inverse to $NH_3$-N levels. Particulate loads were generally highest in winter months. The peaks for organic carbon in December and June lagged one to two months behind the major plankton peaks.

Highest chlorophyll *a* values were recorded in November following the October net phytoplankton

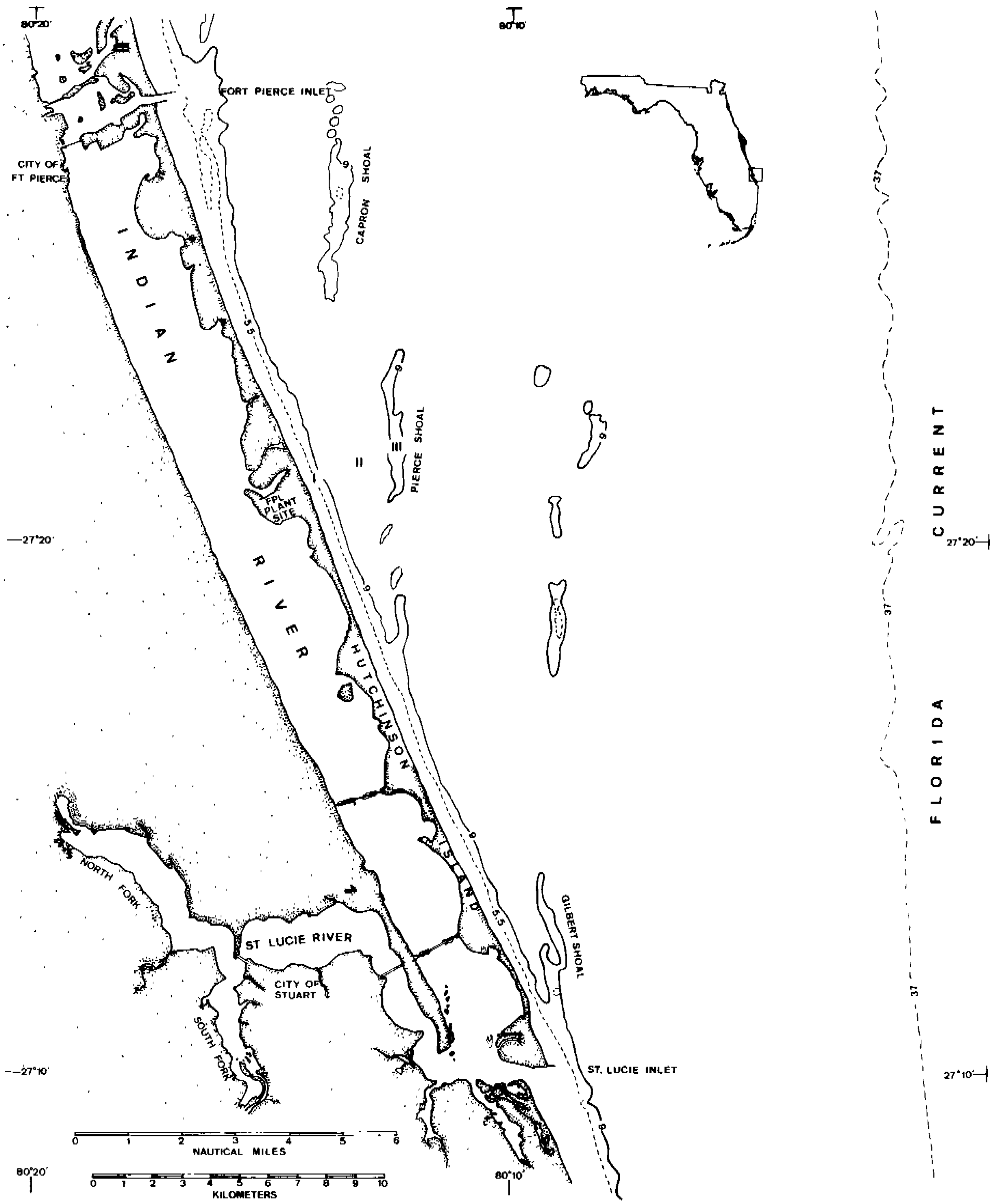


Figure 1. Study area, showing station locations.

peak. Minor chlorophyll *a* peaks also occurred in February, April and July. Carotenoid values reflected chlorophyll *a* trends. Neither pigment increased following the spring net phytoplankton peak. Highest phaeopigment values occurred in October-November. Lesser peaks occurred in April and August.

Physicochemical parameters showed little significant diel variation (Worth and Hollinger, 1977). Results of the Spearman's rank correlation analyses did not indicate any consistent trends (Table 1), although some interesting correlations were noted. Zooplankton paralleled phytoplankton abundance; a positive correlation was observed at Station II-night. Zooplankton showed a negative correlation with bottom $NH_3$-N values at Stations I and III. Martin (1968) suggested that zooplankton excretion of $PO_4$-P and $NH_3$-N depends on phytoplankton availability. In Martin's study, $PO_4$-P and $NH_3$-N levels would remain low during periods of phytoplankton abundance. As phytoplankton concentrations decreased zooplankton would shift to lipid and protein energy metabolism and levels of $PO_4$-P and $NH_3$-N excretion would increase. The negative correlation between zooplankton and $NH_3$-N in our data may indicate such a metabolic shift. The lack of statistical correlation between zooplankton and $PO_4$-P may reflect the greater influence of freshwater input and higher $PO_4$-P values. A negative correlation was observed in the previous two years (Walker and Steidinger, 1979).

Zooplankton and chlorophyll *a* showed no correlations; however, zooplankton and phaeopigments had a positive correlation at Station II. Glooschenko et al. (1972) directly correlated phaeopigment levels with zooplankton grazing. In our first two years' sampling, however, no phaeopigment/zooplankton correlation was noted.

TABLE 1. SPEARMAN'S RANK CORRELATION ANALYSIS: $r_s$ SIGNIFICANT AT $P_{.05}$

| Variables $Y_1$ | $Y_2$ | Stations | N | $r_s$ Value |
|---|---|---|---|---|
| Phytoplankton | Chlorophyll *a* | I S-Night | 12 | .7010 |
| Zooplankton | Chlorophyll *a* | —no correlation— | | |
| Zooplankton | $PO_4$-P | —no correlation— | | |
| Zooplankton | $SiO_2$-Si | II B-Day | 10 | .7212 |
| Zooplankton | Phaeopigments | II S-Day | 11 | .8182 |
| | | II S-Night | 12 | .8112 |
| Zooplankton | Phytoplankton | II-Night | 12 | .7622 |
| Zooplankton | $NH_3$-N | I B-Night | 12 | -.6993 |
| | | III B-Day | 11 | -.6636 |
| Temperature | Zooplankton | I S-Night | 12 | .6091 |
| | | I B-Night | 12 | .7325 |
| Temperature | Chlorophyll *a* | I S-Day | 11 | -.6273 |
| Temperature | $PO_4$-P | I S-Day | 11 | .6205 |
| | | II B-Day | 10 | .8545 |
| | | III S-Day | 11 | .8091 |
| Temperature | Phytoplankton | III B-Day | 11 | .6364 |
| Temperature | Salinity | —no correlation— | | |
| Temperature | $SiO_2$-Si | —no correlation— | | |
| Salinity | $PO_4$-P | —no correlation— | | |
| Salinity | $SiO_2$-Si | II B-Night | 12 | .6713 |

S—Surface

B—Bottom

## NET PHYTOPLANKTON

Net phytoplankton (>202 $\mu$m) identified during the diel sampling program is listed in Table 2. Phytoplankters denoted by an asterisk were not observed during the first two years of sampling. A total of 63 genera including 157 species, varieties and forms were identified. Centric diatoms (32 genera including 75 species) were the dominant net phytoplankton group and comprised 50.17% of the total net phytoplankton. Pennate diatoms (21 genera, 23 species) contributed 42.23% of the total. Dinoflagellates, although diverse (9 genera with 58 species), were numerically insignificant and comprised only 0.32% of the total net phytoplankton.

Phytoplankters which numbered more than 1% of the total count for their respective category (centric diatom, pennate diatom or dinoflagellate) were ranked in order of numerical dominance (Table 3). The dominant centric diatoms were *Bellerochea horologicalis*, *Skeletonema costatum*, *S. tropicum*, *Bacteriastrum delicatulum*, *Rhizosolenia imbricata*, *Chaetoceros coarctatus*, *C. decipiens*, *Palmeriana hardmanianus* (= *Hemidiscus hardmanianus*), *Chaetoceros gracilis*, *C. lorenzianus* and *C. diversus*. *Bellerochea horologicalis* was the dominant net phytoplankter (27.21%) as well as the dominant centric diatom (54.22%).

The dominant pennate diatoms were chiefly species of *Nitzschia*. In order of dominance, they were *Nitzschia longissima*, *Thalassionema nitzschioides*, *Thalassiothrix mediterranea* var. *pacifica*, *Nitzschia closterium*, *N.* spp., *Bacillaria paxillifer*, *Asterionella glacialis* and *Nitzschia pungens* var. *atlantica*.

The dominant dinoflagellates belonged to two genera, *Ceratium* and *Pyrocystis*. The order of numerical dominance was *Ceratium trichoceros*, *Pyrocystis fusiformis* f. *biconica*, *Ceratium massiliense*, *Pyrocystis fusiformis* f. *fusiformis*, *P. noctiluca*, *Ceratium furca*, *C. hexacanthum*, *C. fusus* and *C. tripos* var. *atlanticum*.

With few exceptions, the dominant net phytoplankters during this study were also dominant in the first two years of sampling (Tester and Steidinger, 1979). In all three years, *Bellerochea horologicalis* was the most abundant of total phytoplankton and diatoms. *Skeletonema costatum* was second in abundance. *Thalassionema* and *Nitzschia* species were the most numerous pennate diatoms and *Ceratium* and *Pyrocystis* were the dominant dinoflagellate genera in all three years. Dinoflagellates, however, never numerically dominated the total phytoplankton during this year or during the previous two year study (Tester and Steidinger, 1979).

TABLE 2. HUTCHINSON ISLAND PHYTOPLANKTON SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES.

