AB-101

ECOLOGICAL MONITORING
AT THE FLORIDA POWER & LIGHT CO.
ST. LUCIE PLANT

ANNUAL REPORT

1977

VOLUME 1

Prepared for

FLORIDA POWER & LIGHT COMPANY

MIAMI, FLORIDA

By

APPLIED BIOLOGY, INC.

ATLANTA, GEORGIA

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VOLUME 1

A. INTRODUCTION

BACKGROUND

This document has been prepared in response to the Nuclear Regulatory Commission's Environmental Technical Specifications found in Appendix B to Operating License No. DPR-67 for Unit No. 1 of Florida Power & Light Company's St. Lucie Plant.

In 1970, Florida Power & Light Company (FPL) was issued a construction Permit No. CPPR-74 by the United States Atomic Energy Commission (now Nuclear Regulatory Commission). This permit allowed construction of Unit No. 1 of the St. Lucie Plant, an 850-megawatt nuclear-powered electric generating station on Hutchinson Island in St. Lucie County, Florida. Unit 1 was placed on-line in March 1976. Plant operation was intermittent in 1976 but was base loaded throughout 1977, except for repair outages.

The St. Lucie Plant presently generates electricity with one 850-megawatt net electric pressurized water reactor. The condenser cooling water is provided by a once-through circulating water system which consists of intake and discharge pipes in the ocean linked by canals to the plant. Cooling water is drawn from the Atlantic Ocean through a vertical intake structure located 365 m (1200 ft) offshore. The intake structure is covered with a concrete velocity cap, the top of which is approximately 2.4 m (8 ft) below the water

surface. From the intake point, water is drawn into the intake canal through a pipe buried under the dunes. The 90-m (300-ft) wide canal carries the cooling water about 1500 m (5000 ft) to the plant intake structure where pumps provide 33,400 liters/sec (530,000 gal/min) of flow. The water moves through the intake screens, passes through the plant condensers, and is released into the discharge canal.

The design temperature rise of the water passing through the condensers is approximately 24°F (13.4°C). After leaving the plant, the heated water passes through a 60-m (200-ft) wide discharge canal before entering a pipe buried under a dune and the ocean floor. The water is carried about 365 m (1200 ft) offshore and discharged through a Y-shaped pipe 5 m (18 ft) below the water surface. The discharge pipe is located 730 m (2400 ft) north of the intake.

The Florida Department of Natural Resources Marine Research Laboratory in conjunction with FPL conducted preoperational baseline environmental studies of the marine environment adjacent to the St. Lucie Plant from September 1971 to July 1974. Applied Biology, Inc., was contracted by FPL in 1975 to conduct the operational phase of the ecological monitoring program at the St. Lucie Plant. A sampling program was designed in accordance with the Nuclear Regulatory Commission's Environmental Technical Specifications for St. Lucie Unit No. 1. Preliminary studies on fish populations in the plant's

cooling water canals began in December 1975; the complete sampling program was initiated in March 1976. Results of the 1976 study were submitted to FPL by Applied Biology, Inc., in the 1976 Annual Report entitled *Ecological Monitoring at the Florida Power & Light Co. St. Lucie Plant*. Data generated during the present study will be compared with results of the baseline study and the 1976 operational study to assess the effects of plant construction and operation on the major biotic communities in the nearshore marine environment.

AREA DESCRIPTION

The St. Lucie Plant is located on a 457.3-hectare (1130-acre) site on Hutchinson Island approximately midway between Ft. Pierce and St. Lucie Inlets on Florida's lower east coast (Figures A-1 and A-2). It is bounded on the east by the Atlantic Ocean and on the west by the Indian River, a shallow lagoonal estuary.

The Indian River is an integral part of the ecosystem in this area, being linked by tidal flushing to the Atlantic Ocean via Ft. Pierce and St. Lucie Inlets, and to Lake Okeechobee via the St. Lucie River and Canal.

Hutchinson Island extends 37.5 km between inlets and obtains a maximum width of 1.8 km at the plant site. Elevations approach 5 m atop dunes bordering the beach, then decrease to sea level in the mangrove swamps that are common on much of the western side. Island

vegetation is typical of southeast Florida coastal areas with dense stands of Australian pine, palmetto, sea grape, and spanish bayonet inhabiting the higher elevations, and mangroves in the lower elevations and swamps. Large portions of the interior mangrove communities have been extensively altered over past decades by county mosquito control practices. Large stands of black mangroves, including some on the plant site, have been killed by controlled flooding.

Coquinoid rock formations parallel much of the island off the ocean beaches and provide suitable substrata for intertidal accumulations of "worm reef." Worm reefs, which resemble stone, are formed of sand and mucus by colonial marine worms. A relatively extensive worm reef community lies approximately 0.5 km south of the intake pipeline. Relic worm reef formations protrude through present-day beaches along much of the island's southern end.

The ocean bottom offshore from the plant site consists entirely of sand and shell sediments with no reef obstructions or rock outcroppings. The unstable substrate limits the establishment of rooted macrophytes or attached benthic communities.

The Florida Current, which flows parallel to the continental shelf margin, begins to diverge from the coastline at West Palm Beach. At Hutchinson Island, the current is approximately 33 km offshore. Oceanic water associated with the western boundary of the current,

however, especially during summer months, periodically meanders over the inner shelf.

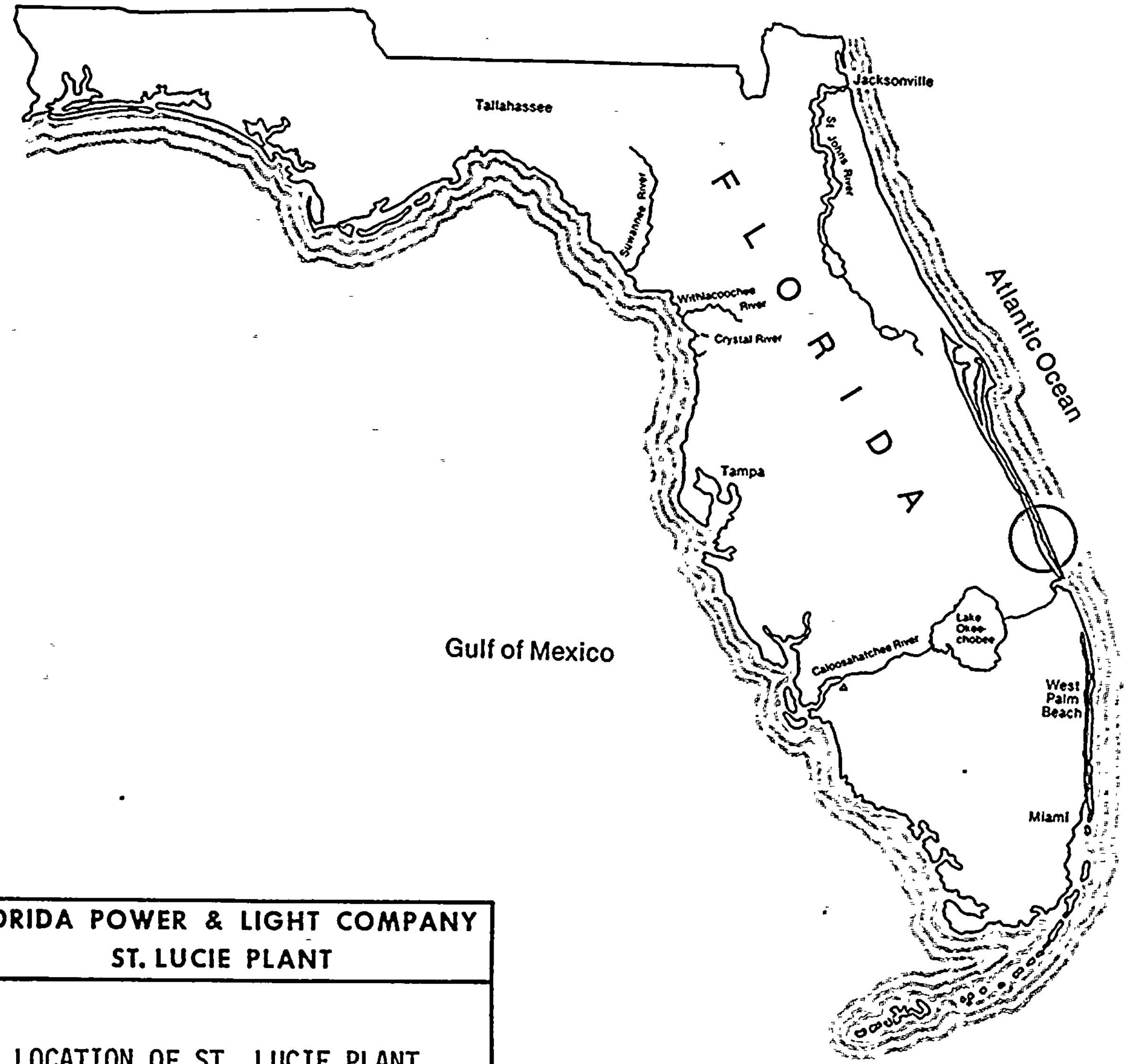
SAMPLING DESIGN

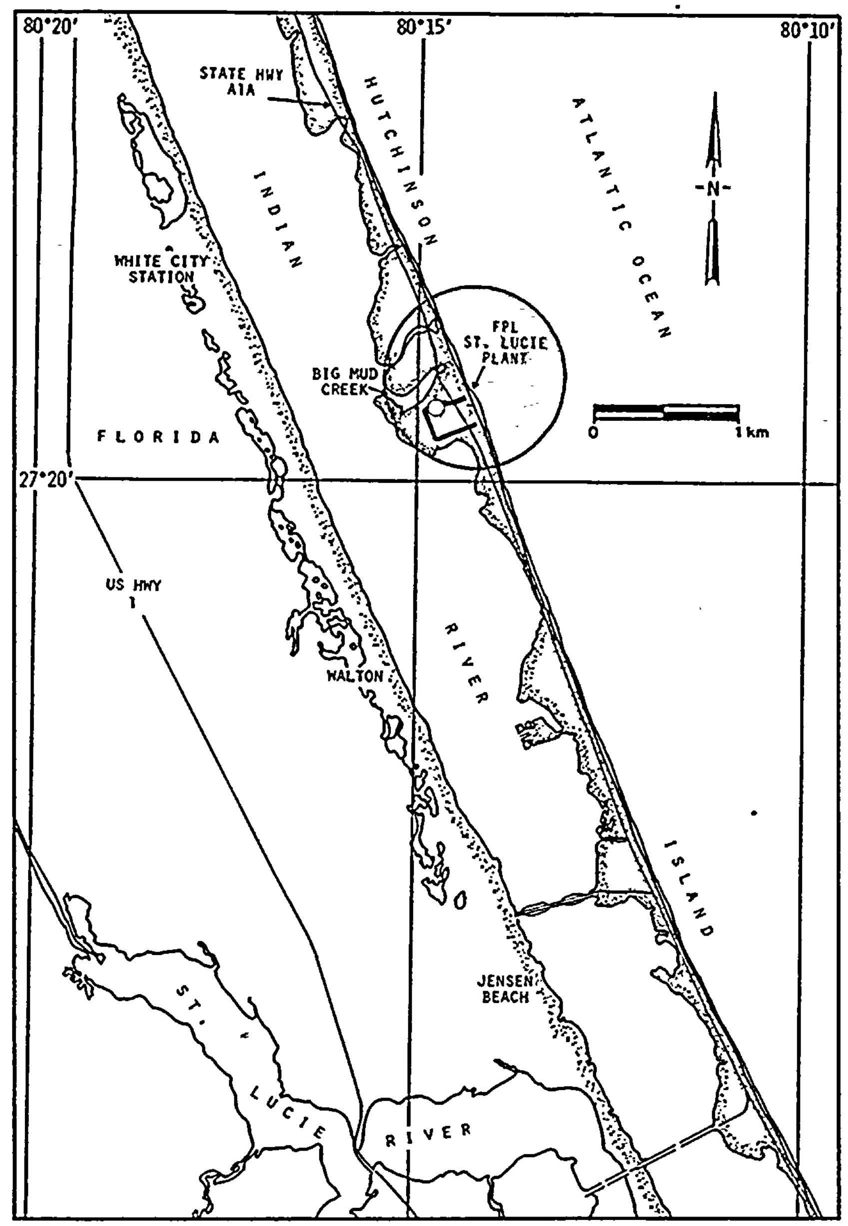
Systematic sampling was continued in 1977 according to the outline in Table A-1. To increase the efficiency of the study, some changes were made in the sampling design. These changes will be discussed in the appropriate sections of this report.

Selection of station locations was based on proposed configurations of the thermal plume provided by FPL and the locations of dominant macrohabitats established by the preoperational survey. Stations used in each phase of the study are shown on maps in the respective sections of the report.

A description of the offshore stations is given in Table A-2. Stations 1, 2 and 3 were selected to be perpendicular to the beach on a transect coincident with the postulated slack current thermal plume configuration. Additional offshore stations (4 and 5) were established to the south and north, respectively, of Station 2. A control station (Station 0) was established south of the plant discharge.

Three beach seine stations were located near shore, at points north of the discharge (Station 6), south of the intake (Station 8), and midway between those two points (Station 7). Six additional stations were established in the plant intake (Stations 11, 13, 14, and 15) and discharge (Stations 12 and 16) canals.