| Species | Month | Day-Night | Station | Count Range (cells/m³) | Count Mean (cells/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| CENTRALES | | | | | | | |
| **Actinocyclus* sp. | Oct.; July | D | II, III | 1 | 1.0 | 25.0-28.3 | 34.63-35.61 |
| **A. tenellus* | Oct. | D-N | III | 1 | 1.0 | 28.0-28.3 | 35.15-35.52 |
| *Actinoptychus senarius* | Oct.-Nov.; May | N | I, III | 1-3 | 1.5 | 24.5-28.4 | 33.86-35.95 |
| *A. vulgaris*? | Oct. | D | III | 1 | 1.0 | 28.2-28.3 | 35.15-35.22 |
| *Bacteriastrum delicatulum* | Oct. | D-N | I-III | 1,052-23,810 | 15,800.0 | 28.0-28.4 | 33.95-35.52 |
| *B. hyalinum* var. *hyalinum* | Oct. | N | I | 10,283 | 10,283.0 | 28.2-28.4 | 34.06-34.24 |
| **B. hyalinum* var. *princeps* | Oct. | N | III | 1,976 | 1,976.0 | 28.0-28.3 | 35.22-35.52 |
| *Bellerochea horologicalis* | Sept.-Aug. | D-N | I-III | 15-295,021 | 29,550.0 | 18.7-28.4 | 33.68-39.33 |
| **Biddulphia* sp. | Nov. | D | III | 2 | 2.0 | 24.6 | 33.86 |
| **Biddulphia*? sp. | Feb.-Mar. | D-N | I, II | 1-22 | 11.5 | 19.5-22.0 | 36.05-36.22 |
| *B. alternans* | Oct.-Dec. | D-N | I-III | 4-7,453 | 1,046.0 | 18.7-28.3 | 33.68-36.43 |
| **B. antediluviana* | Apr. | N | I | 2 | 2.0 | 25.4-25.5 | 35.99-36.06 |
| **B. balaena* var. *arctica* | Sept. | D-N | I-II | 1-2 | 1.5 | 27.2-27.8 | 34.71-35.89 |
| *B. longicruris* | Nov.-Dec. | D-N | I-III | 1-100 | 27.0 | 21.5-24.7 | 33.68-36.32 |
| *B. pulchella* | Dec.; March | D | I | 3-6 | 4.5 | 18.9-22.0 | 35.94-36.22 |
| *B. tuomeyi* | Oct.-Dec. | D-N | I-III | 2-8 | 5.3 | 18.7-28.4 | 33.68-36.05 |
| *Cerataulina pelagica* | Oct.; Dec.; Mar. | D | I-III | 1-63 | 28.4 | 21.5-28.4 | 33.95-36.32 |
| **Cerataulus smithii* | Dec. | N | III | 1 | 1.0 | 19.0-19.5 | 35.94-36.05 |
| *Chaetoceros* spp. | Oct.-Nov.; Jan.-May; July-Aug. | D-N | I-III | 2-8,671 | 754.6 | 18.7-28.4 | 33.79-39.33 |
| **C.* sp. cf. *radiatus* | Oct. | D | III | 1 | 1.0 | 28.2-28.3 | 35.15-35.22 |
| *C. coarctatus* | Sept.-Jan.; Mar.-May; Aug. | D-N | I-III | 1-27,579 | 1,399.2 | 18.9-28.5 | 33.86-39.33 |
| *C. compressus* | Nov.-Dec. | D | I, II | 4-28 | 16.0 | 20.7-24.5 | 33.79-36.43 |
| *C. curvisetus* | Nov.-Dec. | D-N | I-III | 4-83 | 26.8 | 18.7-24.5 | 33.68-35.56 |
| *C. decipiens* | Oct.-Dec.; Mar. | D-N | I-III | 62-11,158 | 2,845.3 | 18.7-28.4 | 33.68-36.43 |
| *C. didymus* | Nov. | D | III | 578 | 578.0 | 24.6 | 33.86 |
| *C. diversus* | Oct.; Dec. | D-N | I-III | 27-16,452 | 6,298.8 | 19.0-28.4 | 34.06-36.05 |
| *C. eibenii* | Dec. | D | III | 383 | 383.0 | 21.5-21.7 | 36.32 |
| *C. gracilis* | Oct.-Nov. | D-N | I-III | 1,050-15,810 | 5,615.8 | 24.3-28.4 | 33.68-35.52 |
| *C. laciniosus* | Oct. | D | I, III | 1,474-1,984 | 1,729.0 | 28.2-28.4 | 33.95-35.22 |
| *C. lauderi* | Oct. | N | III | 356 | 356.0 | 28.0-28.3 | 35.22-35.52 |
| *C. lorenzianus* | Oct.-Jan.; Mar.; May-Aug. | D-N | I-III | 7-3,734 | 1,861.3 | 18.9-28.4 | 33.86-39.33 |
| *C. peruvianus* | Oct.; Dec. | D-N | I-III | 1-1,984 | 572.7 | 18.9-28.4 | 33.95-36.05 |
| *C. socialis* | June | N | I | 1,242 | 1,242.0 | 25.6-25.7 | 35.68-36.38 |
| *C. subtilis* | Oct. | N | I | 10,283 | 10,283.0 | 28.2-28.4 | 34.06-34.24 |
| **C. wighamii* | Sept. | N | I | 10,274 | 10,274.0 | 27.5-27.8 | 34.71-35.26 |
| *Climacodium frauenfeldianum* | Oct.-Nov.; Jan.; June | D-N | I-III | 2-23 | 7.1 | 22.7-28.4 | 33.86-35.61 |
| *Corethron criophilum* | Oct.; March | D-N | I, III | 1,046-7,712 | 3,580.7 | 21.5-28.4 | 33.95-36.89 |
| *Coscinodiscus* sp. | June | N | II | 1 | 1.0 | 25.7-26.7 | 35.32-35.61 |
| *C. centralis* | Oct.-Nov. | D-N | I-III | 1-159 | 45.9 | 24.3-28.4 | 33.68-35.52 |
| *C. concinnus* | Sept.-Nov.; Jan. | D-N | I-III | 1-889 | 142.7 | 22.6-28.4 | 33.68-35.61 |
| **C. lineatus* | Oct. | N | I | 2 | 2.0 | 28.2-28.4 | 34.06-34.24 |
| *C. radiatus* | Oct.-Dec.; Aug. | D-N | I-III | 1-60 | 16.7 | 18.7-28.4 | 33.79-39.33 |
| *C. wailesii* | Sept.-May; July | D-N | I-III | 1-5,602 | 334.9 | 18.7-28.4 | 33.68-36.89 |
| *Cyclotella* spp. | Nov.-Jan. | D-N | I-III | 5-27 | 16.1 | 18.7-24.7 | 33.68-36.05 |
| *Cyclotella* sp. "A" | Oct. | D-N | I-III | 16-2,905 | 760.8 | 28.0-28.4 | 33.95-35.52 |
| **Detonula* sp. "A" | Jan. | D-N | I-III | 3-39 | 17.5 | 22.6-23.1 | 34.52-35.61 |
| *Ditylum brightwelli* | Oct. | D-N | I-III | 52-913 | 331.0 | 28.0-28.4 | 33.95-35.52 |
| **Eucampia zoodiacus* | Jan.; Mar. | D-N | I-III | 1-194 | 68.7 | 22.0-23.1 | 34.52-36.40 |
| *Eupodiscus radiatus* | Nov.-Jan.; Mar. | D-N | I-III | 1 | 1.0 | 18.7-24.5 | 33.68-36.89 |
| *Guinardia flaccida* | Sept.-Oct.; Dec.-Jan.; Mar.-June; Aug. | D-N | I-III | 1-406 | 52.0 | 19.0-28.4 | 33.95-39.33 |
| **Hemiaulus* sp. | Dec. | N | II | 2 | 2.0 | 19.2-19.7 | 35.86-35.94 |

TABLE 2. HUTCHINSON ISLAND PHYTOPLANKTON SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Species | Month | Day-Night | Station | Count Range (cells/m³) | Count Mean (cells/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| *H. hauckii* | Oct.; Dec.-Jan.; Apr. | D-N | I-III | 1-395 | 76.7 | 19.0-28.3 | 34.55-36.22 |
| *H. heibergii* | Oct.; March | D-N | I-III | 2-2,075 | 541.5 | 22.0-28.4 | 34.06-36.40 |
| *H. membranaceus* | Dec.-Jan.; March; June | D | I, II | 2-6 | 3.25 | 18.9-26.8 | 34.52-36.40 |
| *H. sinensis* | Oct.; March | D-N | I, III | 4-7,905 | 3,368.0 | 21.8-28.4 | 33.95-36.22 |
| *Isthmia enervis* | Sept.; Nov.; Feb.-May | D-N | I-III | 3-179 | 53.6 | 19.5-28.1 | 33.79-36.40 |
| **Lauderia* sp. | Apr. | N | I | 2 | 2.0 | 25.4-25.5 | 35.99-36.06 |
| *Leptocylindrus danicus* | Oct.-Jan.; May | D-N | I-III | 1-6,719 | 2,207.6 | 19.2-28.4 | 33.68-36.26 |
| *Lithodesmium undulatum* | Oct.-Nov. | D-N | I-III | 1-1,398 | 537.0 | 24.5-28.4 | 33.86-35.52 |
| *Odontella chinensis* | Nov.-Apr. | D-N | I-III | 1-700 | 46.8 | 18.7-25.5 | 33.68-36.89 |
| *O. mobiliensis* | Oct.-Dec.; Apr.; June-July | D-N | I-III | 1-5 | 2.5 | 18.7-28.3 | 33.68-36.11 |
| *O. obtusa* | Sept.-Oct. | D-N | II, III | 2-6 | 4.0 | 27.2-28.4 | 34.86-35.89 |
| *O. regia* | Apr.-May | D | I-III | 1 | 1.0 | 23.7-24.8 | 35.88-36.20 |
| *O. rhombus* | Oct.-Dec. | D-N | I-III | 1-12 | 4.14 | 20.7-28.4 | 33.68-36.43 |
| *Palmeriana hardmanianus* (= *Hemidiscus hardmanianus*) | Sept.-Nov.; Jan.; March; Aug. | D-N | I-III | 1-16,639 | 1,306.8 | 21.5-28.5 | 33.68-39.33 |
| *Paralia sulcata* (= *Melosira sulcata*) | Sept.-Dec.; Feb.-March; June | D-N | I-III | 2-593 | 61.4 | 19.5-28.4 | 33.86-36.43 |
| **Podosira* sp. | Oct. | N | III | 12 | 12.0 | 28.0-28.3 | 35.22-35.52 |
| **Rhizosolenia acuminata* | Jan. | D | I | 3 | 3.0 | 23.0-23.1 | 34.52-35.07 |
| *R. alata* | Sept.-Oct.; Dec.-Jan.; Mar.-Apr.; June-Aug. | D-N | I-III | 1-1,219 | 67.1 | 18.9-28.5 | 33.95-39.33 |
| *R. calcar avis* | Sept.-Jan.; Mar.; Aug. | D-N | I-III | 1-232 | 30.0 | 18.7-28.4 | 33.86-39.33 |
| *R. castracanei* | Sept.-Oct.; Dec.-May; Aug. | D-N | I-III | 1-15 | 3.6 | 18.9-28.5 | 34.52-39.33 |
| *R. delicatula* | March | D | I | 1 | 1.0 | 21.8-22.0 | 36.10-36.22 |
| *R. imbricata* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 1-37,188 | 1,107.7 | 18.7-28.4 | 33.95-39.33 |
| *R. robusta* | Oct.; Dec.-Jan.; Mar.-Apr.; Aug. | D-N | I-III | 1-1,945 | 134.1 | 20.7-28.5 | 33.95-39.33 |
| *R. setigera* | Oct.-Dec.; Mar.; May-July | D-N | I-III | 1-4 | 1.5 | 19.0-28.4 | 33.86-36.89 |
| *R. stolterfothii* | Oct.-Apr.; June; Aug. | D-N | I-III | 1-5,000 | 268.6 | 19.0-28.4 | 33.86-39.33 |
| *R. styliformis* | Sept.-Jan.; Mar.-Apr.; June; Aug. | D-N | I-III | 1-147 | 14.6 | 18.7-28.4 | 33.86-39.33 |
| **Skeletonema* sp. | Apr. | N | I | 6,782 | 6,782.0 | 25.4-25.5 | 35.99-36.06 |
| *S. costatum* | Sept.-Dec.; Mar.; June; Aug. | D-N | I-III | 1,471-408,740 | 29,838.6 | 18.7-28.4 | 33.68-39.33 |
| *S. tropicum* | Oct.-Dec. | D-N | I-III | 50-43,702 | 8,429.6 | 18.7-28.4 | 33.68-36.05 |
| *Stephanopyxis palmeriana* | Dec.-Mar.; May; Aug. | D-N | I-III | 1-258 | 88.2 | 18.7-28.4 | 34.55-39.33 |
| *S. turris* | Nov.-Dec. | D-N | II, III | 2-48 | 15.5 | 19.2-24.6 | 33.68-35.94 |
| *Streptotheca tamesis* | Oct.-Nov.; July-Aug. | D-N | I-III | 1-131 | 22.2 | 24.3-28.4 | 33.68-39.33 |
| *Thalassiosira eccentrica* | Oct. | D-N | III | 1 | 1.0 | 28.2-28.3 | 35.15-35.22 |
| *T. subtilis* | Oct.-Feb. | D-N | I-III | 12-7,688 | 716.0 | 19.0-28.4 | 33.68-36.05 |
| *Triceratium favus* | Oct.-Dec. | D-N | I-III | 1-2 | 1.1 | 21.5-28.4 | 33.79-36.32 |
| Unidentified centric diatom | Nov.; Feb.-Apr. | D-N | I, III | 1-57 | 13.4 | 18.7-25.5 | 33.86-36.22 |
| PENNALES | | | | | | | |
| *Amphora* spp. | Oct.; Apr. | D | I, III | 1 | 1.0 | 23.8-28.3 | 35.15-36.08 |
| *Asterionella glacialis* (= *A. japonica*) | Oct.-Dec.; Mar.-Apr.; June-July | D-N | I-III | 2-10,283 | 3,310.6 | 19.0-28.4 | 33.86-36.89 |
| *A. notata* | Sept. | D | I-III | 125-3,175 | 1,890.0 | 27.1-28.1 | 34.52-35.89 |
| *Bacillaria paxillifer* (= *Nitzschia paradoxa*) | Sept.-Dec.; Apr. | D-N | I-III | 7-12,853 | 2,805.1 | 18.7-28.4 | 33.68-36.43 |
| **Campylodiscus samoensis* | July | N | III | 1 | 1.0 | 25.6 | 35.68-36.04 |
| *Climasophenia elongata* | Sept.-Oct.; Apr. | D-N | I, III | 1-5 | 2.3 | 25.4-28.3 | 34.52-36.06 |
| **Cocconeis* sp. | March | N | II | 1 | 1.0 | 20.7-21.4 | 36.60-36.89 |
| *Cymatosira belgica* | Nov. | D | III | 6 | 6.0 | 24.6 | 33.86 |
| *Diploneis crabro* | Oct. | N | II | 2 | 2.0 | 28.4 | 34.86-35.15 |
| *D. crabro* var.? | Dec. | D | II | 1 | 1.0 | 20.7-21.2 | 36.31-36.43 |

TABLE 2. HUTCHINSON ISLAND PHYTOPLANKTON SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Species | Month | Day-Night | Station | Count Range (cells/m³) | Count Mean (cells/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| **Grammatophora* sp. | March | D | III | present | — | 21.6-21.9 | 36.22-36.40 |
| *G. marina* | Sept.-Dec.; Apr.; June | D-N | I-III | 2-27 | 10.4 | 18.9-28.4 | 33.68-36.38 |
| *Gyrosigma* spp. | Oct.; Dec.; Apr.-May | D-N | I-III | 1-11 | 3.3 | 20.7-28.4 | 33.95-36.43 |
| *Licmophora* spp. | Sept.; Dec.; Feb.; Mar.; May-July | D-N | I-III | 1-1,045 | 187.1 | 19.5-27.8 | 34.71-36.89 |
| *Navicula* spp. | Sept.-Oct.; Jan.; May-July | D-N | I-III | 1-6,849 | 1,233.1 | 22.8-28.4 | 34.63-36.26 |
| *N. lyra* var. *lyra* | Oct. | D | III | 1 | 1.0 | 28.2-28.3 | 35.15-35.22 |
| **N. lyra* var.? | Sept.-Oct.; Dec.; March-May | D-N | I-III | 1-2 | 1.4 | 20.7-28.4 | 33.95-36.89 |
| *Nitzschia* spp. | Sept.-Oct.; Dec.; Feb.-Aug. | D-N | I-III | 1-6,276 | 1,986.6 | 18.8-28.4 | 34.06-39.33 |
| *N. closterium* | Sept.-Jan.; Apr.-Aug. | D-N | I-III | 657-65,282 | 6,224.6 | 18.9-28.4 | 33.79-39.33 |
| *N. longissima* | Oct.-Dec.; March-July | D-N | I-III | 735-361,416 | 37,508.9 | 18.9-28.4 | 33.86-36.40 |
| *N. pungens* var. *atlantica* | Oct.-Nov.; Jan.; Apr.; Aug. | D-N | I-III | 197-10,283 | 4,099.1 | 23.0-28.5 | 33.79-39.33 |
| *Orthoneis splendida* | Feb. | N | I | 1 | 1.0 | 18.8-19.7 | 35.95 |
| *Plagiogramma vanheurckii* | Sept.-Dec.; Apr. | D-N | I-III | 8-404 | 92.1 | 18.7-28.4 | 33.68-36.43 |
| *Pleurosigma* spp. | Oct.; Feb.-May; July | D-N | I-III | 1-12 | 2.1 | 19.5-28.4 | 33.95-36.89 |
| *P. balticum* | Dec.; Mar.; May; July | D-N | I, III | 1-2 | 1.3 | 21.5-25.3 | 35.51-36.40 |
| *P. macrum* | Feb. | D-N | II | 1 | 1.0 | 19.5-19.8 | 36.05-36.25 |
| *Rhabdonema adriaticum* | Sept.-Oct.; Dec.; Apr. | D-N | I-III | 2-11 | 4.6 | 20.7-28.4 | 33.95-36.43 |
| *Raphoneis surirella* | Sept. | D | II | 4 | 4.0 | 27.2-27.4 | 35.52-35.89 |
| *Synedra* spp. | Sept.-Nov.; March-June | D-N | I, III | 1-4 | 1.5 | 21.5-28.4 | 33.86-36.89 |
| *Thalassionema nitzschioides* | Sept.-Jan.; Mar.-Apr.; June; July | D-N | I-III | 3-298,617 | 21,058.6 | 18.7-28.4 | 33.68-39.33 |
| *Thalassiothrix* sp. | Dec. | N | III | 27 | 27.0 | 19.0-19.5 | 35.94-36.05 |
| *T. frauenfeldii* | Sept.-Jan.; Mar.-Apr. | D-N | I-III | 1-3,360 | 723.7 | 18.7-28.4 | 33.86-36.89 |
| **T. mediterranea* var. *pacifica* | Oct.-Nov. | D-N | I-III | 281-94,606 | 37,289.9 | 24.1-28.4 | 33.68-35.52 |
| Unidentified naviculoid diatom | Oct.-Dec.; Mar.; May-July | D-N | I-III | 1-308 | 25.8 | 19.0-28.4 | 33.86-36.89 |
| Unidentified pennate diatom | Dec.; March; May | D-N | I-III | 1 | 1.0 | 21.5-25.4 | 35.95-36.32 |
| DINOPHYCEAE | | | | | | | |
| **Amphisolenia* sp. | Dec. | D | II | 1 | 1.0 | 20.7-21.2 | 36.31-36.43 |
| *A. bidentata* | Dec.-Jan.; Apr.-May; Aug. | D-N | I-III | 1-4 | 1.9 | 20.7-27.8 | 35.37-39.33 |
| **Amphisolenia thrinax* | Apr. | D | I | 1 | 1.0 | 23.8-24.7 | 35.88-36.08 |
| *Ceratium* spp. | Sept.-Jan. | D | I-III | 1-3 | 1.8 | 21.5-28.3 | 33.86-36.32 |
| *C. candelabrum* var. *depressum* | Nov. | D | III | 4 | 4.0 | 24.6 | 33.86 |
| *C. carriense* var. *carriense* | Sept.-Oct.; Dec.-June; Aug. | D-N | I-III | 1-22 | 5.1 | 18.9-28.3 | 34.52-39.33 |
| *C. carriense* var. *volans* | Dec.-Jan.; Apr.-Aug. | D-N | I-III | 1-7 | 2.5 | 18.9-26.9 | 34.52-36.32 |
| *C. contortum* var. *contortum* | Dec.-Jan.; Apr.; June | D-N | I-III | 1-4 | 1.6 | 21.5-27.1 | 34.96-36.32 |
| *C. contortum* var. *karstenii* | Sept.-Jan.; March-July | D-N | I-III | 1-19 | 4.6 | 18.7-28.4 | 33.86-36.89 |
| **C. contortum* var.? | Dec. | N | III | 1 | 1.0 | 19.0-19.5 | 35.94-36.05 |
| **C. declinatum* var. *declinatum* | May; Aug. | D | I-III | 1-5 | 2.3 | 24.4-27.8 | 35.95-39.33 |
| **C. declinatum* var. *normale*? | Dec. | D | III | 1 | 1.0 | 21.5-21.7 | 36.32 |
| *C. extensum* | Sept.-Oct.; Dec.-Jan.; Mar.-July | D-N | I-III | 1-28 | 5.8 | 18.7-28.4 | 34.52-36.89 |
| *C. falcatum* | Nov.; Apr. | D-N | III | 1 | 1.0 | 24.5-24.6 | 33.86-36.10 |
| *C. furca* | Sept.-Aug. | D-N | I-III | 1-210 | 15.3 | 19.0-28.4 | 33.68-39.33 |
| *Ceratium fusus* var. *fusus* | Sept.-Apr.; June-Aug. | D-N | I-III | 1-54 | 7.7 | 18.7-28.4 | 33.68-39.33 |
| *C. fusus* var.? | Nov., March | D-N | I, III | 1 | 1.0 | 21.5-24.6 | 33.86-36.40 |
| *C. hexacanthum* | Sept.; Dec.-Jan.; Apr.-Aug. | D-N | I-III | 1-41 | 11.2 | 18.9-28.4 | 34.52-39.33 |

TABLE 2. HUTCHINSON ISLAND PHYTOPLANKTON SEPT. 1973-AUG. 1974 DIEL SAMPLING. *NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Species | Month | Day-Night | Station | Count Range (cells/m³) | Count Mean (cells/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| *C. hircus* | Sept.-Nov.; Apr.; Aug. | D-N | I-III | 1-27 | 6.5 | 24.3-28.4 | 33.68-39.33 |
| *C. horridum* | Sept.; Nov.; Jan.-March; May-June; Aug. | D-N | I-III | 1-71 | 6.7 | 19.5-27.8 | 33.68-39.33 |
| *C. inflatum* | Sept.-Oct.; Jan.; Apr. | D-N | I-III | 1-5 | 2.2 | 22.7-28.4 | 34.06-36.11 |
| **C. japonicum* | Dec.-Jan. | D-N | II | 1 | 1.0 | 19.2-22.8 | 35.37-35.94 |
| *C. lineatum* | Dec.; March | D-N | III | 1 | 1.0 | 21.5-21.7 | 36.32-36.89 |
| *C. longirostrum* | Nov.-Dec. | D-N | II, III | 1-6 | 3.3 | 20.7-24.5 | 33.68-36.43 |
| *C. lunula* var. *lunula* | Sept.; Dec.-June; Aug. | D-N | I-III | 1-17 | 3.0 | 18.9-28.4 | 34.52-39.33 |
| **C. lunula* var.? | March | N | I | 1 | 1.0 | 21.5-21.8 | 36.40 |
| *C. macroceros* | Dec.-Jan.; May-July | D-N | I-III | 1-14 | 2.9 | 19.0-26.9 | 34.55-36.43 |
| *C. massiliense* | Sept.-Aug. | D-N | I-III | 1-315 | 37.0 | 18.7-28.4 | 33.68-39.33 |
| *C. pentagonum* | Sept.; Dec.-Jan. | D-N | II, III | 1-3 | 1.4 | 19.0-27.2 | 34.96-36.43 |
| *C. ranipes* var. *palmatum* | Dec. | D | II | 1 | 1.0 | 20.7-21.2 | 36.31-36.43 |
| **C. sumatranum* | Dec. | D | I | 1 | 1.0 | 18.9-19.5 | 35.94-36.05 |
| *C. trichoceros* | Sept.-Aug. | D-N | I-III | 1-1,061 | 117.8 | 18.7-28.4 | 33.68-39.33 |
| *Ceratium tripos* var. *tripos* | Jan.-Feb.; Apr.; Aug. | D-N | I-III | 1-5 | 1.8 | 19.5-27.8 | 34.52-39.33 |
| *C. tripos* var. *atlanticum* | Sept.-Nov.; Jan.-Feb. | D-N | I-III | 1-48 | 13.6 | 18.8-28.4 | 33.68-35.95 |
| *C. vultur* | Dec.; Jan.; Apr. | D-N | I-III | 1-9 | 3.0 | 20.7-24.7 | 35.41-36.43 |
| *C.* sp. cf. *vultur* | June | D | I | 1 | 1.0 | 26.8 | 35.32-35.61 |
| *Ceratocorys horrida* | Jan. | N | III | 1 | 1.0 | 22.7-22.8 | 35.23-35.26 |
| *Dinophysis caudata* | Oct.-Nov.; Aug. | D-N | I-III | 1-40 | 10.7 | 24.3-28.4 | 33.86-39.33 |
| *Gonyaulax* sp. | Oct. | D | II | 2 | 2.0 | 28.4 | 34.78-35.22 |
| *G. diegensis* | Oct. | D | III | 4 | 4.0 | 28.2-28.3 | 35.15-35.22 |
| **G. fratercula* | Nov. | N | III | 23 | 23.0 | 24.3-24.5 | 33.68-33.96 |
| *G. polygramma* | Sept.-Oct. | D-N | I, III | 1-51 | 18.3 | 27.1-28.4 | 34.06-35.52 |
| *Prorocentrum micans* | Sept.; Aug. | D | I, III | 1 | 1.0 | 27.1-27.8 | 35.45-39.33 |
| *Protoperidinium* spp. | Sept.-Nov. | D-N | I-III | 2-42 | 13.1 | 24.3-28.4 | 33.68-35.26 |
| **P. brochii* | Sept. | N | I | 2 | 2.0 | 27.5-27.8 | 34.71-35.26 |
| *P. claudicans* | Aug. | D | I | 2 | 2.0 | 27.5-27.8 | 38.59-39.33 |
| *P. conicum* f. *conicum* | Oct.-Nov.; Jan.; Aug. | D-N | I-III | 1-42 | 14.9 | 22.8-28.4 | 33.86-39.33 |
| **P. conicum* f. *quardafuiana* | Dec. | N | I | 1 | 1.0 | 18.7 | 35.49-35.56 |
| *P. crassipes* | Oct.; Aug. | D | III | 2-21 | 11.5 | 27.0-28.5 | 35.15-39.33 |
| *P. depressum* | Sept.; Oct.; Jan. | D-N | I-III | 2-42 | 10.2 | 22.6-28.3 | 34.52-35.26 |
| *P. divergens* | Oct. | N | II | 3 | 3.0 | 28.4 | 34.86-35.15 |
| *P. grande* | Oct.-Nov. | D-N | I, III | 1-10 | 5.5 | 24.6-28.4 | 33.86-34.24 |
| **P. oblongum* | Sept.-Nov. | D-N | I-III | 1-17 | 4.9 | 24.3-28.4 | 33.68-35.52 |
| *P. pentagonum* | Oct. | N | II | 1 | 1.0 | 28.4 | 34.86-35.15 |
| *P. spiniferum* | June | N | I | 1 | 1.0 | 25.6-25.7 | 35.68-36.38 |
| *P. venustum* | Nov. | D-N | III | 2-4 | 3.0 | 24.3-24.6 | 33.86-33.96 |
| *Pyrocystis fusiformis fusiformis* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 1-122 | 12.0 | 18.7-28.4 | 34.06-39.33 |
| *P. fusiformis* f. *biconica* | Sept.-Aug. | D-N | I-III | 1-251 | 56.2 | 18.7-28.5 | 33.68-39.33 |
| *P. hamulus* var. *hamulus* | Dec. | D | II | 1 | 1.0 | 20.7-21.2 | 36.31-36.43 |
| *P. hamulus* var. *inaequalus* | Dec. | D | II | 1 | 1.0 | 20.7-21.2 | 36.31-36.43 |
| *P. noctiluca* | Sept.-Aug. | D-N | I-III | 1-56 | 13.1 | 18.7-28.3 | 33.79-38.95 |
| *Pyrophacus horologium* | Oct.; Jan. | D-N | I-III | 1-8 | 2.6 | 22.8-28.4 | 33.95-35.52 |
| *P. steinii* | Oct.; Jan. | D-N | I, III | 1-3 | 2.0 | 23.0-28.4 | 34.06-35.22 |
| Unidentified dinoflagellate | Sept.-Oct.; Aug. | D | I-III | 1-8 | 3.4 | 26.8-28.4 | 33.95-39.33 |
| MISCELLANEOUS | | | | | | | |
| *Oscillatoria erythraea* | Dec.-Jan.; Apr. | D-N | I-III | 62-489 | 237.2 | 18.7-24.7 | 35.37-36.43 |
| *Coccoid blue-green | Oct. | D | III | present | — | 28.2-28.3 | 35.15-35.22 |
| *Small *Protoperidinium*-like species | Sept. | N | II | 297 | 297.0 | 27.1-27.2 | 35.34-35.52 |
| *Unidentified alga | Sept. | D-N | I-III | 4,688-210,682 | 64,881.0 | 27.1-28.1 | 34.52-35.89 |
| *Unidentified chrysophyte | Oct.-Nov.; Jan.-Feb.; Apr.; June-July | D-N | I-III | 1-6 | 2.3 | 19.5-28.4 | 33.79-36.38 |
| *Unidentified filament | Nov.; July | D-N | II, III | 2-10,082 | 5,930.3 | 24.4-25.6 | 33.86-36.04 |

Total net phytoplankton had two peaks of abundance: fall and spring (Figure 2). The October peak was about four times greater than the May peak. Centric diatoms were dominant from October through January; after March, pennates increased in dominance while centric numbers were low. This change in dominant groups reflects the decrease in numbers or the absence of *Bellerochea horologicalis* and *Skeletonema costatum* with a concurrent increase of *Nitzschia* species. Dinoflagellates were most abundant in October, January, April-May and August (Figure 3). In all three years, phytoplankton peaks were greatest in the fall. A lesser peak occurred in late spring-early summer.