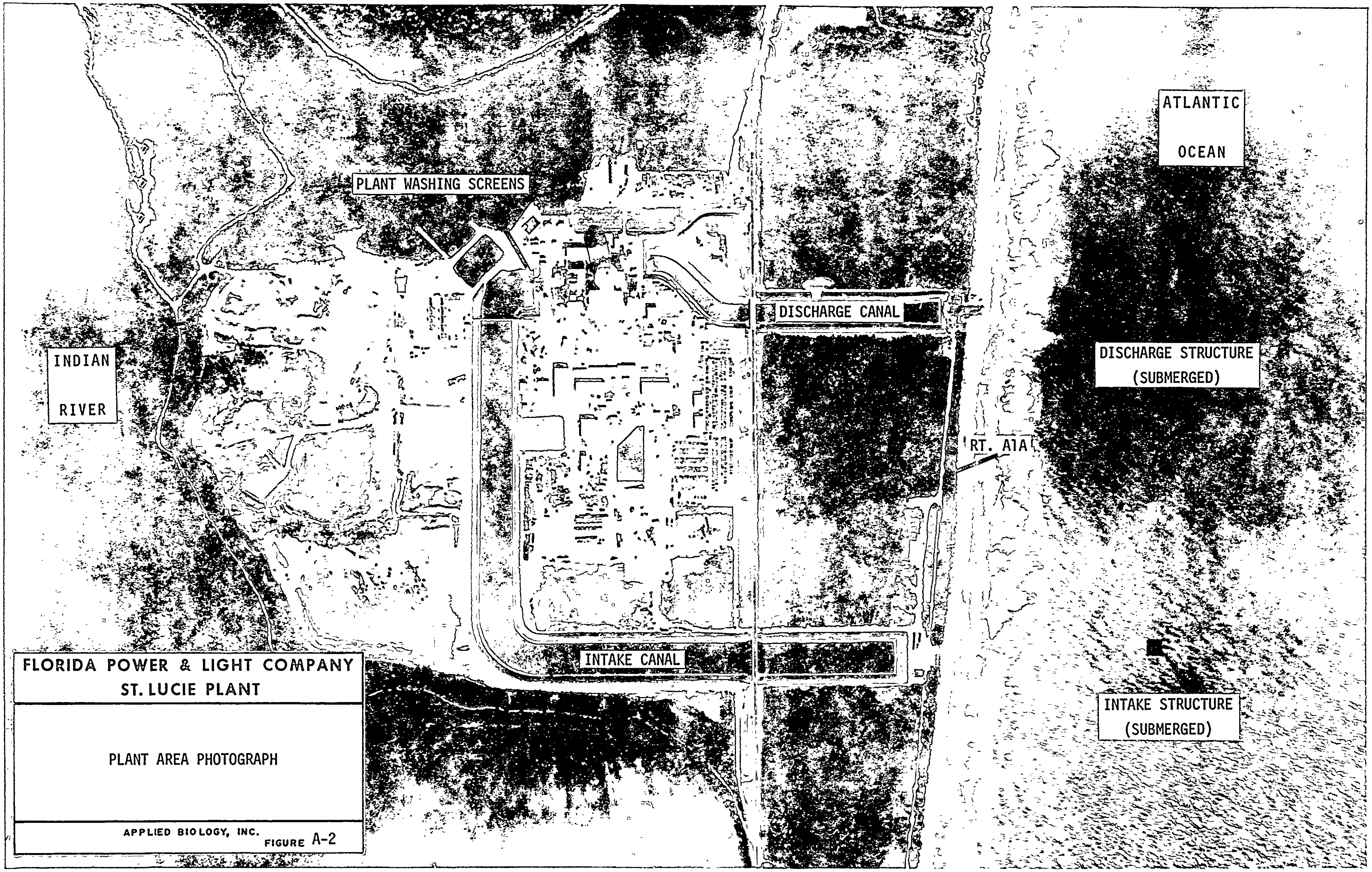


FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT

LOCATION OF ST. LUCIE PLANT

APPLIED BIOLOGY, INC.

FIGURE A-1



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ST. LUCIE PLANT

PLANT AREA PHOTOGRAPH

APPLIED BIOLOGY, INC. FIGURE A-2

TABLE A-1

BIOLOGICAL SAMPLING SCHEDULE (NUMBER SAMPLES/STATION)
ST. LUCIE PLANT
1976-1977

Section	Offshore									Intake				Discharge		Sampling frequency
	0	1	2	3	4	5	6	7	8	11	13	14	15	12	16	
Adult fish-beach seine							3	3	3							monthly
Adult fish-gill net	1	1	1	1	1	1					1S	1S	1S		1S	monthly
											1B	1B	1B		1B	monthly
Adult fish-otter trawl	1	1	1	1	1	1										monthly
Aquatic macrophytes	2	2	2	2	2	2										quarterly
Benthos-trawl	1	1	1	1	1	1										monthly (with adult fish)
Benthos-grab	4	4	4	4	4	4										quarterly
Ichthyoplankton (fish eggs & larvae)	2	2	2	2	2	2				2				2		twice monthly
Impingement										3						twice weekly (with pumps on)
Phytoplankton and chlorophyll	2S	2S	2S	2S	2S	2S				2S				2		monthly
	2B	2B	2B	2B	2B	2B				2B						monthly
Thermograph monitoring										Cont.				Cont.		monthly
Water quality & nutrients	2S	2S	2S	2S	2S	2S				2S				2		monthly
	2M	2M	2M	2M	2M	2M										monthly
	2B	2B	2B	2B	2B	2B				2B						monthly
Zooplankton	2S	2S	2S	2S	2S	2S				2ø				2ø		monthly
	2B	2B	2B	2B	2B	2B										monthly

S = surface sample
M = mid-depth sample
B = bottom sample
ø = oblique tow
Note: Stations 9 and 10 are part of another study.

TABLE A-2

DESCRIPTION OF OFFSHORE STATIONS
ST. LUCIE PLANT
1977

Station	Latitude-Longitude	Geographic location	Mean sampling depth (m)	Substrate
0 (control)	27°19.1'N 80°13.2'W	4.7 km S of plant discharge, on beach terrace	8.2	Fine gray sand
1	27°21.1'N 80°14.1'W	0.5 km offshore, at seaward margin of beach terrace	7.6	Gray, hard-packed fine sand
2	27°21.4'N 80°13.3'W	1.5 km E-NE of Station 1 in offshore trough, approximately midway between beach terrace and offshore shoal	11.3	Shell hash
3	27°21.7'N 80°12.4'W	3 km from Station 1, on coincident compass heading, atop Pierce Shoal	7.6	Medium sand with few large shell particles
4	27°20.6'N 80°12.8'W	1.6 km S-SE of Station 2 and 0.6 km west of southernmost tip of Pierce Shoal, in offshore trough	11.3	Shell hash
5	27°22.9'N 80°14.0'W	2.2 km N-NE of Station 2 and 2.1 km E of beach, in offshore trough	11.3	Shell hash

B. FISH AND SHELLFISH

INTRODUCTION

Fishes distribute themselves within the aquatic ecosystem according to their physiological limitations and biological needs. A consequence of this distribution has been the development of communities or assemblages of fishes which are dependent on the physical conditions and resources of an area. The aquatic communities off Hutchinson Island are unique in that they are transitional between temperate faunas to the north and tropical faunas to the south. Natural variations in the physical conditions, such as seasonal temperature changes or fluctuations in the proximity of the Florida Current to the coast, could result in variations in the composition or abundance of fishes in the area. Similarly, although on a much more localized scale, effects on fish assemblages could also result from operations of the St. Lucie Plant.

This study, a continuation of the study initiated by Applied Biology, Inc., in December 1975, was to further document the composition and abundance of fishes in the vicinity of the St. Lucie Plant and to evaluate habitat, distribution and life history aspects of these fishes. Data obtained were to be used in conjunction with data from the 1976 (ABI, 1977) and baseline (Futch and Dwinell, 1977) studies to determine if plant operations had any significant effect on the fishes in the area.

The evaluation of the ichthyofaunal assemblage and the potential effects of plant operation required studies of both inshore and oceanic areas. Inshore samples were taken in the immediate vicinity of the plant. This sampling included collecting impinged specimens at the intake traveling screens and gill netting in the intake and discharge canals. Oceanic samples were taken by gill netting, trawling and beach seining. In analyzing oceanic samples, emphasis was placed on the possible effects of the offshore thermal discharge upon migratory fishes of sport and commercial importance. Ichthyoplankton sampling was conducted both inshore and offshore to evaluate entrainment and thermal discharge effects, respectively.

Prior to a discussion of the specific sampling techniques employed, and the results obtained, a brief overview of the ichthyofaunal assemblage is given. This overview is followed by a generalized account of fish habitats and trophic interrelationships (the food chain) in the vicinity offshore from Hutchinson Island.

The Ichthyofaunal Assemblage

The most comprehensive list of fishes of the Indian River and adjacent waters has recently been compiled by Gilmore (1977)[a], based

[a]Other, less comprehensive studies included those of Evermann and Bean (1897), V.G. Springer (1960), S. Springer (1963), Gunter and Hall (1963), Christensen (1965), Anderson and Gehringer (1965) and Bullis and Thompson (1965). Briggs (1958) included this area in his distributional study of Florida fishes, although he did not collect there.

on extensive collections and literature review by the Harbor Branch Foundation (see also Gilmore, 1974; Jones et al., 1975). Regarding this ichthyofauna, which includes that of the Hutchinson Island area, Gilmore (1977) stated that:

> The richness of this fauna appears to be directly affected by water temperature moderation and recruitment via the Florida Current, moderate inshore salinities, and the transitional zoogeographic setting of the study area. The Indian River region encompasses several biotopes, all of which affect the distribution and composition of the local fish fauna. The study area is broad (latitude 27°00-29°00'N) and includes nearly all of the aquatic fish communities in east Florida... The fish distribution is further complicated by its transitional nature, as the warm-temperature Carolinian and the tropical Caribbean fish faunas overlap considerably here; 28% of the fish fauna is considered tropical, 22% are warm-temperate, and 50% are eurythermic tropicals and continental species having a wide distribution both north and south of this region.
>
> These [tropical] fishes originated in the Caribbean faunal province and apparently came into the region via the Florida Current. Warm-temperate Carolinian fishes are more commonly found in the open bottom continental shelf biotope... Distribution of the Carolinian species must be explained by adult migration, with some aid from larval fishes transported via southbound counter-currents of the Florida Current and other inshore water mass movements.

The Harbor Branch Foundation studies established that at least 654 species of fishes occur in the Indian River lagoon, its tributaries, and the adjacent continental shelf at depths less than 200 m,

and that at least 704 species should eventually be collected or identified from this area (Gilmore, 1977; Gilmore, personal communication). This research indicated that probably less than 40% of the fish species from the Indian River and adjacent areas were characteristic of the surf zone, open bottom and neritic zone (G. Gilmore, personal communication), the three relatively distinct oceanic habitats within the influence of normal operations of the St. Lucie Plant. The majority of the species were from the rich grass flats within the Indian River lagoon, from around inlets and inshore reefs which provide cover, and from the offshore reefs. These habitats were either of limited extent (e.g., worm reefs) or beyond the influence of normal operations of the St. Lucie Plant.

The ichthyofauna offshore from the St. Lucie Plant has been studied by Applied Biology, Inc., since December 1975 and by the Florida Department of Natural Resources between September 1971 and August 1974.

Applied Biology, Inc., personnel have collected or observed almost 240 species of fishes in the vicinity of the plant (Appendix Table J-1A). A total of 75 fish species were found during the baseline study conducted by the Florida Department of Natural Resources (Futch and Dwinell, 1977). These fishes were collected by trawl (42 hr effort) and beach seine (9 hr) and were, for the most part,

the more common species in the area. Only six species[a] found during the baseline study have not been collected by Applied Biology. All species which are common in the area have probably been found. Future additions to the species list will include the rarer forms such as transients through the area, strays from deeper waters offshore, and tropical forms carried inshore with eddies from the Florida Current.

Fish Habitats

Three relatively distinct oceanic habitats were within the influence of normal operations of the St. Lucie Plant: surf zone, open bottom and neritic zone.

The surf zone was characterized by water turbulence and shifting sand substrate. Besides the turbulence, a major limiting factor on fish diversity in this habitat was the lack of cover over the bottom. Only one small worm-reef protrusion occurred in the vicinity of the plant, and the amount of cover it provided for fish in the surf zone was minimal. Little or no attached macroscopic vegetation grew in the surf zone, with the exception of that found on the worm reef. Fishes capable of thriving in this turbulent zone were limited to a few taxa. Characteristically, these were the bottom feeding carnivores:

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[a]Clearnose skate (*Raja eglanteria*), northern kingfish (*Menticirrhus saxatilis*), star drum (*Stellifer lanceolatus*), Atlantic threadfin (*Polydactylus octonemus*), freckled driftfish (*Psenes cyanophyrys*) and spotted driftfish (*Ariomma regulus*).

drum (sand drum and kingfish), threadfin and pompano that feed on the burrowing invertebrates such as sand fleas and coquina, which occurred in this habitat. Other fishes, such as the planktivorous herrings and anchovies and the piscivorous jacks, Spanish mackerel and bluefish, are occasionally caught in the surf zone, but are primarily transients. Certain of these transients, particularly herring and anchovy, often occurred in large numbers.

The open bottom beyond the surf zone consisted of a relatively homogeneous shell hash and, like the surf zone, lacked vegetation or other cover that could provide shelter for fishes. Dominant fishes on the open bottom were the flatfishes (flounder, sole and tonguefish), cusk-eels and searobins. These forms have adapted to living in or on the ocean bottom. Protective coloration and the burying behavior of the flatfish, the hard and spiny exterior of the searobin, and the burrowing nature of the cusk-eel provide some protection against predation on these generally small bottom-dwellers. Other common species occurring on or just over the bottom were sand-perch, grunt, mojarra and lizardfish. Additionally, certain taxa were seasonal in occurrence, as evidenced by the large number of juvenile drum collected (by bottom trawl) in November.

The neritic zone consists of the coastal area of open water beyond the surf zone and above the bottom. The vast majority of the

fishes found during this study in the vicinity of the St. Lucie Plant were either residents of, or transients through, the neritic zone. Characteristic of the neritic zone were the herrings and anchovies, sharks, mackerels, bluefish and jacks. Many of the fishes found in this zone were of sport or commercial importance, such as the mackerels, bluefish and tuna, which make large north-south seasonal migrations. Other taxa, such as mullet, menhaden and certain drum, make seasonal migrations from the Indian River lagoon out into neritic waters to spawn. In addition, the Florida Current provides a continuous source of recruitment of tropical forms from south Florida and the Caribbean into the Hutchinson Island area.