Oceanic phytoplankton increased in abundance and diversity during fall and winter although oceanic influence was also apparent in August 1974 (Worth and Hollinger, 1977).

*Chaetoceros coarctatus*, *Rhizosolenia castracanei* (two large oceanic diatoms), *Amphisolenia bidentata* and *Ceratium lunula* (two large oceanic dinoflagellates) showed increases in abundance during August. The two diatoms and *A. bidentata* were not recorded in June and July and *C. lunula* was not recorded in July. *Chaetoceros coarctatus* and *R. castracanei* were high in night collections at Station III but in day collections (made the following day), counts were highest at Station I. The two dinoflagellates were recorded only during day collections at Station I or Stations I and II. Other oceanic species present were *Rhizosolenia calcar avis*, *Ceratium massiliense*, *Pyrocystis fusiformis* f. *fusiformis* and *P. fusiformis* f. *biconica*.

However, two characteristic estuarine species, *Skeletonema costatum* and *Ceratium hircus*, were also present and numerous but only at Station I. *Ceratium hircus* occurred during day collections and *S. costatum* at night. This occurrence suggests that there was also an estuarine influence at the nearshore station. Both collections (day and night) were on high slack tides (Worth and Hollinger, 1977), which no doubt accounts for the presence of estuarine species.

Zooplankton data did not indicate oceanic influence for August.

Species diversity generally reflected seasonal abundance (Table 4, Figures 4 and 5). Diversity and phytoplankton abundance were greatest in October. Diversity was low during February when numbers were low and in May and July when pennates dominated the phytoplankton.

Values for the Morisita Index (Table 5) indicate that both day samples and night samples of Stations II and III have a higher affinity than those from either Stations I and II or I and III. Within stations, affinity between day and night samples was highest for Station II. Day-night differences may be accounted for by changes in grazing pressures, currents, diurnal migration or other factors.

## ZOOPLANKTON

The diel zooplankton taxa in Table 6 have been placed in holoplankton and meroplankton categories as outlined in Walker et al. (1979). Copepods, comprising 55.92% of the total zooplankton, were the dominant zooplankton group (Table 7, Figure 6). Thirty-three genera were identified and included 39 species. Calanoids dominated the copepods. As in the previous two years' sampling, the dominant copepod was the calanoid, *Paracalanus*, which contributed 34.47% of the total copepods and 19.28% of the total zooplankton (Table 7). It occurred in every sample as did *Corycaeus* and *Oithona*. The other dominant copepod genera in order of numerical abundance were *Acartia*, *Temora*, *Corycaeus*, *Labidocera*, *Oithona*, *Euterpina*, *Farranula*, and *Centropages*. With one exception (*Centropages*) and some changes in ordering, these copepods were also dominant in the previous two years' sampling (Walker et al., 1979).

The tintinnids (38.08%) dominated the "other holoplankton" numerically (Table 7), although they only occurred in high numbers in October (total count 22,361 organisms/m$^3$). In the remaining months, total counts were less than 120 organisms/m$^3$. *Oikopleura* spp. comprised 32.84% of total "other holoplankton" and were present throughout the year. In order of abundance, the remaining dominant "other holoplankton" were ostracods, *Sagitta* immature, *Lucifer faxoni*, foraminiferans, *Sagitta inflata*, *Doliolum* spp., *Sagitta helenae* and *Evadne* spp.

Total meroplankton formed 29.48% of total zooplankton (Table 7). Echinoderm ophioplutei contributed 41.32% of the total meroplankton numbers. Peak numbers occurred in October and accounted for 92.30% of the total ophiopluteus numbers for all diel samples. The other dominant meroplankton were cirriped nauplii, gastropod veligers, echinoplutei, crab zoea, penaeid protozoea, polychaete larvae, cirriped cypris, bivalve veligers, unidentified eggs and terebellid larvae. Crab zoea occurred in every sample.

Zooplankton peaks occurred in October (highest counts), January, May and August with a lesser peak in March (Figure 7). Seasonal zooplankton occurrences, with exception of the prominent October peak, are similar to the previous two years of sampling. The midwinter peak occurred all three years. Total holoplankton peaks closely followed total zooplankton numbers (Figure 7). Meroplankton, however, had a prominent peak in October with low counts the remainder of the sampling period.

Winter appears to be a period of strong oceanic influence based on the occurrence of oceanic forms. Eleven oceanic forms (two chaetognaths, nine copepods) occurred exclusively in winter, while seven other oceanic copepods had highest counts in winter. The two chaetognaths, *Krohnitta pacifica* and *Sagitta serratodentata*, were recorded only in January. The nine copepods recorded exclusively in winter were:

TABLE 3. NUMERICALLY DOMINANT PHYTOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING.

DIATOMS—% Total Diatom/Total Phytoplankton—92.41%

Centric Diatoms

| Species | Total Count (cells/m³) | % Centric Total | % Phytoplankton Total | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| *Bellerochea horologicalis* | 1,536,119 | 54.22 | 27.21 | 63.89 |
| *Skeletonema costatum* | 686,288 | 24.22 | 12.15 | 31.94 |
| *S. tropicum* | 101,155 | 3.57 | 1.79 | 16.67 |
| *Bacteriastrum delicatulum* | 63,200 | 2.23 | 1.12 | 5.56 |
| *Rhizosolenia imbricata* | 46,523 | 1.64 | 0.824 | 58.33 |
| *Chaetoceros coarctatus* | 44,774 | 1.58 | 0.793 | 44.44 |
| *C. decipiens* | 42,680 | 1.51 | 0.756 | 20.83 |
| *Palmeriana hardmanianus* | 33,978 | 1.20 | 0.602 | 36.11 |
| *Chaetoceros gracilis* | 33,695 | 1.19 | 0.597 | 8.33 |
| *C. lorenzianus* | 31,642 | 1.12 | 0.560 | 23.61 |
| *C. diversus* | 31,494 | 1.11 | 0.558 | 6.94 |

% Total Centrics/Total Phytoplankton—50.17%

Pennate Diatoms

| Species | Total Count (cells/m³) | % Pennate Total | % Phytoplankton Total | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| *Nitzschia longissima* | 787,687 | 33.03 | 13.95 | 29.17 |
| *Thalassionema nitzschioides* | 758,109 | 31.79 | 13.43 | 50.00 |
| *Thalassiothrix mediterranea* var. *pacifica* | 410,288 | 17.20 | 7.27 | 15.28 |
| *Nitzschia closterium* | 224,086 | 9.40 | 3.97 | 50.00 |
| *Nitzschia* spp. | 51,652 | 2.17 | 0.915 | 36.11 |
| *Bacillaria paxillifer* (= *Nitzschia paradoxa*) | 50,491 | 2.12 | 0.894 | 25.01 |
| *Asterionella glacialis* (= *A. japonica*) | 33,106 | 1.39 | 0.586 | 13.89 |
| *Nitzschia pungens* var. *atlantica* | 32,793 | 1.37 | 0.581 | 11.11 |

% Total Pennates/Total Phytoplankton—42.24%

DINOFLAGELLATES—% Total Dinoflagellate/Total Phytoplankton—0.324%

| Species | Total Count (cells/m³) | % Dinoflagellate Total | % Phytoplankton Total | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| *Ceratium trichoceros* | 8,009 | 43.72 | 0.142 | 94.44 |
| *Pyrocystis fusiformis* f. *biconica* | 3,823 | 20.87 | 0.068 | 94.44 |
| *Ceratium massiliense* | 2,181 | 11.91 | 0.039 | 81.94 |
| *Pyrocystis fusiformis* f. *fusiformis* | 696 | 3.80 | 0.012 | 80.56 |
| *P. noctiluca* | 682 | 3.72 | 0.012 | 72.22 |
| *Ceratium furca* | 612 | 3.34 | 0.011 | 55.56 |
| *C. hexacanthum* | 337 | 1.84 | 0.006 | 41.67 |
| *C. fusus* | 292 | 1.59 | 0.005 | 52.78 |
| *C. tripos* var. *altanticum* | 245 | 1.34 | 0.004 | 25.00 |

*Candacia bipinnata*, *Centropages violaceus*, *Lucicutia flavicornis*, *Pontellina plumata*, *Scolecithrix danae*, *Scolecithricella ctenopus*, *Copilia mirabilis*, *Miracia efferata* and *Sapphirina stellata*. Those oceanic copepods with highest counts in December and January included *Calocalanus pavo*, *Candacia pachydactyla*, *Euchaeta marina*, *Nannocalanus minor*, *Rhincalanus cornutus*, *Macrosetella gracilis* and *Undinula vulgaris*. Similar occurrences of oceanic zooplankton were noted in the September 1971-August 1973 sampling. Nevertheless, Worth and Hollinger (1977) interpreted physical and chemical data to indicate minimal oceanic influences in winter, although they noted Gulf Stream oceanic intrusion in February 1973.

## DIEL MIGRATION

Zooplankton diel migration has been correlated with light quality and intensity, temperature, salinity, water pressure and other factors (Baylor and Smith, 1957; Moore and Bauer, 1960; Grindley, 1964; Woodmansee, 1966). Zooplankton probably migrate in response to a complex of these factors, and reactions vary between zooplankton groups (Lewis, 1959; Moore

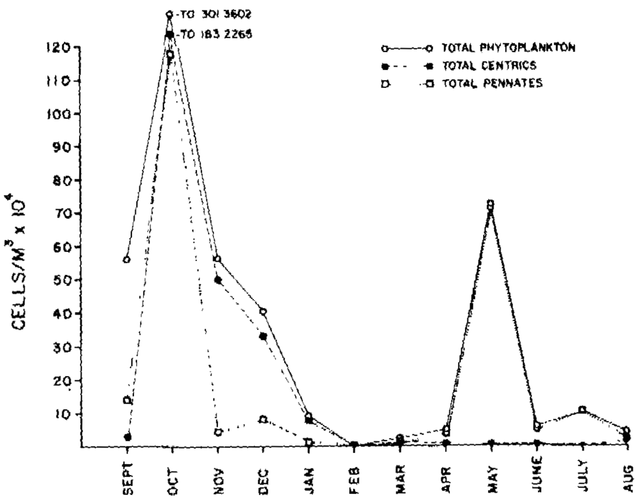


Figure 2. Total phytoplankton, total centric and total pennate diatom abundance for combined Stations I-III, September 1973 through August 1974.

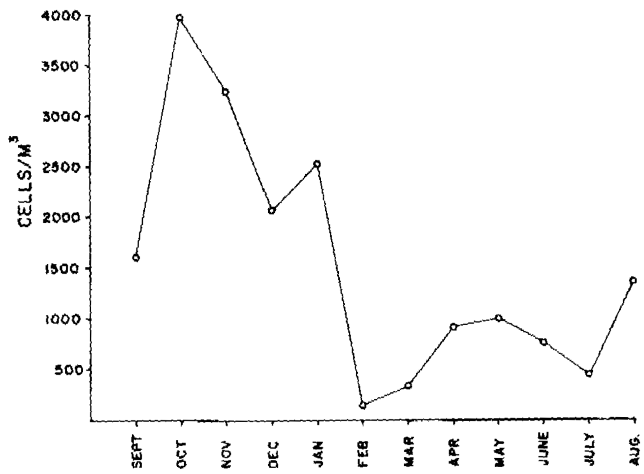


Figure 3. Total dinoflagellate abundance for combined Stations I-III, September 1973 through August 1974.


Figure 4. Shannon's diversity index values for total phytoplankton for combined Stations I-III, September 1973 through August 1974.

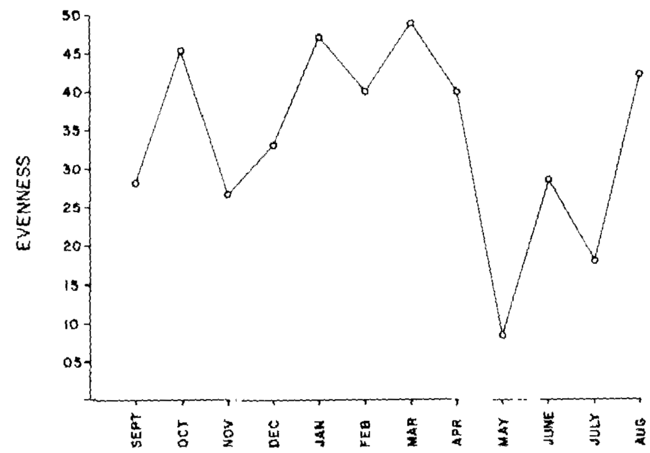


Figure 5. Evenness component values for total phytoplankton for combined Stations I-III, September 1973 through August 1974.

and Bauer, 1960). Certain groups may migrate considerably although the plankton community as a whole may show little migration (Grindley, 1972). These different behavioral responses are reflected in diel changes in the species composition of the plankton. Diel migration is also important to consider when assessing standing stock. In estuaries, diel migration cycles are further influenced by tides (Woodmansee, 1966; Grindley, 1972).

Numerical diel differences for individual organisms, three phytoplankton categories and four zooplankton categories were tested with analysis of variance. September samples were not included in these analyses since day-night sampling was less than five hours apart. Diel phytoplankton counts were not significantly different. Day and night counts for total zooplankton, copepods, "other holoplankton" and meroplankton differed, but only significantly for total zooplankton ($F = 4.71^*$ with 1 and 20 df) and total copepods at Station III ($F = 7.24^*$ with 1 and 20 df). Counts for total zooplankton and copepods were greater at night. However, counts for "other holoplankton" and meroplankton indicated greater abundance during the day.

Within the four zooplankton groups, day-night counts differed significantly for *Calanopia americana*, *Sagitta helenae* and cumaceans. *Sagitta helenae* numbers were generally greater at night and were significantly greater at Station I ($F = 5.15^*$ with 1 and 20 df). Day occurrences of cumaceans were only

TABLE 4. SHANNON'S DIVERSITY INDEX FOR PHYTOPLANKTON.

| | H′ | Evenness Component |
|---|---|---|
| Total Diversity | 3.3035 | .4501 |
| September | 1.5830 | .2805 |
| October | 2.9645 | .4534 |
| November | 1.6120 | .2657 |
| December | 2.0907 | .3298 |
| January | 2.7544 | .4702 |
| February | 1.8279 | .3987 |
| March | 2.7415 | .4883 |
| April | 2.2656 | .3994 |
| May | .4173 | .0827 |
| June | 1.4871 | .2855 |
| July | .8101 | .1791 |
| August | 2.2198 | .4200 |

TABLE 5. MORISITA INDEX OF SAMPLE AFFINITY FOR PHYTOPLANKTON.

| Station Comparisons | | | | Day-Night Comparisons | |
|---|---|---|---|---|---|
| Station | Day | Night | D&N Total | Station | D-N Comparison |
| I:II | .7162 | .6559 | .7289 | I | .5566 |
| II:III | .9295 | .7493 | .8566 | II | .8392 |
| I:III | .6794 | .5100 | .8037 | III | .5947 |

recorded twice: September at Station III and March at Station I. In both instances, cumaceans were recorded as "present" (observed in whole aliquot but not in counted squares) and the September occurrence can probably be attributed to the late sampling hour. Night counts of cumaceans for Stations I and II and total night counts were significantly greater ($F = 6.64^*$ with 1 and 20 df; $F = 4.52^*$ with 1 and 16 df; $F = 12.46^{**}$ with 1 and 16 df, respectively). In February, cumaceans were particularly abundant at Station I (146 organisms/$m^3$). This may have been a swarming phenomenon associated with reproduction. Bottom grab samples for the first two years contained gravid females in late spring-early summer (Camp et al., 1977).

*Calanopia americana* occurred almost exclusively at night. It was recorded in eleven day samples, six of which were recorded as "present". In contrast, it occurred in thirty-one night samples; only five of these occurrences were marked as "present". Station II night counts and total night counts were significantly greater ($F = 5.63^*$ with 1 and 20 df; $F = 16.77^*$ with 1 and 22 df, respectively).

In Bermuda inshore waters, *Calanopia americana* remains on the bottom during the day and migrates upward shortly before sunset (Clarke, 1934). Herman and Beers (1969) sampled Bermuda inshore waters at night and reported *C. americana* as the dominant copepod at an enclosed water station (26% of total copepod population). Fish (1962) found *C. americana* from night collections at Barbados. Grice (1957), Woodmansee (1958) and Reeve (1970) recorded *C. americana* in low numbers in day samples for Florida inshore waters. In Florida offshore waters, *C. americana* is present in the plankton at all hours, but is most numerous at night (Owre and Foyo, 1967; Bowman, 1971).

Other zooplankters had total nocturnal/diurnal count ratios of 2.0 or more, but the counts were not statistically different. Among the copepods, *Labidocera aestiva*, *Acartia bermudensis*, *Acrocalanus longicornis* and *Euterpina acutifrons* were more numerous at night. Among the "other holoplankton", mysids occurred almost exclusively at night. *Oikopleura* spp., *Lucifer faxoni* and foraminiferan numbers were greater at night. Ostracod numbers were about three times greater at night. Seasonally, ostracods peaked in April and May. During these two months, females with eggs and free eggs were found only in night samples. Apparently, reproduction occurs in late spring and eggs are released at night.

Day or night dominance among meroplankters varied. Echinoderm larvae (echinoplutei and ophioplutei) and molluscan larvae (bivalve and gastropod veligers) were more numerous by day. Crustacean larvae (cirriped nauplii and cypris, shrimp larvae, penaeid protozoea and crab zoea) increased in numbers at night.

Although diel patterns have been indicated, they are, with some exceptions, tentative. Twelve monthly samples are inadequate to assess seasonal effects on diel patterns since plankton numbers and distributions are known to vary yearly. In addition, nets were towed from bottom to surface and probably resulted in some day sampling of benthic populations associated with the sediment. Consequently, diel migration was undoubtedly underestimated. Nevertheless, certain zooplankters showed diel patterns consistent with the literature. *Calanopia americana* is definitely nocturnal in inshore waters (Fish, 1962; Herman and Beers, 1969). Cumaceans and mysids are also nocturnal and remain near or in the bottom substrate by day (Davis, 1955; Grindley, 1972). Woodmansee (1966) reported nocturnal/diurnal ratios of 2.0 for *Lucifer faxoni* adults in inshore waters. The ratio was 2.7 in this study. Grindley (1972) reported increased numbers of ostracods at night in South African estuaries.

## CONCLUSIONS

The area off Hutchinson Island is dynamic and moderately productive with definite estuarine and oceanic influences. The Indian River discharges through Ft. Pierce Inlet and supplies the area with nutrients (e.g. $PO_4$-P, $SiO_2$-Si) and estuarine plankters such as *Skeletonema costatum* and *Pseudodiaptomus coronatus*. The oceanic influence of the Gulf Stream varies seasonally and is minimal in fall.

TABLE 6. HUTCHINSON ISLAND ZOOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES

| Organism | Month | Day-Night | Station | Count Range (organism/m³) | Count Mean (organism/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| HOLOPLANKTON | | | | | | | |
| Copepoda | | | | | | | |
| Calanoida | Sept.-Apr.; June-Aug. | D-N | I-III | 4-22,217 | 1,022.7 | 18.7-28.4 | 33.68-39.33 |
| *Acartia bermudensis* | Jan.-Aug. | D-N | I-III | 3-397 | 94.4 | 18.7-28.5 | 34.52-39.33 |
| *A.* copepodite | Jan.-Aug. | D-N | I-III | 4-1,177 | 158.5 | 18.7-28.4 | 33.79-39.33 |
| **Acrocalanus longicornis* | Dec.-May; July | D-N | I-III | 2-86 | 19.6 | 18.9-25.3 | 35.23-36.43 |
| *Calanopia americana* | Sept.-Aug. | D-N | I-III | 7-224 | 46.1 | 18.8-28.4 | 33.86-39.33 |
| *Calocalanus pavo* | Sept.; Dec.; Apr.; June | D-N | I-III | 2-27 | 12.0 | 18.7-27.1 | 35.32-36.43 |
| **Candacia bipinnata* | Feb. | N | III | present | — | 19.5-19.6 | 35.86-36.00 |
| *C. pachydactyla* | Sept.; Dec.-May | D-N | II, III | 4-30 | 11.6 | 19.5-27.2 | 34.96-36.89 |
| *C. pachydactyla* copepodite | Sept. | D-N | III | 25 | 25.0 | 27.1-27.2 | 35.45-35.89 |
| *Centropages furcatus* | Sept.-Aug. | D-N | I-III | 2-613 | 74.9 | 18.7-28.5 | 33.68-39.33 |
| *C. violaceus* | Dec. | D | I, II | 8 | 8.0 | 18.9-20.7 | 35.94-36.43 |
| *Clausocalanus furcatus* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 2-180 | 44.0 | 18.7-28.5 | 34.63-39.33 |
| *Eucalanus attenatus* | Jan.; Apr.-May | D-N | I-III | 2-45 | 19.3 | 22.6-24.8 | 35.37-36.26 |
| *E. crassus* | Sept.-Oct.; Dec.-Apr.; Aug. | D-N | I-III | 4-14 | 8.6 | 18.7-28.5 | 34.55-39.33 |
| *E. monachus* | Sept.-Apr.; June-Aug. | D-N | I-III | 3-144 | 32.7 | 18.7-28.5 | 33.68-39.33 |
| *E. monachus* copepodite | Dec.-Mar.; May-Aug. | D-N | I-III | 3-76 | 29.0 | 19.5-27.8 | 34.63-39.33 |
| *Euchaeta marina* | Dec.-Feb.; Apr.-May; July | D-N | I-III | 3-25 | 9.1 | 18.7-25.6 | 34.96-36.43 |
| *E. marina* copepodite | Jan.; May | D | II, III | 3 | 3.0 | 22.8-24.8 | 35.41-36.26 |
| *Labidocera aestiva* | Sept.-Mar.; May-Aug. | D-N | I-III | 2-920 | 10.5 | 18.7-28.5 | 33.68-39.33 |
| *L. aestiva* copepodite | Sept.-Jan.; Mar.-Aug. | D-N | I-III | 3-686 | 160.1 | 18.7-28.4 | 33.68-39.33 |
| *Lucicutia flavicornis* | Jan.; Apr. | D-N | I-III | present | — | 22.8-24.5 | 34.52-36.11 |
| **Nannocalanus minor* | Nov.-Aug. | D-N | I-III | 3-89 | 23.7 | 18.7-28.5 | 33.86-39.33 |
| **N. minor* copepodite | May; Aug. | D | II, III | 16-49 | 32.5 | 24.5-28.4 | 35.95-39.33 |
| *Paracalanus* spp. | Sept.-Aug. | D-N | I-III | 9-4,484 | 1,100.8 | 18.7-28.5 | 33.68-39.33 |
| *Pontellina plumata* | Dec. | D | I | present | — | 18.9-19.5 | 35.94-36.05 |
| *Pseudodiaptomus coronatus* | Dec.-July | D-N | I-III | 2-76 | 14.4 | 18.7-26.8 | 35.49-36.89 |
| *Rhincalanus cornutus* | Dec.-Jan.; Mar.; May | D-N | I-III | 5-16 | 8.5 | 18.9-24.7 | 34.55-36.89 |
| *R. cornutus* copepodite | May | N | III | 5 | 5.0 | 24.7 | 35.95 |
| *Scolecithrix danae* | Dec. | D | I | present | — | 18.9-19.5 | 35.94-36.05 |
| **Scolecithricella ctenopus* | Dec. | D | III | 3 | 3.0 | 21.5-21.7 | 36.32 |
| *Temora turbinata* | Sept.-Aug. | D-N | I-III | 4-1,398 | 311.1 | 18.7-28.5 | 33.68-39.33 |
| *T. turbinata* copepodite | Sept.-Aug. | D-N | I-III | 7-3,784 | 310.4 | 18.7-28.5 | 33.68-39.33 |
| *T. stylifera* | Sept.; Dec.-Aug. | D-N | I-III | 3-64 | 18.1 | 18.7-28.5 | 34.55-39.33 |
| *T. stylifera* copepodite | Sept.; Dec.-Aug. | D-N | I-III | 4-239 | 47.0 | 18.7-28.5 | 34.55-39.33 |
| *Undinula vulgaris* | Dec.-May; July-Aug. | D-N | I-III | 2-68 | 20.8 | 18.7-28.4 | 34.63-39.33 |
| Unknown calanoid | Sept. | N | I | present | — | 27.5-27.8 | 34.71-35.26 |
| Cyclopoida | | | | | | | |
| *Copilia mirabilis* | Dec.-Jan. | D-N | I-III | present | — | 18.9-23.0 | 34.96-36.43 |
| **C. vitrea* | Apr. | N | III | present | — | 24.5 | 36.04-36.10 |
| *Corycaeus* spp. | Sept.-Aug. | D-N | I-III | 3-2,235 | 161.5 | 18.7-28.5 | 33.68-39.33 |
| *Farranula carinata* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 4-149 | 23.5 | 18.9-28.4 | 33.95-39.33 |
| *F. gracilis* | Sept.-July | D-N | I-III | 3-108 | 30.5 | 18.7-28.4 | 33.86-36.89 |
| *F. rostrata* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 3-238 | 41.7 | 18.7-28.5 | 34.06-39.33 |
| **Lubbockia aculeata* | July | D-N | II, III | 5 | 5.0 | 25.0-25.6 | 34.63-36.04 |
| *Oithona* spp. | Sept.-Aug. | D-N | I-III | 3-829 | 101.0 | 18.7-28.5 | 33.68-39.33 |
| *O. plumifera* | Sept.; Dec.-Aug. | D-N | I-III | 2-164 | 29.9 | 18.7-28.4 | 34.63-39.33 |
| *O. setigera* | Aug. | D | I | 11 | 11.0 | 27.5-27.8 | 38.59-39.33 |
| *Oncaea* spp. | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 2-149 | 29.5 | 18.7-28.5 | 33.95-39.33 |
| *O. mediterranea* | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 3-114 | 28.8 | 18.7-28.5 | 34.63-39.33 |
| *Saphirella* spp. | Sept.-Nov.; Feb.-Mar. | N | I-III | 4-30 | 13.0 | 19.5-28.4 | 33.86-36.89 |
| *Sapphirina nigromaculata* | Dec.-Jan.; Mar.-Apr.; June-July | D-N | I-III | 4-14 | 8.0 | 19.2-25.7 | 34.52-36.40 |
| *S. stellata* | Jan. | D | II | present | — | 22.8 | 35.37-35.61 |