Trophic Interrelationships: The Food Chain

The lack of macroscopic vegetation in the open oceanic area offshore from the St. Lucie Plant, in sharp contrast with the extensive grass flats in the adjacent Indian River lagoon, results in a food chain based almost entirely on microscopic algae (phytoplankton). The phytoplankton use solar energy and dissolved nutrients, and, through photosynthesis, become available to animals as food.

The primary consumers of the phytoplankton are the zooplankton. These animals are also microscopic or semi-microscopic in size and vast in numbers. Some larval fishes also feed to some extent on microalgae (Lebour, 1924) and a few, such as menhaden with their

exceptionally fine filtering apparatus, feed partly on diatoms and dinoflagellates throughout life (Bigelow, 1925).

It is extremely difficult to obtain measurements of the relative volumes of plants and animals in the sea, although it is obvious that the mass of plant material produced each day must be considerable to support the grazers. In turn, the grazers of the neritic zone accomplish two important ends: first, the utilization of the primary food and, second, the transformation of this primary food into animal substance of size sufficiently large to be caught and utilized by carnivorous forms (Sverdrup et al., 1942). The large number of carnivores in the neritic zone is evidence of the abundance of the grazers.

The plankton feeders either pick the individual zooplankters from the water or are equipped with some type of screening device (e.g., gill rakers in certain fishes) through which the water is passed while the small organisms are retained as food. Depending on the fineness of the screening device, phytoplankton and detritus may also be retained and ingested. Differences between these two methods of feeding are based primarily on the relative degree of selectivity involved. Many of the copepods (within the zooplankton), barnacles, mussels, clams and sponges indiscriminately filter plankton from the water. On the other hand, certain copepods, the arrow worm and ctenophores are active predators which seize zooplankters

(and larval fishes) that drift within their reach. Among the plankton feeding fishes are the herrings and anchovies, which either select out individual zooplankters or filter indiscriminately with the aid of the gill rakers.

The plankton feeding fishes, such as the herrings and anchovies, generally occur in great abundance and provide the link between the zooplankton and the larger predators. These larger predators are the fishes most familiar to man, such as the sharks, mackerels, bluefish, jacks and billfish.

Another group of organisms within the oceanic food chain, and equally vital to the entire system, consists of the detritus feeders, browsers and scavengers. Although these forms may be separately defined, they all feed more or less indiscriminately upon living or dead organic matter and are combined for purposes of this report. The majority of the benthic invertebrates are found in this assemblage: polychaetes, echinoderms, gastropods and several crustaceans including crabs, shrimps, amphipods and isopods. Many of the fishes, in turn, are considered "bottom-feeders" and prey on these benthic forms (and each other) both in the surf and over the open bottom. The more common fishes in this category are the flatfishes, searobins, cusk-eels, lizardfish, pompanos and drums.

As implied in the preceding discussion, the aquatic flora and fauna off Hutchinson Island, whether the smallest plant or the largest fish, are intricately interrelated. Additional, and often more specific, trophic interrelationships will be discussed in following sections of this report.

IMPINGEMENT

Materials and Methods

The intake structure consists of four bays, each with a bar grill, a traveling screen, a circulating water pump, and auxiliary equipment. Pumps at the intake structure provide a total maximum flow of 2×10^6 liters/min (5.3×10^5 gal/min). The approach velocity to each bay is approximately 30 cm/sec (1 ft/sec; FPL, 1971). The traveling screens have a mesh size of 9.5 mm^2 (0.4 in^2) Organisms impinged on these screens are washed into a collecting basin and do not survive.

Impingement sampling was conducted approximately twice weekly. Each 24-hour sampling period was divided into three consecutive 8-hour segments: 0100 to 0900, 0900 to 1700, and 1700 to 0100 hr. Data from each time period were analyzed by one-way analyses of variance to determine the significance of diel variations.

Specimens washed off the traveling screens were collected in a 2.9-m^3 (3.8-yd^3) basket of 9.5-mm^2 (0.4-in^2) mesh. Specimens were

identified to species, counted, measured to the nearest millimeter, and weighed to the nearest gram. Standard length (SL), the distance from the tip of the snout to the base of the tail, was measured for most fishes. Total length (TL) was measured for fishes with indiscernible tail fins. Carapace (shell) length was measured for shrimp and lobster; carapace width was recorded for crabs. Although fishes and shellfishes were often individually weighed and measured, these were combined in the Appendix tables to form broad size classes within each species and reported as the number of individuals, range of standard lengths and total weight.

On the few occasions when several hundred individuals of the same species were found (e.g., anchovy and tomtate), a representative aliquot was generally taken. Ten to 25% of the specimens were counted and weighed, the range of lengths was recorded and then all the individuals were weighed. The total number of individuals was calculated by:

$$N = \frac{W}{W_1} \times N_1$$

where: N = total number of individuals

W = total weight

N_1 = number of individuals in aliquot

W_1 = aliquot weight

The taxonomic nomenclature for fishes was in accordance with Bailey et al. (1970), with the exception of a few changes made in more recent literature.

Only the shellfishes of commercial importance were considered for this report. These were shrimp (*Penaeus* spp., *Trachypenaeus* spp. and *Sicyonia* spp.), blue crab (*Callinectes* spp.), stone crab (*Menippe mercenaria*) and spiny lobster (*Panulirus argus*).

The species data detailed in the Appendix tables are summarized by category or taxon in the text (both for impingement data and those collected by other methods). Categories or taxa are groups of closely related fishes. These are generally fishes of the same species, genus, or family, although closely related families (e.g., the three families comprising the flatfish taxon) were also combined on occasion.

Results and Discussion

A total of 98 samples was collected and analyzed during 1977. Sampling time comprised 28.9%[a] of plant operation time during the year. The results of each sample include the number of individuals, length ranges and weight for each species collected during the three diel time periods, and are presented in the Appendix (Tables J-1 through J-98). These data are summarized in Table B-1.

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[a] $\frac{\text{98 24-hr samples}}{\text{339 days per yr on-line}} \times 100$

Fish

Fishes were collected during almost every sampling period and averaged 223 individuals and 2.7 kg (6 lb) per day. Impingement rates were low (<50 fish per day) at the start of the year, increased in February and March, and then declined for most of May through July (Figure B-1). The highest number of fishes (7567) for a single day was impinged in late August. The number of fishes collected then decreased through September and was usually less than 100 individuals per day through the remainder of the year.

Impingment rates based on biomass (kg per day) coincide with rates based on the number of fishes, with the exception of May through early June samples (Figure B-2). Samples during this time each included from one to 15 crevalle jack. These fishes ranged in size from 235 to 407 mm SL and averaged about 800 g (1.8 lb) in weight. In other words, fish biomass was high relative to the number of individuals found. This species will be further discussed elsewhere in this section.

Based on a sample size of 28.9%, the extrapolated total fish impingement during 1977 was 74,754 individuals and 915 kg (2015 lb). The extrapolated total fish impinged during 1977 would have been 80,612 individuals and 987 kg (2171 lb) if the plant had been on-line 365 days (sample size = 26.8%). For comparative purposes[a], the commercial

[a]Although very few commercial species were found during impingement sampling, commercial landings data are available and provide a means of placing the biomass of impinged fishes in perspective.

landings of finfish on Florida's east coast totaled 15.8 million kg (34.8 million lb) in 1975, the latest year for which landings data are available. Fish caught in Martin and St. Lucie Counties comprised about 3.5 million kg (7.8 million lb) of this total (NOAA, 1977).

The predominant fishes collected during impingement sampling were members of the grunt (Pomadasyidae) and anchovy (Engraulidae) families, based on the numbers of individuals collected. Based on biomass, the predominant fishes were jack (Carangidae) and grunt.

The grunt family comprised 50.3% of the total number of fishes collected and 31.1% of the biomass (Table B-2). Although nine species of grunt have been collected in the vicinity of the St. Lucie Plant, the tomtate (*Haemulon aurolineatum*) is by far the most abundant. This species is common in the neritic zone, on offshore reefs and surf-zone reefs; it is of frequent occurrence around inlets and on the grass flats in the Indian River (Gilmore, 1977). Tomtate feed on annelid worms, molluscs, crustaceans and some small fish (Böhlke and Chaplin, 1968). Although of forage value, its maximum size is only about 230 mm (9 in), and it is not of sport or commercial importance.

The tomtate was the most abundant species in the impingement samples, and accounted for over 99% of the catch on 29-30 August, when the largest amount of fishes was found (Figures B-1 and B-2).

This high rate of tomtate impingement was coincident with a temporary increase in the rate of chlorination from 682 kg per day to 1136 kg per day (1500 to 2500 lb per day). Corrective measures (i.e., monitoring of the intake screens and residual chlorine levels) have since been initiated when increased chlorination was necessary, and no comparable impingement rates have occurred.

Anchovies comprised 28.0% of the total number of fishes collected but, because of their relatively small size, only 3.1% of the total biomass (Table B-2). Seven species of anchovy have been found in the vicinity of the St. Lucie Plant (Appendix Table J-1A), although only the longnose, bay and Cuban anchovies (*Anchoa nasuta, A. mitchilli* and *A. cubana,* respectively) are particularly abundant. Anchovies were very abundant during the early part of the year and accounted for the numerical peaks seen in February and March (Figure B-1). They are common to abundant in the neritic zone, surf zone, open sand bottom and in the Indian River over the grassflats and around mangroves. The bay anchovy is even found in freshwater tributaries and canals (Gilmore, 1977). These species are not directly used by man, but, because of their abundance and wide habitat distribution, are of major importance as forage for the larger food and sport species.

Jacks accounted for only 4.7% of the total number of fishes collected but were the predominant taxon based on biomass (40.9%); (Table B-2). This is a large family of fishes and 16 species have

been collected in the vicinity of the plant (Appendix Table J-1A). The vast majority of jacks in the 1977 impingement samples were the previously mentioned crevalle jacks; second most abundant were the Atlantic bumper (*Chloroscombrus chrysurus*). The commercially important Florida pompano (*Trachinotus carolinus*) is also a member of this family; although fairly common in the surf zone, only one Florida pompano was found in the impingement sampling.

The crevalle jack and Atlantic bumper are common in the neritic and surf zones, on inshore and offshore reefs, over open sand bottom, and in the Indian River around inlets and grass flats (Gilmore, 1977). These predaceous species are not considered food fishes or of commercial importance. The crevalle jack is of limited importance as a sport fish because of its fairly large size and fighting ability.

Fishes other than grunt, anchovy and jack occurred in relatively low numbers. No other group of fishes individually comprised over 6.6% of the total number of fishes collected or 3.7% of the biomass (Table B-2). Few sport or commercial fishes were found.

Among the sport or commmercial fishes were the drum (Sciaenidae), represented by seatrout and spot in the impingement samples. Silver seatrout (*Cynoscion nothus*) were represented by 38 individuals, mostly found in January through March. Two weakfish (*C. regalis*) were also found. The spot (*Leiostomus xanthurus*) was represented by nine

individuals in the sampling. The spotted seatrout (*C. nebulosus*), an important food and sport fish common in the adjacent Indian River, has not been found in the impingement samples, nor in oceanic sampling by other methods (e.g., gill net). The red drum and black drum (*Sciaenops ocellata* and *Pogonias cromis*), also important sport fishes in the Indian River, were not collected.

Sport or commercial fishes other than drum included snapper with 10 individuals (primarily lane and yellowtail snapper) found during all impingement sampling periods, mullet (9 individuals), great barracuda (7), and Florida pompano (1). It is of importance that no snook, cobia, grouper, bluefish, billfish, king or Spanish mackerels were collected during the impingement surveys, although these species were known to occur offshore or in the surf zone.

The diel studies, conducted to determine if differences occurred between daytime and nighttime impingement rates, indicated that a mean of 37 fish per 8 hr were collected from 0100-0900 hr, 157 fish from 0900-1700 hr, and 27 fish from 1700-0100 hr. Although differences between time periods were not statistically significant (α=0.05) due to considerable variations within each time period between days sampled, more fish were impinged during the day (0900-1700 hr). This may be the result of differences in diel activity patterns of the fish (i.e., increased activity during the day), although plant-related effects, such as daytime chlorination, cannot be eliminated from consideration.

Comparison of the 1976 and 1977 impingement data was somewhat limited because of differences in plant operation mode. The plant was not on-line until April 1976 and was off-line during most of August and September, when the peak impingement rates were recorded in 1977. However, the two high impingement periods recorded in 1976 (May and October) did not recur in 1977. This indicates peak impingement rates may be isolated events rather than seasonal phenomena.

Based on sample sizes of 23.4[a] and 28.9% for 1976 and 1977, respectively, extrapolated total impingement while the plant was on-line was about 69,000 fishes in 1976 and 74,800 in 1977. Extrapolated total impingement if the plant had been on-line 365 days each year was about 131,100 fishes in 1976 and 80,600 in 1977 (sample sizes of 12.3% and 26.8%, respectively).

Based on the same sample sizes, the extrapolated total fish biomass was about 230 kg (506 lb) in 1976 and 915 kg (2015 lb) in 1977 while the plant was on-line; and 437 kg (961 lb) in 1976 and 987 kg (2171 lb) in 1977 if the plant had been on-line 365 days each year.

The above extrapolations indicate that impingement rates based on the number of fishes decreased from 1976 to 1977 while impingement

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[a] $\frac{\text{45 24-hr samples}}{\text{192 days per yr on-line}} \times 100$

rates based on fish biomass increased from 1976 to 1977. These differences between the two years are explained by the relative abundances of the different taxa making up the samples. Large numbers of small species, such as anchovy and Atlantic bumper, were predominant in the 1976 samples, while smaller numbers of generally larger species, such as tomtate and crevalle jack, predominated in 1977.