TABLE 6. HUTCHINSON ISLAND ZOOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Organism | Month | Day-Night | Station | Count Range (organism/m³) | Count Mean (organism/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| Harpacticoida | | | | | | | |
| *Clytemnestra* copepodite | Oct.; Apr. | D-N | II | 4 | 4.0 | 24.3-28.4 | 34.78-36.11 |
| *Euterpina acutifrons* | Sept.-Aug. | D-N | I-III | 3-598 | 86.0 | 18.7-28.4 | 33.68-39.33 |
| *Macrosetella gracilis* | Dec.; June | D-N | I-III | 10 | 10.0 | 19.2-27.1 | 35.32-36.43 |
| *M. gracilis* copepodite | Dec.-Jan. | D-N | I-III | 5-14 | 9.0 | 19.0-23.1 | 34.52-36.05 |
| *Miracia efferata* | Dec. | N | I | present | — | 18.7 | 35.49-35.56 |
| *Longipedia*-type | Sept. | D-N | I-III | 26 | 26.0 | 27.1-28.1 | 34.52-35.89 |
| Harpacticoid | Sept.-Aug. | D-N | I-III | 4-494 | 58.9 | 18.7-28.4 | 33.86-39.33 |
| Copepod nauplii | Sept.-Aug. | D-N | I-III | 4-937 | 86.2 | 18.7-28.4 | 33.68-39.33 |
| Copepodite | Sept.-May; July-Aug. | D-N | I-III | 3-385 | 89.0 | 18.7-28.5 | 33.68-39.33 |
| Copepod eggs | Oct.; Mar.-Apr.; July | D-N | I-III | 2-17 | 13.0 | 21.6-28.4 | 33.95-36.40 |
| Copepod egg sac | Oct.-Feb; May; July | D-N | I-III | 3-68 | 22.1 | 19.0-28.4 | 33.68-36.43 |
| Unknown copepod | Oct. | N | III | present | — | 28.0-28.3 | 35.22-35.52 |
| Caligoid | Apr. | N | I | present | — | 25.4-25.5 | 35.99-36.06 |
| Monstrilloid | Sept.; July | D-N | I, II | 10 | 10.0 | 24.5-28.1 | 34.52-35.75 |
| "OTHER HOLOPLANKTON" | | | | | | | |
| Chaetognatha | | | | | | | |
| *Krohnitta pacifica* | Jan. | N | II | 7 | 7.0 | 22.6-22.9 | 34.96-35.12 |
| *Sagitta helenae* | Sept.-Aug. | D-N | I-III | 4-313 | 29.8 | 18.7-28.5 | 33.68-39.33 |
| *S. hispida* | Sept.; Dec. | D-N | I, III | present | — | 21.5-27.8 | 34.71-36.32 |
| *S. inflata* | Oct.; Dec.-Aug. | D-N | I-III | 3-188 | 33.0 | 18.7-28.5 | 34.06-39.33 |
| *S. serratodentata* | Jan. | D-N | III | present | — | 22.7-23.0 | 35.23-35.42 |
| *S. tenuis* | Sept. | D | III | 20 | 20.0 | 27.1 | 35.45-35.52 |
| *S.* immature | Sept.-Aug. | D-N | I-III | 3-290 | 54.3 | 18.7-28.5 | 33.68-39.33 |
| Larvacea | | | | | | | |
| *Oikopleura* spp. | Sept.-Aug. | D-N | I-III | 2-4,025 | 304.0 | 18.7-28.5 | 33.68-39.33 |
| *Fritillaria* spp. | Sept.; Jan.; Mar. | D-N | I-III | 3-12 | 5.0 | 22.6-27.2 | 34.96-36.11 |
| Thaliacea | | | | | | | |
| *Doliolum* spp. | Sept.; Dec.-Feb.; Apr.-May; Aug. | D-N | I-III | 2-812 | 90.2 | 19.2-28.5 | 34.52-39.33 |
| *Salpa* spp. | Sept.-Oct.; Dec.-Jan.; Apr.-June; Aug. | D-N | I-III | 4-53 | 13.3 | 19.0-28.4 | 34.52-39.33 |
| Thecosomata | | | | | | | |
| *Creseis acicula* | Sept.; Dec.-June; Aug. | D-N | I-III | 5-51 | 12.0 | 18.8-28.5 | 34.52-39.33 |
| *C. virgula* | Dec.-Jan.; June; Aug. | D-N | I-III | 3-23 | 15.6 | 18.9-27.3 | 34.52-39.33 |
| Pteropod | Sept.; Dec. | D-N | I, II | present | — | 20.7-27.8 | 34.71-36.43 |
| Cladocera | | | | | | | |
| *Evadne* spp. | Sept.-Apr.; July-Aug. | D-N | I-III | 3-288 | 33.5 | 19.5-28.4 | 33.68-39.33 |
| Ostracoda | | | | | | | |
| Ostracod | Sept.-Aug. | D-N | I-III | 3-329 | 73.9 | 18.7-28.5 | 33.86-39.33 |
| Ostracod eggs | Apr.-May | N | I-III | 16-160 | 68.3 | 24.3-25.4 | 35.95-36.26 |
| Siphonophora | | | | | | | |
| **Ablya* spp. | Dec.-Jan.; Apr.-July | D-N | II, III | 4-5 | 4.5 | 20.7-26.7 | 35.23-36.43 |
| Siphonophore | Sept.-Oct.; Dec.-Jan.; Apr.-May; July-Aug. | D-N | I-III | 4-59 | 15.6 | 18.9-28.5 | 34.52-39.33 |
| Nemertea | | | | | | | |
| *Pilidium larvae | Sept.; Dec. | D-N | I-III | 5-31 | 15.8 | 18.7-27.8 | 34.71-36.43 |
| Crustacea | | | | | | | |
| *Lucifer faxoni* | Sept.-Aug. | D-N | I-III | 3-449 | 67.6 | 18.7-28.5 | 33.86-39.33 |
| Amphipod | Sept.-Aug. | D-N | I-III | 3-203 | 20.6 | 18.7-28.5 | 33.86-39.33 |
| Isopod | Sept.-Oct.; Dec.; Feb.-Mar.; May; June | D-N | I-III | present | — | 18.7-28.4 | 34.06-36.40 |
| *Eurydice* spp. | Sept.-Aug. | D-N | I-III | 3-22 | 10.4 | 18.7-28.4 | 33.68-38.95 |
| Cumacean | Sept.-Oct.; Jan.-Aug. | D-N | I-III | 4-146 | 22.8 | 19.5-28.3 | 34.55-39.33 |
| Mysid | Dec.-Aug. | D-N | I-III | 3-24 | 9.3 | 18.7-27.3 | 34.96-39.33 |
| Hydrozoa | | | | | | | |
| Hydroid | Oct.; Dec.; Feb.-Apr.; June | D-N | I-III | 3-9 | 6.0 | 18.7-28.3 | 35.12-36.43 |
| Insecta | | | | | | | |
| Insect | Oct.; May | D | II, III | present | — | — | — |
| Polychaeta | | | | | | | |
| *Tomopteris* spp. | Apr. | N | II | present | — | 24.3-24.4 | 35.97-36.11 |

TABLE 6. HUTCHINSON ISLAND ZOOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING.
*NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Organism | Month | Day-Night | Station | Count Range (organism/m³) | Count Mean (organism/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| Sipunculida | | | | | | | |
| Sipunculid | Oct.; Feb.; July | D | I, II | 15 | 15.0 | 18.7-28.4 | 34.63-36.00 |
| Platyhelmintha | | | | | | | |
| Turbellarian | July | D | II | present | — | 25.0-25.2 | 34.63-35.61 |
| Foraminifera | | | | | | | |
| Foraminiferan | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 3-1,201 | 73.1 | 18.7-28.4 | 33.95-39.33 |
| *Globigerina* spp. | Nov.-Jan.; Apr. | D-N | I-III | 4-41 | 14.8 | 19.0-24.7 | 33.86-36.43 |
| Tintinnids | | | | | | | |
| Tintinnid | Oct.-Jan.; Mar. | D-N | I-III | 3-6,301 | 1,327.1 | 19.2-28.4 | 33.68-36.43 |
| MEROPLANKTON | | | | | | | |
| Echinodermata | | | | | | | |
| Asteroid post-larvae | Sept.-Oct.; Jan.; July | D-N | I-III | 9-60 | 36.0 | 23.0-27.8 | 33.95-35.75 |
| Echinopluteus | Sept.-May; Aug. | D-N | I-III | 4-4,235 | 365.0 | 18.7-28.4 | 33.68-39.33 |
| Echinoid post-larvae | Oct.; Feb.-Mar.; July | D-N | I-III | 3-72 | 30.0 | 19.5-28.4 | 34.63-36.40 |
| Ophiopluteus | Sept.-Mar.; May; Aug. | D-N | I-III | 4-22,670 | 1,829.1 | 18.7-28.4 | 33.68-39.33 |
| Ophiuroid post-larvae | Oct.; Feb.-Apr. | N | I-III | 4-51 | 12.3 | 18.8-28.3 | 35.22-36.89 |
| Mollusca | | | | | | | |
| Bivalve larvae | Sept.-Aug. | D-N | I-III | 3-355 | 64.2 | 18.7-28.4 | 33.68-39.33 |
| Gastropod larvae | Sept.-Aug. | D-N | I-III | 3-1,126 | 129.5 | 18.7-28.5 | 33.68-39.33 |
| *Echinospira* larvae | Feb.-Mar.; May-June | D-N | I-III | 2 | 2.0 | 18.7-27.1 | 35.32-36.40 |
| *Octopus juvenile | Apr. | N | II | 4 | 4.0 | 24.3-24.4 | 35.97-36.11 |
| Decapoda | | | | | | | |
| Cirriped nauplii | Sept.-May; July-Aug. | D-N | I-III | 2-5,470 | 351.4 | 18.7-28.4 | 33.68-39.33 |
| Cirriped cypris | Sept.-Aug. | D-N | I-III | 3-558 | 70.1 | 18.7-28.4 | 33.68-39.33 |
| *Cirriped adult | Oct. | N | III | present | — | 28.0-28.3 | 35.22-35.52 |
| Shrimp | Nov.; June; Aug. | N | I-III | 4-23 | 11.5 | 24.3-27.0 | 34.86-39.33 |
| Shrimp larvae | Sept.-Aug. | D-N | I-III | 2-288 | 30.4 | 18.7-28.5 | 33.68-39.33 |
| Penaeid protozoea | Sept.-Aug. | D-N | I-III | 5-615 | 98.1 | 18.7-28.4 | 33.68-39.33 |
| *Holophorus*-type larvae | Sept.-Nov.; Apr.-July | D-N | I, III | 5-237 | 54.5 | 22.6-28.4 | 33.86-36.38 |
| Crab larvae | Sept.; Nov.-Aug. | D-N | I-III | 2-67 | 13.9 | 18.7-28.5 | 33.68-39.33 |
| Crab zoea | Sept.-Aug. | D-N | I-III | 4-1,122 | 97.9 | 18.7-28.5 | 33.68-39.33 |
| Crab megalopa | Sept.-Mar.; May-Aug. | D-N | I-III | 2-48 | 12.4 | 18.7-28.4 | 32.86-39.33 |
| Porcellanid zoea | Sept.-Aug. | D-N | I-III | 2-50 | 11.7 | 19.5-28.4 | 33.68-39.33 |
| Glaucothöe | Mar.; May; July | D-N | I, III | 3-13 | 8.0 | 21.5-25.4 | 35.51-36.40 |
| Caprellid | Sept.; Nov.-Dec.; Feb.-Apr. | N | I-III | 3-13 | 6.7 | 18.7-27.2 | 33.86-36.89 |
| Crustacean nauplii | Sept.-Nov. | D-N | I-III | 4-180 | 67.0 | 24.6-28.4 | 33.86-35.89 |
| Polychaeta | | | | | | | |
| Polychaete larvae | Sept.-Aug. | D-N | I-III | 2-674 | 94.2 | 18.7-28.5 | 33.68-39.33 |
| Magelonid larvae | Sept.; Nov.-Dec. | D-N | I-III | 13-16 | 14.5 | 20.7-27.8 | 33.86-36.43 |
| Terebellid larvae | Nov.-Feb.; Apr.-July | D-N | I-III | 3-562 | 91.9 | 18.7-27.1 | 33.79-36.43 |
| Pisces | | | | | | | |
| Fish larvae | Sept.-Oct.; Dec.-Aug. | D-N | I-III | 3-82 | 16.9 | 18.7-28.5 | 34.06-39.33 |
| Fish egg | Sept.-Aug. | D-N | I-III | 3-527 | 50.3 | 18.7-28.4 | 33.68-39.33 |
| Engraulid egg | Oct. | D | II, III | present | — | 28.2-28.4 | 34.78-35.22 |
| Bryzoa | | | | | | | |
| Cyphonautes larvae | Sept.-Dec.; Feb.; Apr.; Aug. | D-N | I-III | 3-216 | 40.2 | 18.7-28.4 | 33.86-38.95 |
| Cnidaria | | | | | | | |
| Medusae | Sept.-Aug. | D-N | I-III | 3-108 | 16.5 | 18.7-28.4 | 33.68-39.33 |
| **Aequorea* spp. | Sept. | D-N | I-III | present | — | 27.1-28.1 | 34.52-35.89 |
| *Obelia* spp. | Nov.-May; July-Aug. | D-N | I-III | 3-298 | 38.3 | 19.5-27.8 | 33.86-39.33 |
| Phoronida | | | | | | | |
| Actinotroch larvae | Sept.-Oct.; Dec.; Feb.; May-Aug. | D-N | I-III | 5-76 | 29.2 | 19.0-28.4 | 34.52-39.33 |
| Cephalochordata | | | | | | | |
| Amphioxus larvae | Sept.-Oct.; Mar.; July-Aug. | D-N | I-III | 4-13 | 9.3 | 21.5-28.3 | 35.15-39.33 |
| Stomatopoda | | | | | | | |
| *Lysiosquilla* larvae | Mar.; May-July | D-N | I-III | present | — | 21.5-26.9 | 35.32-36.89 |
| *Squilla* larvae | Jan.-Mar.; May-Aug. | D-N | I-III | 4-12 | 7.4 | 18.8-28.4 | 34.52-39.33 |