The variations in the relative abundances of the taxa could be due to large populations of certain species (particularly anchovy) in the intake canal prior to the plant's going on-line in 1976. The high populations could have occurred during canal construction when access was available from the surf and the Indian River. This concept of high populations and subsequent impingement when the plant went on-line is hypothetical; however, it is somewhat supported by the large anchovy impingement in 1976, which did not recur in 1977. If, in fact, an initial accumulation of fishes had occurred, the comparatively higher number of fishes impinged in 1976 should not recur.

Shellfish

A total of 7202 commercially important shellfishes weighing 30.8 kg (68 lb) was found during impingement sampling (Table B-2). Shrimp comprised 88.7% of the total number of shellfishes collected and 42.1% of the biomass. Blue crabs accounted for 10.1% of the number of shellfishes and 54.9% of the biomass. Stone crab and spiny lobster together comprised only 1.2 and 3.0% by number and biomass, respectively.

Shrimp (primarily *Penaeus* spp., although *Trachypenaeus* spp. and *Sicyonia* spp. were also included) were collected during almost every sampling period (Figure B-3) and averaged 65 individuals and 132 g per day. Based on a sample size of 28.9%, the extrapolated total shrimp impinged while the plant was on-line during 1977 was 22,110 individuals weighing approximately 45 kg (100 lb). Extrapolated shrimp impingement would be 23,840 individuals weighing 48 kg (106 lb) if the the plant were on-line 365 days. For comparative purposes, the commercial landings of shrimp on Florida's easy coast totaled 1.2 million kg (2.6 million lb) in 1975 (NOAA, 1977). Although only 2600 kg (5800 lb) of shrimp were recorded from St. Lucie County and none from Martin County in 1975, the wide-ranging shrimp boats operate off this area and land their catches elsewhere.

An average of 37 shrimp per 8 hr was found during the 0100-0900 hr period, 4 during 0900-1700 hr, and 22 during 1700-0100 hr. A significantly (α=0.05) higher number of shrimp were impinged during the 0100-0900 hr period than during the 0900-1700 hr period. Differences between other periods were not significant (α=0.05). Juvenile and adult penaeids are omnivorous bottom feeders and are generally most active at night (Eldred et al., 1971; Calder et al., 1974)[a]. These diel activity patterns account for the larger numbers of shrimp being collected at night in the impingement samples.

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[b]See Eldred et al. (1961) and Joyce and Eldred (1966) for pertinent references regarding this important resource.

Blue crabs (*Callinectes* spp.) were collected during 88% of the sampling periods (Figure B-3) and averaged 7.4 individuals and 173 g per day. The extrapolated total blue crab impinged during 1977 was 2516 individuals weighing about 59 kg (130 lb) while the plant was on-line, and would have been 2713 individuals weighing 63 kg (139 lb) if the plant had been on-line 365 days. Commercial landings of blue crab on Florida's east coast totaled almost 1.9 million kg (4.2 million lb) in 1975. About 2900 kg (6300 lb) were reported for Martin and St. Lucie Counties (NOAA, 1977).

Stone crab (*Menippe mercenaria*) and spiny lobster (*Panulirus argus*) impingement rates were low, each ranging from 0 to 3 individuals per day (Figure B-3). Totals of 59 stone crabs weighing 710 g and 26 spiny lobster weighing 227 g were collected during the year's sampling. These crustaceans were mostly juveniles and, being secretive in behavior, may have entered the intake seeking shelter. Stone crab and spiny lobster are commercially harvested in Martin and/or St. Lucie Counties, although the combined landings of these shellfishes are only about 0.3% of the Florida east coast total.

Impingement of commercially important shellfishes was similar during 1976 and 1977 studies in that shrimp had the most individuals impinged, then blue crab, stone crab and spiny lobster. Blue crab, then shrimp, were the most abundant each year based on biomass. However, the relative abundances of these four taxa varied between 1976

and 1977, particularly for shrimp and blue crab (Table B-2). These differences may be due to natural yearly variations or to the plant being off-line during most of July, August and September 1976, when large numbers of shrimp (relative to blue crab) were found in 1977. However, it can only be surmised that shrimp impingement would have been high during July through September 1976 had the plant been on-line.

INSHORE (CANAL) GILL NETS

Materials and Methods

Monthly gill net collections were taken at Stations 13 and 15 in the intake canal and Station 16 in the discharge canal (Figure B-4). More intensive effort in the intake than in the discharge was to determine if fishes were accumulating in the intake canal due to entrapment at the intake velocity cap. Station 14 was not sampled after March[a], when results (from 1976) indicated that sampling two stations near the same location was an unnecessary duplication of effort.

The gill nets measured 30.5 m in length by 3 m in depth (100 x 10 ft) and consisted of two 15-m (50-ft) panels of 38- and 51-mm (1.5- and 2-in) stretch mesh sewn end-to-end. One net was fished at the surface and one net at the bottom at each station. The nets at each station were fished at mid-canal and approximately 6 m (20 ft) apart to prevent entanglement (Figure B-5). Sampling duration was two consecutive 24-hour periods.

[a]Station 16 was inadvertently omitted in March instead of Station 14.

Fishes were removed from the nets and analyzed after each 24-hr period. Analyses were by the same methods described under Impingement: Materials and Methods.

Results and Discussion

Data collected during gill netting in the intake and discharge canals are summarized in Table B-3. The data by sampling period include the length ranges and total weight by species collected and are compiled in Appendix Tables J-99 through J-122. Four shellfishes were taken from the intake canal during these collections (one each of blue crab, speckled crab, shameface crab and spiny lobster). No shellfishes were collected from the discharge canal.

A total of 401 fishes was collected from the intake canal, and one from the discharge canal, during the 12 months sampled (Table B-4). No single species or taxon was particularly dominant relative to the others (Table B-3). Atlantic spadefish comprised 21.0% of the catch, followed by jack (13.9%), snapper (12.2%), porgy (11.7%), and grunt (10.2%). Other taxa collected each comprised less than 9% of the catch. These were mostly sharks and rays, mojarra, drum and mullet. Of particular significance is that no Spanish mackerel or bluefish were found. These important sport and commercial species together comprised 60% of the fishes collected by gill netting offshore (Table B-6), but they apparently avoid entrapment at the intake.

The collection data from the canal gill nets also indicate that certain taxa may become entrapped without necessarily becoming impinged. This appears to be the case for the sharks and rays, snapper, spadefish and mullet, all of which were represented by more individuals in the gill net collections than in the impingement collections.

The rate of capture, calculated as the number of fishes per net per 24 hours, was plotted for the last two years to determine if fishes were accumulating in the intake canal (Figure B-6). The catch per unit effort (CPE) was quite erratic but remained below 5 fish per net per 24 hours until April 1977. The CPE reached almost 6 on this occasion and then dropped back below 5 until November. In November the CPE climbed to 13.4, then dropped back below 5 in December.

Linear regression analyses yielded a line which showed a gradual increase in the CPE from October 1976 (when the plant was more or less consistently on-line) to December 1977 (Y=2.28 + 0.18X; Figure B-6). This slope appears unrealistic because of the unusually high number of fishes collected in November 1977. Because the CPE was again below 5 in December, no particular significance was attributed to the high November catch. Exclusive of the November sample, the slope of the line (Y=3.47 - 0.06X) indicates a slight decrease in the CPE since October 1976.

The taxa found during the 1977 inshore gill net survey were basically the same as those found during 1976, although the percentage composition of the different taxa varied (Table B-4). Spadefish made up 21% of the catch in 1977 and less than 1% in 1976. On the other hand, drum and mullet were the numerically dominant fishes in 1976 (25 and 20%, respectively) and comprised only 6 and 7% of the catch in 1977. Other taxa also varied but not to the extent of the above-mentioned species. Although differences in percentage composition resulted, at least in part, from the presence or absence of schooling species, any significance of these differences is not known.

The offshore inlet of the intake pipe is equipped with a velocity cap to maximize a horizontal direction of approach to the intake. Fishes are more likely to detect and avoid a horizontal flow, whereas they may become entrapped by a downward flow. As determined from canal gill net (and impingement) studies, the velocity cap appears to vary from being extremely effective in excluding some species (e.g., pompano, Spanish mackerel, and bluefish) to being of limited effect in excluding others (e.g., crevalle jack). However, if the previously hypothesized concept of high initial fish populations in the intake canal (resulting from access to the surf and the Indian River during construction) is correct, then the velocity cap might be more effective than the gill net and impingement data indicate.

OFFSHORE GILL NET

Materials and Methods

Monthly gill net collections were made at each of six offshore stations. Stations 1 through 5 were in the vicinity of the plant and Station 0 (control) was located to the south (Figure B-7). The offshore gill net measured 183 m in length by 3.7 m in depth (200 x 3 yd) and was made up of five 36.6-m (40-yd) panels sewn end-to-end. The mesh size of the panels varied, measuring 64-, 74-, 84-, 97-, and 117-mm (2.5-, 2.9-, 3.3-, 3.8-, and 4.6-in, respectively) stretch length. The net was fished on the bottom, perpendicular to shore, for 30 minutes at each station.

When large numbers of fishes were encountered, net retrieval was time-consuming, and the part of the net remaining in the water continued to catch more fish. During these months (January and October), fishing time at subsequent stations was reduced to 10 minutes. The catch data were adjusted to 30 minutes fishing and 10 minutes retrieval time, based on the actual time of operation recorded, to maintain uniform data presentation.

Specimens collected by gill netting offshore were analyzed by the same methods described under Impingement: Materials and Methods. Data by month and station were analyzed statistically by two-way analyses of variance. When significant differences occurred, Tukey's HSD (honest significant difference) comparison was used to identify which means were significant.

Results and Discussion

Data recorded during offshore gill netting surveys are summarized in Table B-5. Specific length and weight data, by station and month, are included in the Appendix (Tables J-123 through J-134).

A total of 1223 fishes was collected by this method during the 12 months sampled (Table B-6). Spanish mackerel and bluefish together comprised over 60% of these fishes. Three species of jacks accounted for over 23% of the fishes collected. All other species combined accounted for only a little over 16% of the total.

The largest total number of fishes (351) was collected from Station 1 (Figure B-7), near the point of discharge; closely followed by the number (305) collected at Station 0, the control; and Station 2 (304 fishes), the location directly out from the discharge. Although considerably fewer fishes were found at Stations 3, 4 and 5 (10 to 198; Table B-5), differences between stations were not significant (α=0.05) because of wide variations within each station between the different months sampled. There were, however, differences in the number of fishes collected between months for all stations combined. More fishes were collected in October than in any other month and, with the exception of January, the differences were significant (α=0.05). There were no significant differences when other months were compared.

Differences between the numbers of fishes collected at the different stations, and during different months, was primarily attributed to chance. That is, the taxa involved were mostly highly mobile schooling species, often migratory, and the data obtained during offshore gill netting probably reflect the fortuitous occurrence (or non-occurrence) of these fishes.

Differences between the numbers of fishes collected at the different stations could also be attributed to the station's location offshore. For example, if the forage species were most abundant near shore, they would attract the larger predators to the nearshore locations. The nearshore location of the discharge (Station 1) could explain the larger number of fishes collected there. Additionally, bottom relief provided by the discharge pipe, warmer water or turbulence at this location may attract the forage fishes and, in turn, the larger predators. However, when the actual numbers of fishes are compared, and considering the lack of statistical differences between stations, the number of fishes collected in the discharge area did not appear excessive.

The Spanish mackerel (*Scomberomorus maculatus*) comprised 33% of the fishes collected during offshore gill netting (Table B-5). Most Spanish mackerel were collected in October, which is the time of southward migration. The largest number of individuals (240) was found at Station 2. Although considerably fewer Spanish mackerel were found

at the other stations (including the discharge area), differences between stations are not significant (α=0.05) because of wide variations within each station.

The Spanish mackerel is a migratory species which moves north in the spring, spawns during the summer months in the northern part of its range (north of Cape Canaveral on the Atlantic coast), and migrates south in the fall (Wollam, 1970). Movements of these fishes are generally near shore, as evidenced by operations of the commercial fishermen. Commercial landings in 1975 in Martin and St. Lucie Counties totaled almost 1.5 millon kg (3.2 million lb), which represented 62% of the entire landings on Florida's east coast (NOAA, 1977).

King mackerel (*Scomberomorus cavalla*) were found only in October. Seventeen individuals were found at the control (Station 0) and 10 were found just south of the plant (Station 4). The king mackerel is very similar to the Spanish mackerel in its migratory habits; it moves north in the spring, spawns in the summer months north of Cape Canaveral on the Atlantic coast, and moves south in the fall (Wollam, 1970). In addition to its commercial importance (0.8 million kg or 1.8 million lb landed in Martin and St. Lucie Counties in 1975), this species is considered the most prominent marine fish in the sport fishery in Florida (Beaumariage, 1973). This species generally occurs farther offshore than the bluefish and Spanish mackerel, as evidenced by the

comparatively low number of individuals in our gill net collections. It is doubtful that plant operations would influence the movements of this species.

The bluefish (*Pomatomus saltatrix*) comprised 27% of the fishes collected by offshore gill netting. The majority (92%) of the bluefish were found in January (Table B-5). The highest number (175) of bluefish was taken in the area of the discharge (Station 1) and the second highest (140) at the control area (Station 0). Considerably fewer bluefish were found at the more offshore stations. Because the bluefish were found during only three months and varied widely in abundance, differences between stations and months are not significant (α=0.05).

Bluefish occur in the winter off the St. Lucie area. Northerly movement occurs during spring and summer (Beaumariage, 1969) and spawning occurs in offshore waters north of Florida in early summer (Deuel et al., 1966). Northward movement along the Florida coast is probably part of a spawning migration by that part of the population that extends its winter range into south Florida waters (Moe, 1972). This species is also of sport and commercial importance, a total of 242,000 kg (533,000 lb) being landed in Martin and St. Lucie Counties in 1975 (NOAA, 1977).

Most of the fishes collected other than mackerel and bluefish were jacks (family Carangidae). The most common jack collected was the Atlantic bumper, which comprised 17.2% of all fishes found (Table B-5). Other jacks found were blue runner, crevalle jack, banded rudderfish, Florida pompano, round scad and Atlantic moonfish. The only commercially important jack was the Florida pompano. Only five pompano were found and all in October: three in the area of the discharge (Station 1) and two north of the plant area at Station 5.

The only other fishes of sport or comercial importance found during gill netting operations were 33 spot and 12 menhaden. The spot (*Leiostomus xanthurus*) were almost all found in August south of the plant at Station 4. The menhaden (*Brevoortia* spp.) were mostly found in January and October north of the plant at Station 5.

During both 1976 and 1977 studies, the largest numbers of fishes were collected in October. The largest percentages of fish were collected at Station 1 in the vicinity of the discharge during both years, although the percentage catch at this station was lower in 1977 than in 1976 (29 vs 47%). This decrease was attributed to large numbers of crevalle jack at Station 1 during November and December of 1976, which did not recur in 1977.

Spanish mackerel and bluefish comprised higher percentages of the offshore gill net catch in 1977 than in 1976 (Table B-6). Jacks,

on the other hand, were more abundant in 1976. Little importance is placed on these differences, primarily because of the fortuitous occurrences of the taxa involved. However, this is not meant to rule out natural fluctuations in abundance, which could also alter species relative abundance. For example, there was considerably more activity by commercial mackerel fishermen in 1977 than in preceding years and large catches were indicated, although landings data are not yet available. Changes in species' percentage composition were not attributed to any plant-related effects.

TRAWL

Materials and Methods

Monthly trawl samples were taken at each of six offshore stations (Figure B-7). One 15-minute tow was made at each station with a 5-m (16.5-ft) semi-balloon bottom trawl of 12.7-mm (0.5-in) stretch mesh in the bag and 6.4-mm (0.3-in) stretch mesh in the cod end. Towing speed was 2-3 knots at each station. All trawling was conducted at night to reduce net avoidance by the fishes.

Fishes collected by trawl were analyzed by the same methods described under Impingement: Materials and Methods. Data by month and station were analyzed statistically by two-way analyses of variance.

Macroinvertebrate samples were obtained concomitant with the fish samples and are discussed in Section C.

Results and Discussion

Numbers of fishes collected during trawling surveys are given in Table B-7. Specific length and weight data, by station and month, are included in Appendix Tables J-135 through J-146.

A total of 2048 fishes were collected by this method during the 12 months sampled (Table B-7). Drum, which include the seatrout, accounted for almost 42% of the fishes found. The flatfish taxon (flounder, sole and tonguefish) comprised almost 11% of the fishes found. All other fishes each comprised less than 9% of the total.

The largest number of fishes (1049) was recorded at Station 1, the discharge area. Eight hundred twenty-four (824) of these fishes, or 79%, were found in the November trawl sample (Table B-7). Most of the fishes found on this occasion were juvenile (9-28 mm SL) seatrout and other drum. It is not known whether the collection of this many juveniles in the area was a chance occurrence, or whether they were attracted to the discharge vicinity.

The next largest number of fishes (339) was found north of the plant at Station 5; then Station 0, the control area (250 fishes); the two stations (2 and 3) farther offshore from the discharge area (175 and 127 fishes, respectively); and the area south of the plant at Station 4 (108 fishes). The differences in the numbers of fishes between stations are not statistically significant (α=0.05) because

of the wide variations within each station between the different months sampled. Additionally, differences were not significant (α=0.05) between months for the total number of fishes found at all stations combined.

Two thousand forty-eight (2048) fishes were found during trawling in 1977 compared to 656 in 1976 (Table B-8). This difference is due primarily to the large number (856) of juvenile drum found in 1977 and partially to the fact that two fewer months were sampled in 1976. The drum accounted for almost 42% of the fishes found in 1977 compared to only 2.0% in 1976 (Table B-8). Exclusive of drum, the relative abundances of the different taxa (flatfish, grunt, searobin, sand perch, mojarra, cusk-eel and lizardfish) in 1976 and 1977 were quite similar. The flatfish, grunt and mojarra enter the commercial landings in Martin and St. Lucie Counties (NOAA, 1977), although they are of minor importance compared to other species.

The differences between the number of fishes collected from March through December (January and February were not sampled in 1976) during 1976 and 1977, both overall and between months, were not significant (α=0.05).

BEACH SEINE

Materials and Methods

Beach seining was conducted each month at each of three stations: north of the discharge, between the discharge and intake adjacent to the plant, and south of the intake (Stations 6, 7 and 8, respectively; Figure B-7). Three replicate seine hauls were made at each station during each sample period.

The seine was 30.5 m in length by 1.8 m in depth (100 x 6 ft), with a mesh size of 12.7 mm^2 (0.5 in^2). It was heavily weighted along the bottom and had extra flotation along the top to maintain a hanging position under surf conditions. The rolled net was carried out to a depth of approximately 1.2 m (4 ft), deployed parallel to shore, and pulled in onto the beach with the ends perpendicular to shore.

Specimens collected by seining were analyzed by the same methods described under Impingement: Materials and Methods. Data by month and station were analyzed statistically by two-way analyses of variance. When significant differences occurred, Tukey's HSD (honest significant difference) comparison was used to identify the means that were significant.

Results and Discussion

The total numbers of shellfishes and fishes collected during beach seining surveys are presented in Table B-9. Specific length and weight data, by station, replicate and month, are included in Appendix Tables J-147 through J-158.

A total of 819 fishes was collected by this method during the 12 months sampled (Table B-9). Sand drum, kingfish and herring each comprised about 21% of the fishes collected. All other fish taxa each comprised less than 10% of the total. The speckled crab, a non-commercial species, was the only shellfish found.

The largest number of fishes (476) was found north of the plant at Station 6. Two hundred twenty (220) fishes were found in the surf adjacent to the plant at Station 7 and 123 were found south of the plant at Station 8. The number of fishes found at Station 6 was significantly higher ($\alpha=0.05$) than the number found at Station 8. There was no significant difference ($\alpha=0.05$) between Stations 6 and 7 or between Stations 7 and 8. The larger number of fishes found at Station 6 was due, at least in part, to a more regular bottom contour that enabled a more rapid transit of the net to the beach and a consequent reduction in the number of fishes escaping capture.

The majority (72%) of the fishes were collected during the summer months of June through September, when 140 to 156 fishes were found each month for all stations combined (Table B-9). From 2 to 64 fishes were found during the other months. Although more fishes were collected during the summer, the monthly (seasonal) differences were not statistically significant ($\alpha=0.05$).

The only species of major sport or commercial value found during beach seining operations was the Florida pompano (*Trachinotus carolinus*). Commercial landings on Florida's east coast amounted to 88,900 kg (195,500 lb) valued at $223,900 in 1975. Landings in St. Lucie and Martin Counties comprised slightly more than half of the Florida east coast total (NOAA, 1977). This species occurred in the beach seine hauls during most months, although they were never found in large numbers at any one time. Seven Florida pompano were found north of the plant, 10 adjacent to the plant, and 5 south of the plant. Juveniles and adults were about equally represented during the year.

The largest numbers of fishes were collected in the summer (June through September) during both 1976 and 1977. The largest percentages of the total catch were found north of the plant at Station 6 during both years (56 and 58% during 1976 and 1977, respectively). Station 7, adjacent to the plant, had 14% of the fishes in 1976 versus 27% in 1977; and Station 8, south of the plant, had 30% in 1976 versus 15% in 1977. Based on the 1976 data, the increase in abundance of fishes from south to north in 1977 appears coincidental. However, the fact that the majority of the fishes were found north of the plant during both years would appear to be more than coincidental. The higher abundance to the north may have been a sampling artifact (i.e., resulting from a more rapid transit of the net and fewer fish escaping at this location), or it may have resulted from some factor presently unknown. Regardless, it is doubtful that the thermal plume

would have a limiting influence on fish abundance to the south, because the prevailing water currents are to the north in the summer, when most of the fishes were collected.

The percentage compositions of the different fish taxa in 1976 and 1977 are shown in Table B-10. Herring were the predominant fishes in 1976. Sand drum, kingfish and herring were the predominant fishes in 1977. Most of these differences in relative abundance are attributed to the fortuitous occurrences of schooling species in the catch. For example, the herring collected in June 1976 at Station 8 and the anchovies found in July 1976 at Station 6 accounted for 52.6% of all fishes collected during beach seining operations that year. Also in 1976, all but three of the 101 spot collected were found in September; none were found in 1977. Exclusive of these particular taxa, the relative abundance of the different taxa was very similar between the two years.

ICHTHYOPLANKTON

A number of places along the Atlantic coast are known to be used by fishes for reproduction or nursery grounds. These reproductive areas either constitute a nursery area or are geographically positioned so that the larvae will drift into a nursery area (Cushing, 1975; Marshall, 1966). Many fishes in their developmental stages are planktonic and are thus limited in their ability to avoid unfavorable environmental conditions. In addition, the eggs and larvae of fishes have specific environmental requirements, with little tolerance for abrupt physical or chemical changes. Consequently, changes in either the location or physical-chemical makeup of reproductive or nursery areas could have a significant effect on ecologically or economically important fishes.

This study was a continuation of research initiated in March 1976. Its purpose was to further document the composition and abundance of ichthyoplankton in the vicinity of the St. Lucie Plant. As with the adult fish study, evaluation of the ichthyoplankton populations and the potential effects of plant operation required studies of both inshore and oceanic (offshore) areas. Inshore sampling was conducted to evaluate the effects of entrainment, or passage of ichthyoplankton through the plant. Offshore sampling was conducted to determine if the area near the St. Lucie Plant was used by fishes for reproduction or as a nursery, and if the offshore thermal discharge affected the distribution and abundance of ichthyoplankton.

Materials and Methods

Ichthyoplankton at Station 11 in the intake canal and Station 12 in the discharge canal and at oceanic Stations 0 through 5 (Figure B-7) was collected twice a month using two 20-cm diameter, 505μ mesh bongo nets (Figure B-8). At each of Stations 0 through 5, nets were towed just below the surface for 15 minutes at 3.5 to 4.0 knots. At Station 11 (intake canal), 10-minute step-oblique tows were taken. At Station 12 (discharge canal), nets were held in place for 10 minutes close to the point of discharge from the plant where the water first enters the canal. A digital flowmeter (General Oceanics Model 2030) mounted in the mouth of each net enabled calculation of the volume of water filtered. Water column (m^3) through the net was calculated by:

$$\text{Volume } (m^3) = AVT$$

where: A = Area of the mouth of the net (m^2)

V = Velocity of current (m/sec)

T = Time (sec).

Ichthyoplankton samples were taken during the day. Supplemental samples were occasionally taken at night. All specimens retained in the cod end collecting bucket were washed into jars, preserved in 5% formalin solution in the field, and returned to the laboratory for microscopic and statistical analysis. Water temperature, dissolved oxygen, salinity and turbidity were recorded at the time and location of each sample.

Eggs were counted and their diameters measured. Although herring and anchovy eggs are distinctive, eggs generally were not identified to taxon, due to the large number of fish species in the area and the lack of specific egg descriptions in the scientific literature. Larval fishes were identified to the lowest taxonomic classification practical, counted and measured to the nearest tenth of a millimeter, total length. Identification of larval fishes was facilitated by photographing larvae and arranging the photographs in developmental series from identifiable large forms to increasingly smaller and developmentally earlier stage larvae. Examples of these photographs are shown in Plates 1 through 7.

Although most of these methods were also used during the 1976 study (ABI, 1977), some changes were made in order to sample more accurately the ichthyoplankton populations in the St. Lucie Plant area. These changes included 1) the use of paired bongo nets versus conical plankton nets at all stations, 2) step-oblique tows versus surface tows in the intake canal, and 3) stationary nets set close to the point of discharge, where the water first enters the canal and is thoroughly mixed, versus surface tows in the discharge canal.

Bongo nets are more efficient qualitative and quantitative samplers than the conventional conical nets for several reasons. The filtration efficiency of bongo nets is higher at the faster speeds (3.5 to 4.0 knots) than that of conical nets (Posgay and Marak, in press).

In addition, because bongo nets have no bridle in front of the net opening, net avoidance is significantly reduced. The use of paired bongo net collections also provides a check on net obstructions and meter reliability. In theory, paired nets should collect equivalent samples. An analysis of variance indicated no significant difference (α=0.10) between paired samples for larval or egg captures (Table B-11). The use of step-oblique tows instead of surface tows in the intake canal ensures a more representative sample of the ichthyoplankton population in that area. Thus a more meaningful comparison can be made with the sample taken at the point of discharge.

Statistical Analysis

Statistical analyses were performed by procedures of the Statistical Analysis System (SAS; Barr et al., 1976). To determine relationships between ichthyoplankton and physical variables, simple correlations, their approximate significance probability, and the number of observations correlated were calculated by use of the Correlation (Corr) Procedure. The General Linear Model (GLM) Procedure was employed to give the regression approach to analysis of variance using class variables to determine overall station and replicate effects. Examples of the variables, class variables and models used are shown in Table B-12. Duncan's multiple range tests were performed by the Duncan Procedure to determine significantly different station means if significant station effects were found at the 0.10 level of significance. Comparisons using the Duncan Procedure were

made at the 0.05 level of significance to reveal only strong differences between ichthyoplankton densities.

The data were analyzed for seasonal and station differences. Collections were grouped as follows: winter samples were from December 1976 through February 1977, spring samples from March through May 1977, summer samples from June through August 1977, and fall samples from September through December 1977.

Results and Discussion

Approximately 400 samples were collected and analyzed during the period from December 1976 through December 1977. The results of each sample analysis include the number of individuals of each taxon, length ranges, the total number of eggs and larvae per cubic meter and water volume (m^3) filtered, and are presented in Appendix Tables K-1 through K-25.

Offshore Stations: Eggs

Fish eggs were collected during every sampling period and averaged 5.464/m^3. Overall, abundance of eggs was highest in late winter and early spring (Figure B-9). The erratic occurrence of eggs during 1977 may be explained by the high species richness in the area, and is indicative of number of species spawning throughout the year, both continuously and seasonally.