TABLE 6. HUTCHINSON ISLAND ZOOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING. *NOT OBSERVED IN SEPTEMBER 1971-AUGUST 1973 SAMPLES (Continued).

| Organism | Month | Day-Night | Station | Count Range (organism/m³) | Count Mean (organism/m³) | Temp. Range °C | Salinity Range ‰ |
|---|---|---|---|---|---|---|---|
| Ascidiacea | | | | | | | |
| Appendicularian larvae | Oct.; Jan.-Feb.; Apr. | D-N | I-III | 5-23 | 12.3 | 19.5-28.4 | 33.95-36.32 |
| Brachiopoda | | | | | | | |
| *"Lingula"* larvae | Sept.-Oct.; May | D-N | II | 13 | 13.0 | 24.4-28.4 | 34.78-36.26 |
| Unidentified Larvae | | | | | | | |
| Crustacean nauplii? | Sept. | D-N | II, III | 13 | 13.0 | 27.1-27.2 | 35.34-35.52 |
| Trochophore | Oct.; Jan.-Mar.; July | D-N | I-III | 2-122 | 32.8 | 18.8-28.3 | 34.52-36.40 |
| Unidentified Eggs | | | | | | | |
| *Unidentified eggs* | Sept.-May; July-Aug. | D-N | I-III | 3-750 | 57.4 | 18.7-28.4 | 33.86-39.33 |
| Unidentified egg mass | Dec. | N | II | 10 | 10.0 | 19.2-19.7 | 35.86-35.94 |

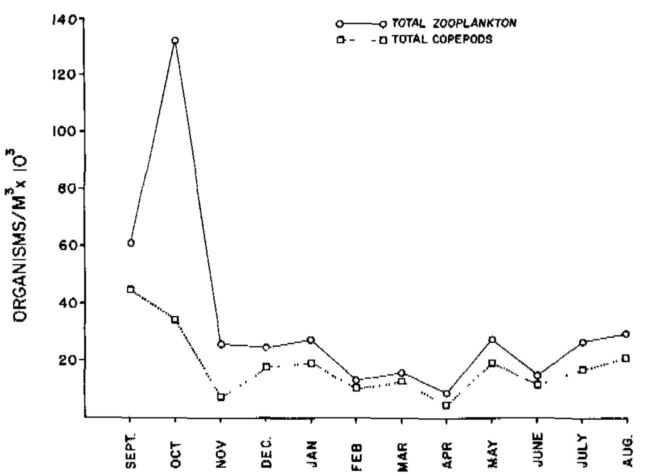


Figure 6. Total zooplankton and total copepod abundance for combined Stations I-III, September 1973 through August 1974.

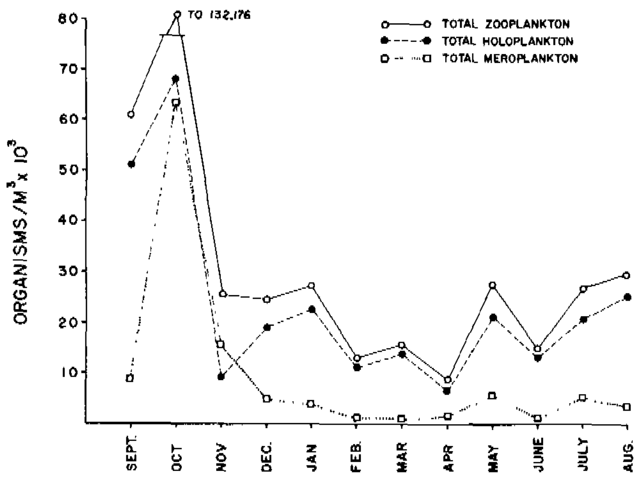


Figure 7. Total zooplankton, total holoplankton and total meroplankton abundance for combined Stations I-III, September 1973 through August 1974.

During this study, winter seemed to be a period of strong oceanic influence, as evidenced by the conspicuous presence of oceanic copepods and increased abundance of oceanic phytoplankters. The plankton community varied dielly and seasonally. Plankton concentration generally increased at night and certain zooplankters demonstrated marked diel variation. *Calanopia americana*, *Sagitta helenae* and cumaceans were nocturnal. Mysids, *Oikopleura* spp., *Lucifer faxoni*, foraminiferans, ostracods and several copepods also occurred in greater numbers at night but diel differences were not statistically significant. Diel tendencies varied among the meroplankton. Echinoderm and molluscan larvae were more numerous by day, while crustacean larvae increased in abundance at night.

Diel migration is an important factor to consider when assessing zooplankton standing stock and species composition. Sampling restricted to day or night would not adequately represent the plankton community. The occurrence of *Calanopia americana* provides an example of this type of sampling bias. During the first two years, samples were collected by day and *Calanopia americana* was considered uncommon. It occurred in only four months or 8.8% of all samples (Walker et al., 1979). In the diel study, this relatively large calanoid was a prominent member of the nocturnal samples. It occurred throughout the year in 58.33% of all samples. Cumaceans, mysids and ostracods also increased in the third year and for the first time during the program, ostracod eggs were recorded. Therefore, characterization of the diurnal and nocturnal components of plankton would be important before the effects of various parameters such as thermal effluents could be evaluated.

TABLE 7. NUMERICALLY DOMINANT ZOOPLANKTON, SEPT. 1973-AUG. 1974 DIEL SAMPLING.

HOLOPLANKTON—% Total Holoplankton/Total Zooplankton—70.52%

Copepods

| Organism | Total Count (organism/m³) | % Total Copepods | % Total Zooplankton | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| *Paracalanus* | 78,159 | 34.47 | 19.28 | 100.00 |
| *Acartia* | 46,896 | 20.69 | 11.57 | 94.44 |
| *Temora* | 42,720 | 18.84 | 10.54 | 98.61 |
| *Corycaeus* | 10,666 | 4.70 | 2.63 | 100.00 |
| *Labidocera* | 10,271 | 4.53 | 2.53 | 90.28 |
| *Oithona* | 7,523 | 3.32 | 1.86 | 100.00 |
| *Euterpina* | 4,127 | 1.82 | 1.02 | 77.78 |
| *Farranula* | 3,759 | 1.66 | 0.927 | 87.50 |
| *Centropages* | 3,379 | 1.49 | 0.833 | 83.33 |

% Total Copepods/Total Zooplankton—55.92%

"Other Holoplankton"

| Organism | Total Count (organism/m³) | % Total "Other Holoplankton" | % Total Zooplankton | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| Tintinnid | 22,560 | 38.08 | 5.56 | 25.00 |
| *Oikopleura* spp. | 19,453 | 32.84 | 4.80 | 90.28 |
| Ostracod | 3,399 | 5.74 | 0.838 | 79.17 |
| *Sagitta* immature | 3,258 | 5.50 | 0.804 | 93.06 |
| *Lucifer faxoni* | 2,770 | 4.68 | 0.683 | 76.39 |
| Foraminifera | 1,973 | 3.33 | 0.487 | 41.67 |
| *Sagitta inflata* | 1,055 | 1.78 | 0.260 | 63.89 |
| *Doliolum* spp. | 992 | 1.67 | 0.245 | 31.94 |
| *Sagitta helenae* | 894 | 1.51 | 0.220 | 79.17 |
| *Evadne* spp. | 669 | 1.13 | 0.165 | 37.50 |

% Total "Other Holoplankton"/Total Zooplankton—14.61%

MEROPLANKTON—% Total Meroplankton/Total Zooplankton—29.48%

| Organism | Total Count (organism/m³) | % Total Meroplankton | % Total Zooplankton | % Frequency of Total Samples (N = 72) |
|---|---|---|---|---|
| Ophiopluteus | 49,385 | 41.32 | 12.18 | 41.67 |
| Cirriped nauplii | 19,677 | 16.46 | 4.85 | 80.56 |
| Gastropod veliger | 8,934 | 7.48 | 2.20 | 98.61 |
| Echinopluteus | 8,394 | 7.02 | 2.07 | 40.28 |
| Crab zoea | 6,557 | 5.49 | 1.62 | 100.0 |
| Penaeid protozoea | 5,102 | 4.27 | 1.26 | 87.50 |
| Polychaete larvae | 4,240 | 3.55 | 1.05 | 86.11 |
| Cirriped cypris | 3,084 | 2.58 | 0.761 | 81.94 |
| Bivalve veliger | 2,826 | 2.36 | 0.697 | 75.00 |
| Unidentified eggs | 2,009 | 1.68 | 0.495 | 54.17 |
| Terebellid larvae | 1,655 | 1.38 | 0.408 | 40.28 |

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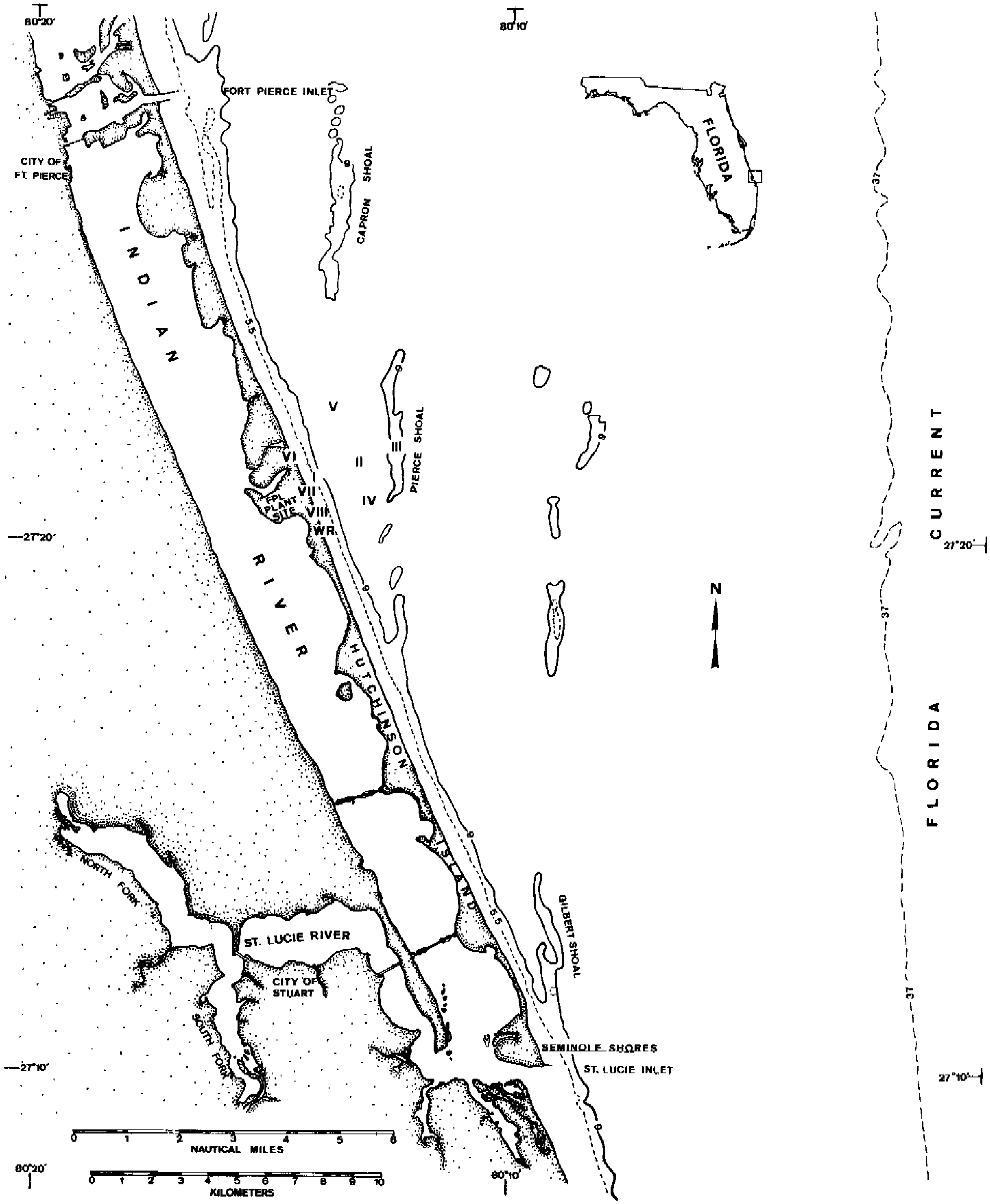


Figure 1. Study area, showing station locations.