No significant differences (α=0.1) in egg densities were detected between Stations 0 through 5 (Table B-13). However, when analyzed by season, significant (α=0.1) differences between stations occurred during the summer (Table B-14). At this time, Station 0 (control) had significantly (α=0.05) higher egg densities than all other oceanic stations (Table B-15). Since no significant differences in egg densities occurred between Station 1 (discharge) and Stations 2 through 5, it is unlikely that the difference in egg densities between Station 0 and the other oceanic stations indicates thermal effect. Furthermore, Station 0 is located farther south (Figure B-7) and may be influenced by different water currents than Stations 1 through 5.

Of the physical parameters correlated with egg abundance, the correlations with water temperature, dissolved oxygen and turbidity proved significant (Table B-16). Egg density was negatively correlated with water temperature and turbidity, and positively correlated with dissolved oxygen. According to Jones (1964), an indirect negative effect of temperature on egg distribution and survival could result from the addition of heated effluents which may lower the density of ambient water. This would affect the buoyancy of pelagic eggs and cause them to sink (deSylva, 1969). This phenomenon would be unlikely in the St. Lucie Plant area since significant differences in egg densities between the offshore stations rarely occurred, and differences in water temperature between these stations for a given sampling period

rarely exceeded 2°C. A more plausible explanation for the negative correlation with temperature and egg density is that more eggs were collected during the cooler months of this study due to increased spawning activity, which is primarily temperature related. The positive correlation between egg density and dissolved oxygen is probably a coincidence rather than cause and effect, since dissolved oxygen was not a limiting factor throughout the year. Reasons for the negative correlation between egg densities and turbidity are not known. These correlations between egg densities and physical parameters, although statistically significant, do not entirely explain the overall variations in egg densities found during the year.

Comparison of the 1977 study results with those of the 1976 study shows some agreement in the above correlations and maximum egg densities, and close agreement in the months in which maximum egg densities occurred. During 1976, egg densities were also found to be negatively correlated with water temperature and positively correlated with dissolved oxygen; egg densities and turbidity were not significantly correlated. In 1976 the highest density of eggs ($26/m^3$) occurred in March, whereas in 1977 high egg densities ($33/m^3$) occurred in February and April.

Offshore Stations: Larvae

Fish larvae, as well as eggs, were collected during every sampling period and averaged $0.696/m^3$. Overall, abundance of larvae was

highest in the winter, then dropped in the spring before increasing again in summer (Figure B-9). Low larval densities occurred in the fall and early winter of 1977. When compared over the entire year, no significant differences (α=0.1) in larval densities were detected between Stations 0 through 5 (Table B-13). However, when analyzed by season, significant differences (α=0.1) between stations occurred during the winter and fall (Table B-17). In the winter, the average larval concentration (number/m^3) was significantly higher (α=0.05) at Station 0 (control station) than at Stations 2 and 3, both of which are offshore from the discharge (Table B-18). In the fall, the average larval concentration was significantly higher at Station 1, near the discharge, than at Stations 2 or 4, offshore from the discharge and south of the discharge, respectively (Table B-18). Additionally, Station 5, located north of the discharge, had average larval concentrations significantly higher than Stations 2 and 4, and significantly lower than Stations 0, 1 and 3. These differences were not attributed to plant operations since no consistent trends were apparent.

Of the physical parameters correlated with larval abundance, the correlations with dissolved oxygen and turbidity proved significant (Table B-16). Larval density was negatively correlated with dissolved oxygen and positively correlated with turbidity. As with egg densities, the correlation between larval densities and dissolved oxygen are probably coincidental, rather than cause and effect, as dissolved oxygen concentrations were not a limiting factor throughout the year.

The positive correlation found between larval density and turbidity may be related to net avoidance by the larvae; that is, they may be more capable of avoiding the net in less turbid water. Regardless, the correlations between larval densities and the physical parameters, although statistically significant, do not entirely explain the overall variations in larval densities found during the study.

Offshore Stations: Fish Taxa Represented

The most abundant larval fish taxa in all seasons were herring and anchovy (Clupeiformes, Tables B-19 through B-22). Figure B-10 illustrates the densities (number of larvae/m^3) of clupeiforms at all oceanic stations for each sampling period covered in this report. High densities of larval clupeiforms occurred in January and June.

Six species of herring and seven species of anchovy were found in the plant area (Appendix Table J-1A). The eggs and larvae of at least three herring species, dominated by menhaden, occurred in the samples. Menhaden in a gravid or ripe condition (determined by the release of eggs upon gentle squeeze pressure) occurred in the St. Lucie area in January and June (Table B-23). Other common herrings, like the Atlantic thread herring and scaled sardine, spawn through most of the year (Houde, 1977a and 1977b; Houde et al., 1974; Richards et al., 1974). Little is known of the spawning areas of the anchovies encountered at St. Lucie, with the exception of the bay anchovy which is an estuarine or nearshore spawner. Anchovy larvae and eggs were uncommon in the St. Lucie ichthyoplankton collections. Because clupeiform fishes

are among the most abundant of all fishes, it is unlikely that the St. Lucie Plant is significantly affecting clupeiform fish populations.

Of the 15 species of drum (Sciaenidae) recorded from the St. Lucie area (Appendix Table J-1A), seven were taken as ripe adults during fall and winter months (Table B-23). The distribution of drum larvae is illustrated in Figure B-11. The maximum density was recorded during the summer, although drum larvae were found throughout the year. Spot and Atlantic croaker predominated in the ichthyoplankton samples, but other taxa (seatrout, kingfish, sand drum and either silver perch or striped croaker) were also collected. These results are compatible with the ichthyoplankton findings of Powles and Stender (1976), who worked from Cape Canaveral, Florida, to Cape Fear, North Carolina. Spot and Atlantic croaker spawn in the winter in offshore waters. Their larvae approach the coast as they grow (Fahay, 1975), and use estuaries as nursery areas. Kingfish (*Menticirrhus* spp.) spawn offshore and use shallow surf zone habitats when young. Seatrout spawn in estuaries or shallow coastal waters, depending on the species, and use a variety of habitats for growth. Juvenile seatrout and other drum, 9 to 28 mm in length, were collected by trawl at Station 1 during November. Apparently the St. Lucie Plant area is used to some extent as a spawning and/or nursery area by these sciaenids, since both larvae and juveniles were collected in the area.

Sixteen species of jack (Carangidae) have been collected in the plant area (Appendix Table J-1A) of which three (scad, blue runner, Atlantic bumper) have been found in ripe condition (Table B-23). Jacks were year-round components of the ichthyoplankton (Figure B-12). The predominant larval jack species were Atlantic bumper and palometa. Few scad were taken, and all were postlarvae or juveniles. The larvae of many jacks occur only in offshore waters where spawning occurs, with development proceeding rapidly so that only juveniles and later stages reach coastal waters (Berry, 1959). Palometa, permit and Florida pompano spawn offshore, with the palometa comparatively rare along the South Atlantic coast (Fahay, 1975). Our collections at St. Lucie indicate that the Atlantic bumper is an abundant larval jack in the St. Lucie area, palometa post-larvae are common, and permit post-larvae are relatively uncommon.

Of 13 bothids and two soleids (in all figures and tables these taxa are reported as members of Bothidae) reported from the St. Lucie area (Appendix Table J-1A), only the spotted whiff and dusky flounder were taken in ripe condition. The characteristics of larval flatfishes are well documented (Futch, 1971; Futch and Hoff, 1971; Gutherz, 1970). Larval flatfish were collected throughout the year (Figure B-13), and the lined sole (*Achirus lineatus*) was the predominant flatfish found. Late stage larvae of flounder or eyed flounder (*Bothus* spp.) appeared sporadically in the collections, as did spotted whiff or fringed flounder (*Citharichythys* spp.) and a species of *Syacium*. One species,

the deepwater flounder (*Monolene sessilicauda*) has tentatively been identified in ichthyoplankton collections, but has not appeared in other St. Lucie fish collections. It was taken only rarely, and may have been transported inshore with Gulf Stream eddies. Larvae of this species are rare inshore. *Bothus* and *Syacium* are abundant components of the ichthyoplankton in the South Atlantic Bight during much of the year (Powles and Stender, 1976). A more northern study demonstrated that bothids tend to spawn offshore, in a relatively long spawning season, and that temperature is important in triggering flatfish spawning activity (Smith et al., 1975).

Spanish mackerel (Scombridae) have been found in ripe condition in St. Lucie waters from May through July (Table B-23), indicating that spawning may occur in the vicinity of the power plant. However, the major spawning area of the Spanish mackerel appears to be off the Carolinas, with a disjunct spawning population in the Gulf of Mexico. Spanish mackerel larvae have been found in the eastern Gulf of Mexico, but not off the east coast of Florida (Wollam, 1970).

It should be noted that several important species, such as snook, bluefish and billfish, were not found in the ichthyoplankton collections. Snook (Centropomidae) are important sport fish in the adjacent Indian River lagoon. Larval snook were neither encountered nor expected in our collections because they breed in coastal water at river mouths or sandy passes, typically in brackish areas, with

the juveniles occurring in estuaries (Marshall, 1958; Springer and Woodburn, 1970; Volpe, 1959). Bluefish (Pomatomidae) is an important sport and commercial species which migrates through the offshore St. Lucie area. The study area is south of their spawning grounds (Deuel et al., 1966). Billfish (sailfish, marlin, etc.) are primarily important as sport species. The billfish are offshore spawners, and the larvae and young fish remain offshore during development. Deuel et al. (1966) also reported king mackerel larvae offshore from Florida's east coast, although recently spawned fishes of either mackerel species were not found south of Cape Canaveral on Florida's east coast. The ichthyoplankton collections rarely yielded scombrid larvae. Those that were found (Plate 3) lack the head spine characteristic of king and Spanish mackerel, are not tunas, and probably represent a non-sport species, the frigate mackerel (Table B-23).

Of several leptocephali collected (mostly at night in a supplemental study), no tarpon, bonefish or American eels were found. Most leptocephali were spotted worm eels, with the remainder consisting of ladyfish, congrid eels and a few unidentified species of eels.

Larvae of mojarras (Gerreidae), blennies (Blennidae, which includes members of Clinidae), and cusk-eels (Ophidiidae) were also collected offshore from the St. Lucie Plant area along with sexually mature adults (Table B-23). None of these taxa have any major sport

or commercial value. Seasonal variations in densities of these and the other larval taxa collected are shown in Appendix Figures K-1 through K-8.

Offshore Stations: Study Comparisons

The results of this study compare closely with those of the 1976 study with respect to maximum larval densities and composition of the taxa. However, these studies differed in the month in which maximum larval densities occurred and in the correlations of larval densities with physical parameters. In 1976 a maximum density of 3.074 larvae/m^3 occurred in September, whereas in 1977 a maximum density of 3.560 larvae/m^3 occurred in January. During both years herrings and anchovies (clupeiforms) were the most abundant larval taxa collected. Blennies, mojarras, drums and jacks commonly occurred in samples collected during 1976 and 1977. In general, the composition of the larval populations in the St. Lucie Plant area has not changed appreciably between these years.

During 1976, larval densities were found to be positively correlated with water temperature and dissolved oxygen, whereas during 1977, larval densities were positively correlated with turbidity and negatively correlated with dissolved oxygen. These differences are probably due to the fact that winter ichthyoplankton samples were not collected during the 1976 study. These additional data may have had a significant effect on the reported correlations for 1976, especially the correlation between larval density and water temperature. In general,

single or multiple variable correlations with ichthyoplankton abundance or location have not been very successful (Parsons and Takahashi, 1973). In a review of the effects of abiotic factors on marine ichthyoplankton, Lillelund (1965) concluded that abiotic factors had only an indirect effect and that overall effects were complex and probably associated with biotic factors.

Evaluation of Offshore Waters as a Nursery Area

According to Joseph (1973) and Clark (1974), in order for an area to serve as a significant nursery area it must meet three broad criteria:

1. The area must be physiologically suitable in terms of chemical and physical features;
2. It must provide an abundant, suitable food supply with a minimum of competition at critical trophic levels; and
3. It must in some way provide a degree of protection from predation.

The offshore waters in the vicinity of the St. Lucie Plant are not typical of a nursery area on the basis of these criteria. Physical characteristics needed in a nursery area are low or fluctuating salinities, silt-sand-mud bottom, and extensive beds of rooted aquatic vegetation. Chemically, the offshore waters in the St. Lucie Plant are homogeneous with little variation. Physically, the offshore areas are characterized by the presence of relatively constant salinities, shell-hash sediments (Gallagher and Hollinger, 1977), and the absence of significant macrophytic grass beds.

Studies on the diet of larval fishes have indicated that small zooplankters, especially copepod larvae, are the first food source many larval fishes use shortly before or after yolk-sac absorption (Bainbridge and McKay, 1968; Cushing, 1959; Lebour, 1921, 1919 and 1918). This period is critical to larval survival because once the larvae absorb their yolk-sacs, they die within hours or a few days if a food source in adequate concentrations is not available. Zooplankton densities in the plant area may be adequate at certain times of the year, but generally were not optimal. These conclusions are documented in studies by Arthur (1977), Houde (1977c), Zaika and Ostrovskaya (1972), Blaxter (1963), Lisinvnenko (1961), and Nishimura (1956).

Little or no protective cover in the form of rooted aquatic plants or bottom structures is found in the plant area. Furthermore, a diverse community of subadult and adult piscivorous fishes were collected in offshore areas in the vicinity of the St. Lucie Plant. Thus, this area does not meet the nursery ground criteria of providing protection from predation.

Although the oceanic habitat in the vicinity of the power plant is not typical of a nursery area, the area appears to be suitable for the development of pelagic eggs and larvae derived from pelagic spawners, as evidenced by the common occurrence of

clupeid and sciaenid larvae. Generally, pelagic spawners are not dependent upon the protective nature of a nursery area but rely upon their great fecundity to sustain their numbers.

Inshore Stations

The average densities of fish eggs at Stations 11 (intake canal) and 12 (discharge canal) during this study were 0.743 and 0.327 eggs/m^3, respectively. The average densities of larvae at intake and discharge canals were 0.033 and 0.017 larvae/m^3, respectively. No significant (α=0.1) differences were found for egg or larval densities between intake and discharge canals. The average densities of eggs and larvae at the intake were comparatively lower than the average densities reported for offshore stations (5.464 eggs/m^3 and 0.696 larvae/m^3), respectively.

The low concentrations of eggs and larvae recorded in the intake canal compared with those at the offshore stations may indicate that the intake pipe is drawing water for cooling from a relatively depauperate area or depth. A second possible cause of the discrepancy is collection methods. Step-oblique tows were taken in the intake canal and surface tows at offshore stations. However, it is unlikely that the magnitude of the concentration differences is adequately accounted for by this procedural difference. The lower concentrations of eggs and larvae in the intake canal may be due to mortality from passage through the pipe or predation in the intake canal. These possible explanations are being investigated.

Of the major categories of fish larvae collected at Stations 11 and 12, blennies and clupeiforms were the most abundant taxa found in the winter; clupeiforms were the most abundant fishes in the spring and summer. Flatfishes were most common in the fall (Tables B-19 through B-22), although they were only occasionally collected and then in very low numbers. Overall, clupeiforms accounted for the bulk of the larval fishes collected at Stations 11 and 12. The entrainment of clupeiforms into the intake canal is not considered to be highly detrimental to the clupeid populations in the plant area because of their high fecundity and abundance.

Inshore Stations: Entrainment

In order to put the impact of entrainment into perspective with the offshore body of water, it is necessary to define an offshore boundary of the region from which ichthyoplankton are probably drawn. For this assessment the boundary is located at Station 3. Fish egg and larval populations beyond this boundary are assumed to be unaffected by plant operation. The distance between the imaginary offshore boundary and the shoreline is approximately 3500 m, with an average depth of 9.2 m for a calculated cross-sectional area of 32,200 m^2.

Since ichthyoplankton tows were made near the surface, additional estimates were calculated based on an average depth of 3 m. This assumes that our surface tows represent ichthyoplankton populations

to at least that depth. With 3 m as the average depth, the cross-sectional area is 10,500 m^2. The average current velocity in this region, with a prevailing direction to the north, is approximately 0.128 m/sec (Envirosphere, 1977). This value multiplied by the cross-sectional area estimates the volume of water flowing past the plant per second, i.e., 4122 m^3/sec assuming an area of 32,200 m^2, or 1344 m^3/sec assuming an area of 10,500 m^2. It is then possible to estimate the percentage of fish eggs and larvae drifting past the plant, within the defined region, that are entrained by the plant.

The following method used to evaluate entrainment was proposed by Goodyear (1977), who established analytical techniques for entrainment in riverine habitats. The following models have been adapted because the offshore area near the St. Lucie Plant is analogous to a riverine situation (i.e., delineated by a definite cross-sectional area and current flow).

$$\text{Percentage Loss} = \frac{\frac{mC_p}{C_r} \times Q_p}{Q_r} \times 100$$

where: C_r = mean concentration in number/m^3 (based on surface tows only) of organisms in a cross section of the river

C_p = mean concentration of organisms in the intake water

Q_r = flow in m^3 per second (cms) past the plant

Q_p = water flow through the plant intake (cms) based on an average of 11 months of plant flow data

m = mortality rate of entrained organisms (assumed to be 100%, making m = 1.0)

NOTE: In the following equations, two values are given for both Q_r and percentage loss. The first value is based on a cross-sectional area of 32,200 m^2 and the second [in brackets] is based on a cross-sectional area of 10,500 m^2.

For fish egg entrainment:

$C_r = 5.464/m^3$

$C_p = 0.743/m^3$

$Q_r = 4122$ cms [1344]

$Q_p = 29.62$ cms

$m = 1.0$

$$\text{Percentage loss} = \frac{\frac{1.0 \times 0.743}{5.464} \times 29.62}{4122} \times 100$$

$$= 0.098\% \; [0.301\%]$$

For fish larvae entrainment:

$C_r = 0.696/m^3$

$C_p = 0.033/m^3$

$Q_r = 4122$ cms [1344]

$Q_p = 29.62$ cms

$m = 1.0$

$$\text{Percentage loss} = \frac{\frac{1.0 \times 0.033}{0.696} \times 29.62}{4122} \times 100$$

$$= 0.034\% \; [0.104\%]$$

A more conservative estimate is made by setting the value of mC_p / C_r equal to 1. Thus, the average concentration of organisms entering the power plant intake is assumed to be equal to the average concentration of organisms in offshore areas.

For fish egg entrainment:

$C_r = 5.464/m^3$

$C_p = 5.464/m^3$

$Q_r = 4122$ cms [1344]

$Q_p = 29.62$ cms

$m = 1.0$

$$\text{Percentage loss} = \frac{\frac{1.0 \times 5.464}{5.464} \times 29.62}{4122} \times 100$$

$= 0.718\%$ [2.204%]

For fish larvae entrainment:

$C_r = 0.696$

$C_p = 0.696$

$Q_r = 4122$ cms [1344 cms]

$Q_p = 29.62$ cms

$m = 1.0$

$$\text{Percentage loss} = \frac{\frac{1.0 \times 0.696}{0.696} \times 29.62}{4122} \times 100$$

$= 0.718\%$ [2.204%]

Regardless of whether the average densities of eggs or larvae in the intake canal were assumed to be equal or not equal to the average egg or larval densities in offshore areas, or whether the cross-sectional area was assumed to be 32,200 m^2 or 10,500 m^2, the percentage loss due to entrainment for eggs or larvae did not exceed 2.2%. However, this figure is conservative and the estimates of percentage loss due

to entrainment were usually less than 1%. These figures are not considered to be a significant proportion of the ichthyoplankton occurring in the vicinity of the St. Lucie Plant.

SUMMARY

The ichthyofauna offshore from the St. Lucie Plant was a transitional assemblage of temperate and tropical forms. Habitats within the influence of normal operations of the St. Lucie Plant included the surf zone, open bottom and neritic zone. The number of fish species found in these habitats is relatively low compared to those of inshore areas of the Indian River lagoon and oceanic reefs.

The predominant fishes found during impingement sampling were grunt, anchovy and jack. Few sport or commercial fishes were found. Shrimp and blue crab were the predominant commercially important shellfishes found. The biomass of impinged fish and shellfish was low compared to commercial landings.

Comparison of impingement data to intake canal gill net data indicated that certain fishes may become entrapped in the intake canal without necessarily becoming impinged. Nevertheless, no large accumulation of fishes in the intake canal was indicated.

The velocity cap appeared to be extremely effective in excluding some species from the intake and of limited effect with others.

None of the migratory species of sport or commercial importance, such as mackerels or bluefish, were found in the intake canal or on the intake screens at the plant.

The largest total number of fishes was found near the point of plant discharge during offshore gill net and trawl collections, although differences in the numbers of fishes collected at the offshore stations were not statistically significant. Differences between stations were primarily attributed to fortuitous occurrences. No effects of the offshore thermal plume on the movement of migratory species, which occur primarily in the fall and winter, were apparent.

The majority of fishes sampled by beach seine were collected during the summer. The largest percentage of the total catch was found north of the plant. Although the reason for the higher abundance to the north is not clear, no plant-induced effects were demonstrated.

Ichthyoplankton densities were generally highest in the winter and lowest in the fall. The most abundant larval fish taxon was clupeiform, a group of primarily forage species which are abundant in the area. Differences in ichthyoplankton densities between offshore stations were not attributed to plant operation since no consistent trends were apparent.

The average densities of ichthyoplankton found in the intake canal were lower than those found at the offshore stations. Estimates of entrainment loss were low and considered an insignificant proportion of the ichthyoplankton population occurring in the vicinity of the plant.

In general, physical characteristics offshore from the St. Lucie Plant are not consistent with those found in typical nursery areas. Nonetheless, the area appears suitable for the development of eggs and larvae derived from certain pelagic spawners which rely upon great fecundity, rather than nursery areas, to sustain their numbers.

Changes in the composition and relative abundance of the ichthyofauna and differences in their normal distribution during the last two years were not attributed to any plant-related effects. The impact of the St. Lucie Plant on the populations of fish and shellfish offshore from Hutchinson Island was considered low.

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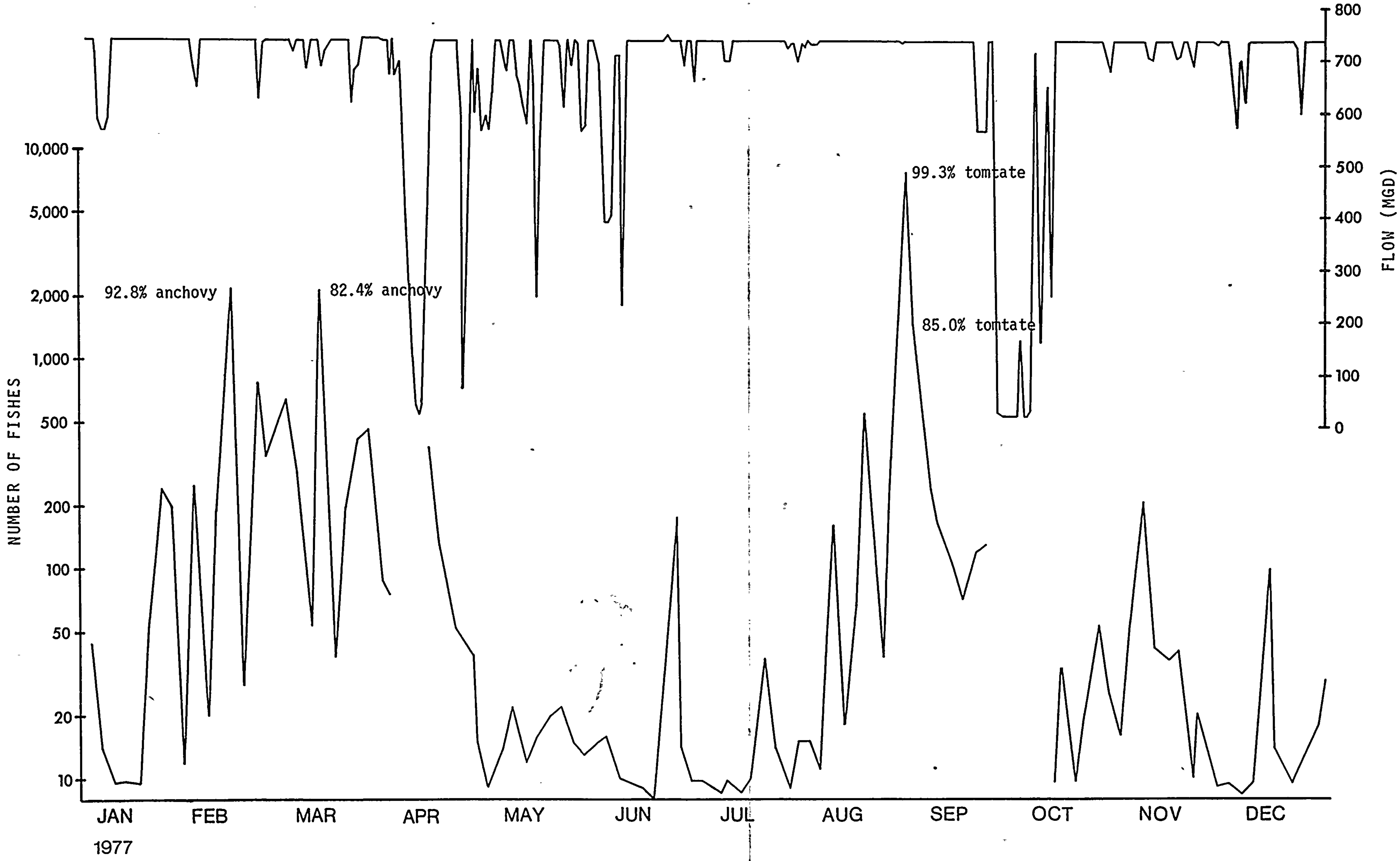

Figure B-1. Rates of impingement: number of fishes collected per hour compared to total flow through the plant in millions of gallons per day, St. Lucie Plant, 1977.