TABLE 1. SPECIES LIST AND STATION OCCURRENCE OF MARINE ALGAE COLLECTED AT HUTCHINSON ISLAND, FLORIDA. SEPTEMBER 1971 THROUGH AUGUST 1974.

| | First Year | | | | | Second Year | | | | | Third Year | | | Worm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genus and Species | I | II | III | IV | V | I | II | III | IV | V | I | II | III | Reef |
| Chlorophyta | | | | | | | | | | | | | | |
| *Acetabularia crenulata* Lamouroux | | | | | | | | | | | | + | | + |
| *Bryopsis* spp. | | | | | | | + | | | | | | | + |
| *Caulerpa cupressoides* (West) C. Agardh | | | | | | | | | | | | | | + |
| *C. fastigiata* Montagne | | | | | | | | | | | | | | + |
| *C. mexicana* (Sonder *ex* Kützing) J. Agardh | | | | | | | | | | | + | | | + |
| *C. prolifera* (Forsskål) Lamouroux | | | | | | | | | | | + | | | + |
| *C. racemosa* var. *latevirens* (Montagne) Weber-van Bosse | | | | | | | | | | | + | + | | + |
| *C. sertularioides* (Gmelin) Howe | | | | | | | | | | | | | | + |
| *Cladophora prolifera* (Roth) Kützing | + | + | | + | + | + | + | | | | + | | + | + |
| *Cladophora* spp. | + | | | | + | | + | | + | | | + | + | |
| *Codium decorticatum* (Woodward) Howe | | | | | | | | | + | | | + | | + |
| *C. intertextum* Collins *et* Harvey | | | | | | | | | | | | + | + | + |
| *C. isthmocladum* Vickers | | | | | | | | | | | | + | | + |
| *C. taylori* Silva | | | | | | | | | | | + | + | | + |
| *Enteromorpha flexuosa* (Wulfen) J. Agardh | | | | | | | | | | | | + | + | + |
| *Laimeda discoida* Decaisne | | | | | | | | | | | + | | | + |
| *Udotea flabellum* (Ellis *et* Solander) Howe | | | | | | | | | | | | | | + |
| *Ulva lactuca* Linnaeus | | | | | | | | | | | | + | + | + |
| *Valonia ventricosa* J. Agardh | | | | | | | | | | | + | + | | + |
| Phaeophyta | | | | | | | | | | | | | | |
| *Bachelotia fulvescens* (Bornet) Kuckuck | | | | | | | | | | + | | | | + |
| *Colpomenia sinuosa* (Roth) Derbes *et* Solier | | | | | | | + | | | | | | | + |
| *Dictyopteris delicatula* Lamouroux | | | | | | | | | | | + | | | + |
| *Dictyota dichotoma* (Hudson) Lamouroux | | + | | + | + | + | | | + | | + | | + | + |
| *D. divaricata* Lamouroux | | | | | | | | | | | | | + | + |
| *D. indica* Sonder | | | | | | | | | | | | + | + | |
| *Ectocarpus confervoides* (Roth) Le Jolis | | | | | | | + | | | | + | | | + |
| *Giffordia conifera* (Børgesen) Taylor | | | | | | | + | + | | + | | | | + |
| *G. mitchelliae* (Harvey) Hamel | | | | | | | + | | + | + | + | + | | |
| *Hydroclathrus clathratus* (C. Agardh) Howe | | | | | | | | | | | | | | + |
| *Padina vickersiae* Hoyt | | | | | | | | | | | | + | + | + |
| *Pocockiella variegata* (Lamouroux) Papenfuss | | | | + | | | | | | + | + | | + | |
| *Rosenvingea intricata* (J. Agardh) Børgesen | | | | | | | | | | | | | | + |
| *R. sanctre-crucis* Børgesen | | | | | | + | + | + | + | | | | | |
| *Sargassum filipendula* C. Agardh | + | + | | + | | | | | | | + | + | | + |
| *S. filipendula* var. *montagnei* (Bailey) Collins *et* Hervey | | + | | | | | | | + | | | + | + | |
| *S. fluitans* Børgesen | | | | | | | | | | | + | + | + | |
| *S. natans* (Linnaeus) Gaillon | | | | | | | | | | | | + | + | |
| *Sargassum* spp. | | | | | + | | | | | | | | | |
| *Spatoglossum schroederi* (C. Agardh) Kützing | | | | | | | | | | | | | + | + |
| *Sphacelaria furcigera* Kützing | | | | | | | + | | | | + | | | |
| Rhodophyta | | | | | | | | | | | | | | |
| *Acanthophora muscoides* (Linnaeus) Bory | | | | | | | | | | | + | + | + | |
| *A. spicifera* (Vahl) Børgesen | | | | | | | | | | | + | + | | + |
| *Acrochaetium sargassi* Børgesen | | | | | | + | + | | + | | | + | + | |
| *Acrochaetium* spp. | | | | | | | | | + | | | | | |
| *Amphiroa fragilissima* (Linnaeus) Lamouroux | | | | | | | | | | | + | + | + | |
| *Bostrychia radicans* f. *moniliforme* Post | | | | | | | | + | | | | | + | + |
| *Botryocladia occidentalis* (Børgesen) Kylin | | | | | | + | + | | + | + | + | + | + | + |
| *Bryocladia cuspidata* (J. Agardh) De Toni | + | | | | | | | | | | | | | |
| *Bryothamnion seaforthii* (Turner) Kützing | + | + | | + | + | + | + | | + | + | + | | + | + |
| *B. triquetrum* (Gmelin) Howe | + | | | + | + | + | + | | + | + | | | + | + |
| *Ceramium codii* (Richards) Feldmann-Mazoyer | | | | | | | | | | | | + | | + |
| *C. corniculatum* Montagne | | | | | | | + | | | + | + | | | |
| *C. fastigiatum* (Roth) Harvey | | | | | | | | | | | + | + | | + |
| *C. rubrum* (Hudson) C. Agardh | | | | | + | | + | | + | + | + | | | + |
| *Ceramium* spp. | + | | | | | + | | | + | | | | | |
| *Champia parvula* (C. Agardh) Harvey | | | | | | | | | | | | + | | + |
| *Chondria cnicophylla* (Melvill) De Toni | | | | | | | | | | | | + | | |
| *C. littoralis* Harvey | | + | | + | | + | + | + | + | + | + | + | | |
| *C. sedifolia* Harvey | | | | | | | | | | | + | | | |

TABLE 1. SPECIES LIST AND STATION OCCURRENCE OF MARINE ALGAE COLLECTED AT HUTCHINSON ISLAND, FLORIDA, SEPTEMBER 1971 THROUGH AUGUST 1974 (Continued).

| Genus and Species | First Year | | | | | Second Year | | | | | Third Year | | | Worm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | I | II | III | IV | V | I | II | III | Reef |
| Rhodophyta (continued) | | | | | | | | | | | | | | |
| *C. tenuissima* (Goodenough *et* Woodward) C. Agardh | | | | | | | | | | | | | + | |
| *Chondria* spp. | | | | + | | | + | + | | | | | | |
| *Chrysymenia enteromorpha* Harvey | | | | | | | | | + | | | + | | |
| *Compsopogon caeruleus* (Balbis *ex* C. Agardh) Montagne | + | | | | | + | | | | | | | | |
| *Crouania attenuata* (Bonnemaison) J. Agardh | | | | | | | | | | | | | | + |
| *Cryptonemia luxurians* (C. Agardh) J. Agardh | | | | | | | | | | | | | | + |
| *Dasya rigidula* (Kützing) Ardissone | | | | | | + | + | | | | | | + | + |
| *Dasya* spp. | | | | | | | | | + | | | | + | |
| *Dasyopsis antillarum* Howe | | | | | | | | | | | | + | | |
| *Eucheuma isiforme* (C. Agardh) J. Agardh | | | | | | + | | | | | + | + | | + |
| *Eucheuma nudum* J. Agardh | | | | | | | + | | | | + | | | + |
| *Eucheuma* spp. | | | | | | | + | | | | | | + | |
| *Galaxaura cylindrica* (Ellis *et* Solander) Lamouroux | | | | | | | | | | | | + | | + |
| *G. rugosa* (Ellis *et* Solander) Lamouroux | | | | | | | | | | | | + | | + |
| *Gelidium crinale* (Hare *ex* Turner) Lamouroux | | + | | + | | + | | | + | | | | | + |
| *Gelidium* spp. | + | | | | | | | | | + | | | | |
| *Gracilaria blodgettii* Harvey | | + | + | + | + | + | | | + | | | | | |
| *G. cervicornis* (Turner) J. Agardh | | + | | | | | | | | | + | | + | + |
| *G. compressa* (C. Agardh) Greville | | | | | + | | | | | | + | | | |
| *G. cylindrica* Børgesen | | | | | | | + | | | | + | + | + | + |
| *G. debilis* (Forsskål) Børgesen | + | + | | + | + | + | + | + | + | + | + | + | + | + |
| *G. ferox* J. Agardh | | | | | | | | | | | | | + | |
| *Gracilaria foliifera* (Forsskål) Børgesen | | | | | | + | + | + | + | | + | + | | + |
| *G. foliifera* var. *augustissima* (Harvey) Taylor | | | | | | | | | + | | | + | | |
| *G. mammilaris* (Montagne) Howe | + | + | | + | + | + | + | + | + | + | + | + | + | + |
| *G. sjoestedtii* (Kylin) Dawson | | | | | | | | | | + | + | + | + | |
| *G. verrucosa* (Hudson) Papenfuss | | | | | | | + | | + | | + | + | | + |
| *Gracilaria* spp. | | + | | | + | | + | | + | + | + | + | + | |
| *Halymenia agardhii* De Toni | | | | | | + | + | | + | | + | + | | + |
| *H. floresia* (Clemente) C. Agardh | + | + | | | + | + | | | + | | + | + | + | + |
| *H. floridana* J. Agardh | | | | | | + | + | | + | | | | + | |
| *Halymenia* spp. | | | | | | | | + | + | | | | | |
| *Heterosiphonia gibbesi* (Harvey) Falkenberg | | | | + | | | | | | | | + | + | + |
| *H. wurdemannii* (Bailey *ex* Harvey) Falkenberg | | | | | | | | | | | | | + | |
| *Hypnea cervicornis* J. Agardh | + | + | | + | + | + | | | | + | + | + | + | |
| *H. cornuta* (Lamouroux) J. Agardh | | | | + | | | | | | | | + | | |
| *H. musciformis* (Wulfen) Lamouroux | | | | | | | | | | | | + | | + |
| *H. spinella* (C. Agardh) Kützing | | + | | + | + | + | | | + | + | + | + | | + |
| *Hypnea* spp. | | + | | | | + | | | + | | + | | | |
| *Jania adhaerens* Lamouroux | | | | | | | | | | | | | + | + |
| *Jania capillacea* Harvey | | | | | | | | | | | | + | | |
| *Jania* spp. | + | | | | | | | | | | | | | |
| *Laurencia corallopsis* (Montagne) Howe | | | | | | | | | | | | + | + | + |
| *L. gemmifera* Harvey | | | | | | | | | | | + | | | |
| *L. obtusa* (Hudson) Lamouroux | | | | | | + | + | | | | + | + | | + |
| *L. papillosa* (Forsskål) Greville | | | | | | | | | | | | | + | |
| *Laurencia* spp. | | | | | | | | | | + | | | | |
| *Lomentaria baileyana* (Harvey) Farlow | | + | | + | + | + | + | | + | | | | | |
| *Neoagardhielea ramosissima* (Harvey *ex* Kützing) Wynne *et* Taylor | | | | | | | | | | | | + | + | + |
| *Polysiphonia subtilissima* Montagne | | | | | | | + | | | | + | + | | + |
| *Polysiphonia* spp. | + | + | | | | | + | | | + | | | | |
| *Pterocladia americana* Taylor | | | | | | | + | | | | | + | | |
| *P. bartlettii* Taylor | | | | | | | | | | | | + | | |
| *Rhodymenia occidentalis* Børgesen | | + | | | | | | | + | | | | | |
| *Rhodymenia* spp. | | | | | | | + | | | | | | | |
| *Soliera tenera* (J. Agardh) Wynne *et* Taylor | | | | + | + | + | + | | + | | + | | | + |
| *Spermothamnion gorgoneum* (Montagne) Bornet | | | | | | | | | | | | | | + |
| *Spyridia filamentosa* (Wulfen) Harvey | | | | | | | | + | | | | + | | + |
| *Wrangelia argus* Montagne | | | | | | | | | | | | + | | + |
| *Wurdemannia miniata* (Draparnald) Feldman *et* Hamel | | | | | | | | | | | | + | | + |