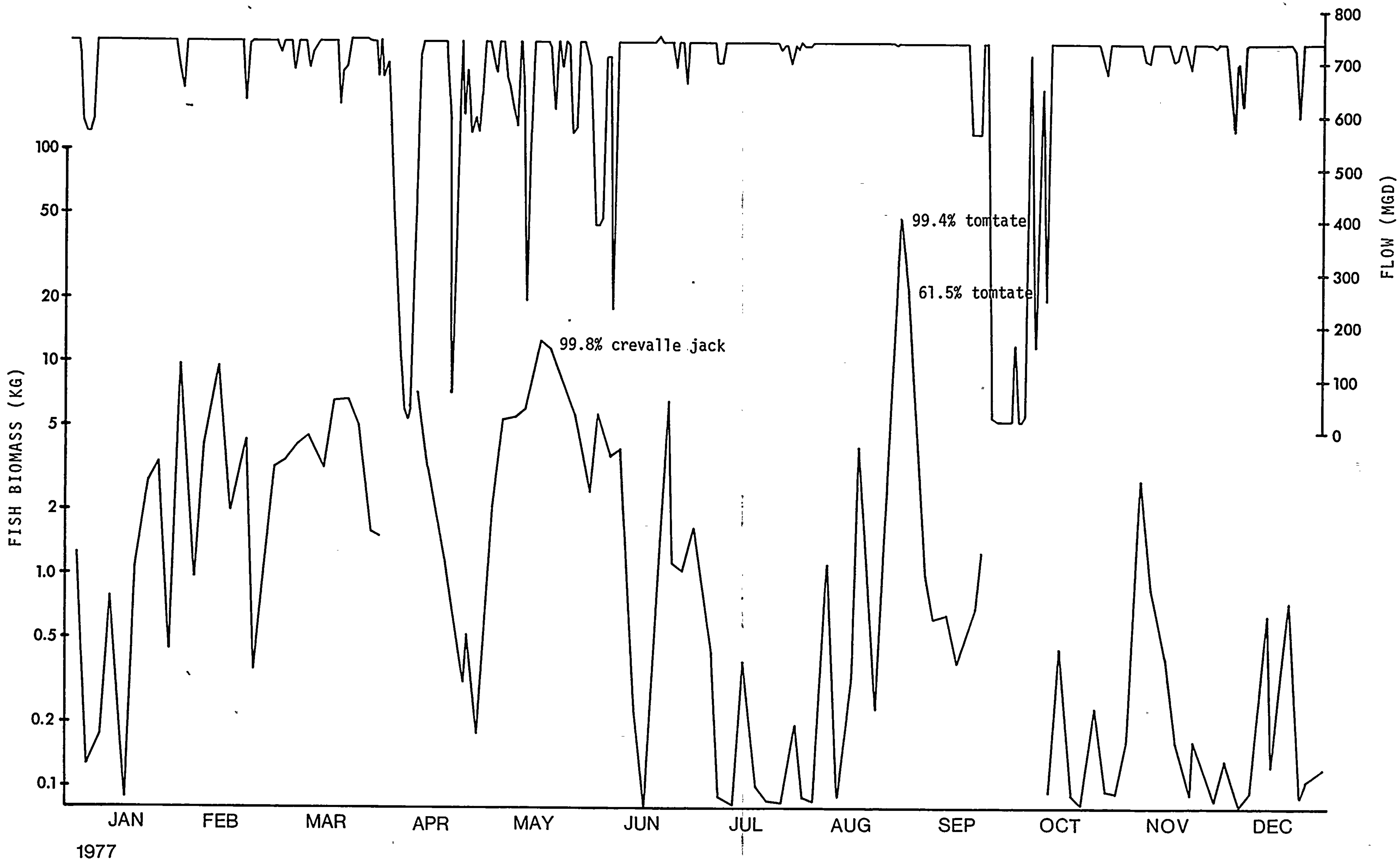

Figure B-2. Rates of impingement: biomass (grams) of fishes collected per hour compared to total flow through the plant in millions of gallons per day, St. Lucie Plant, 1977.

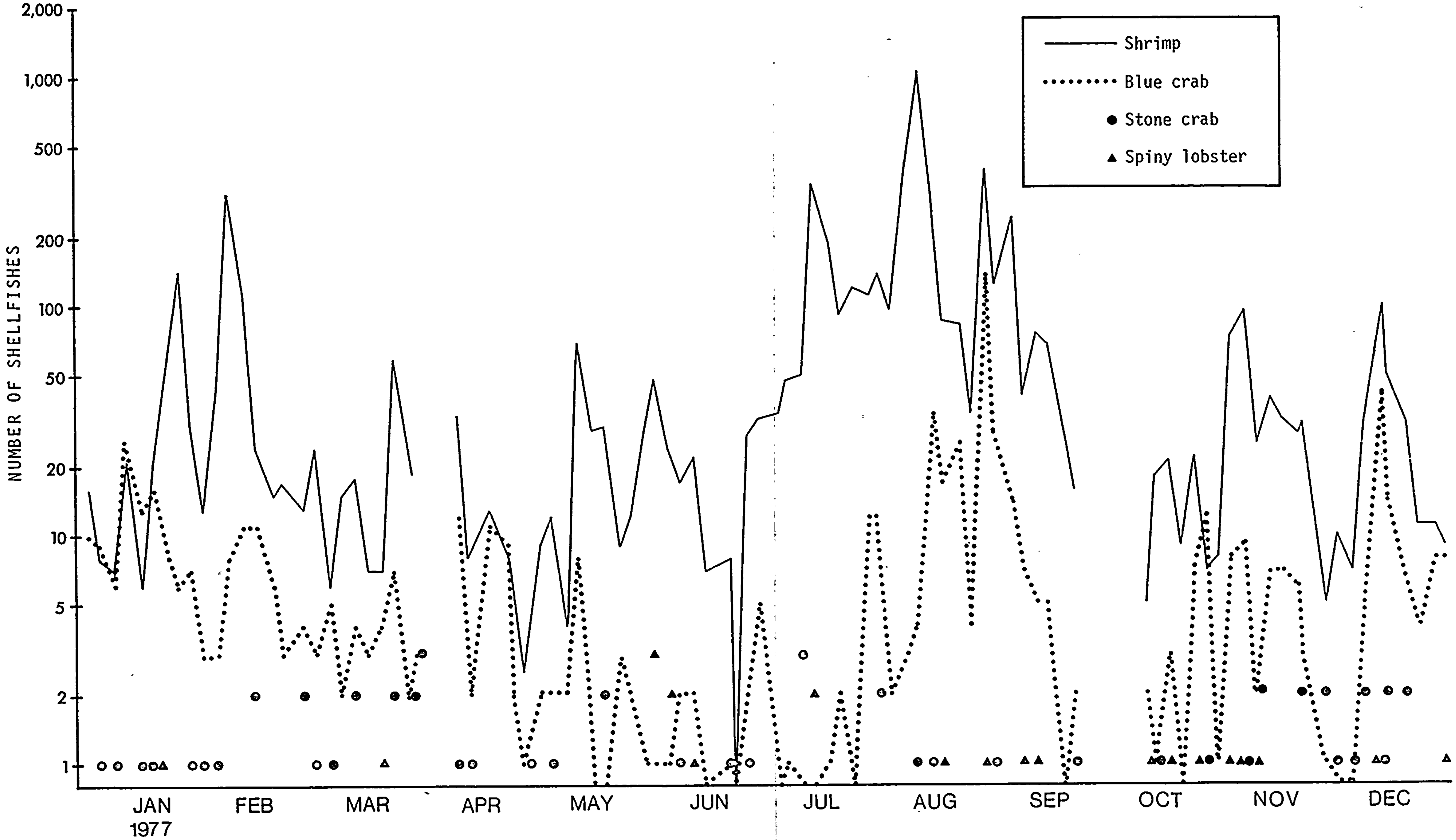

Figure B-3. Rates of impingement: number of commercially important shellfishes collected per day, St. Lucie Plant, 1977.

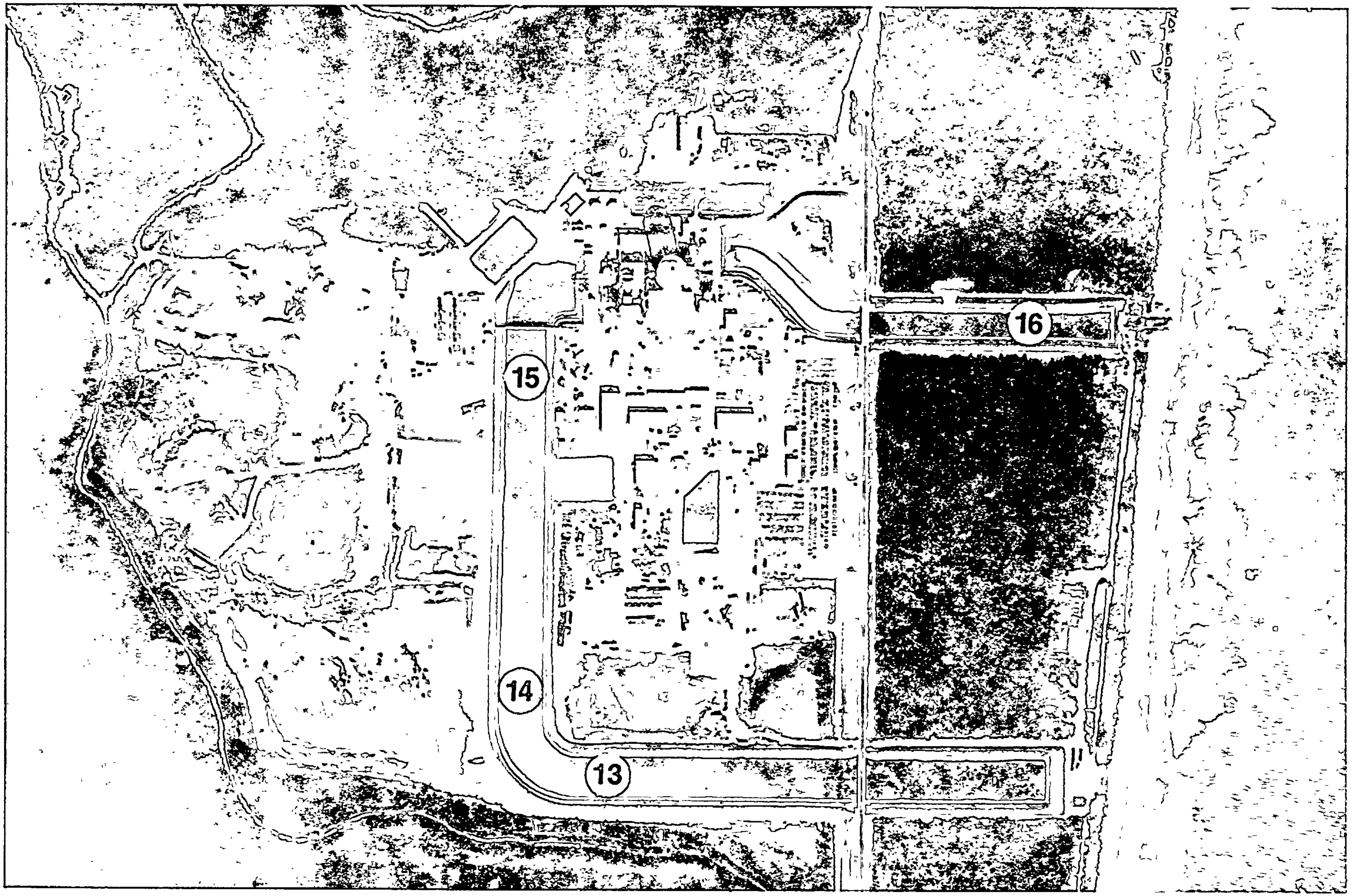

Figure B-4. Inshore (canal) gill net stations, St. Lucie Plant, 1977.

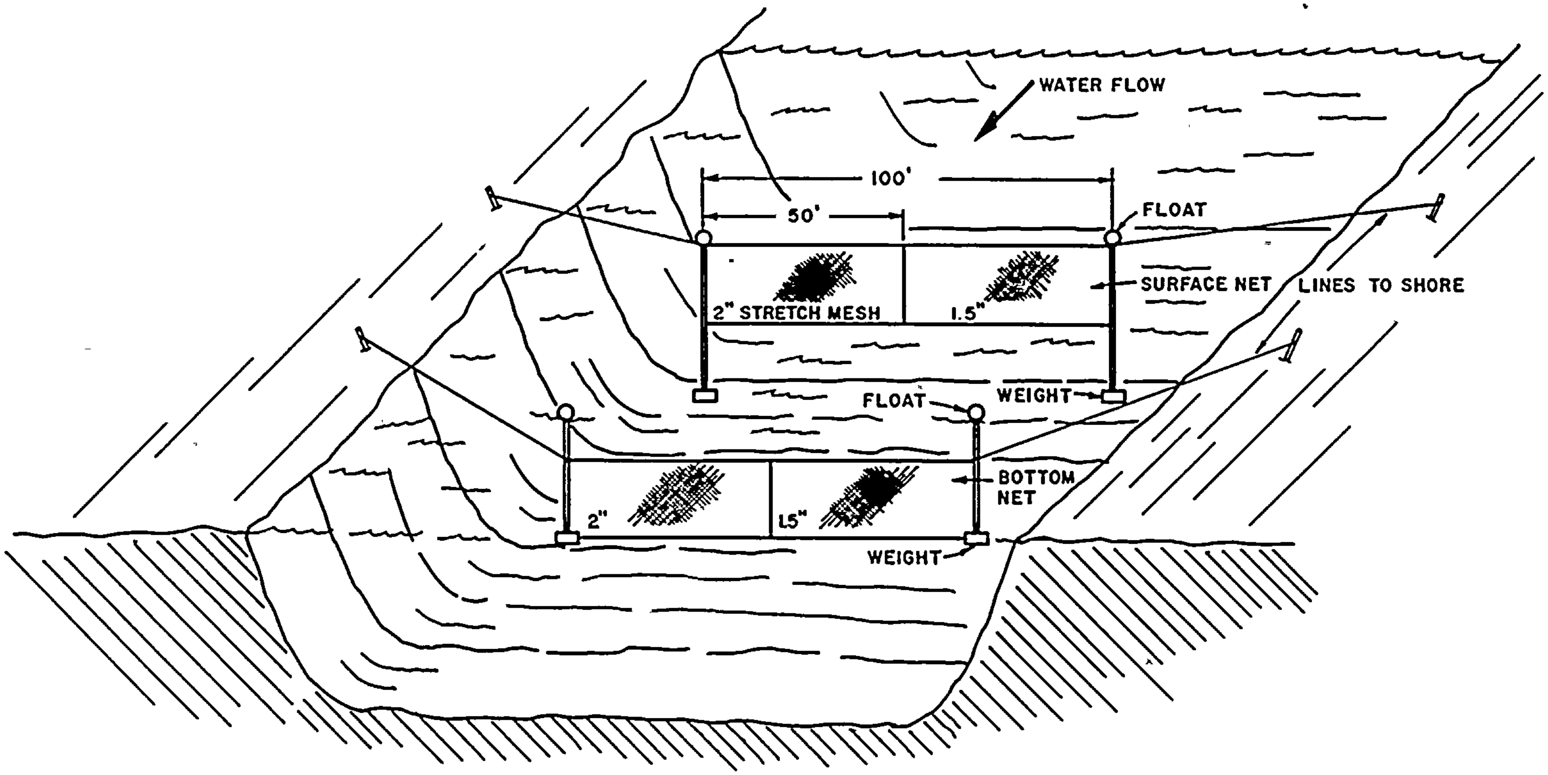

Figure B-5. Diagrammatic view of the inshore (canal) gill nets, St. Lucie Plant, 1977.

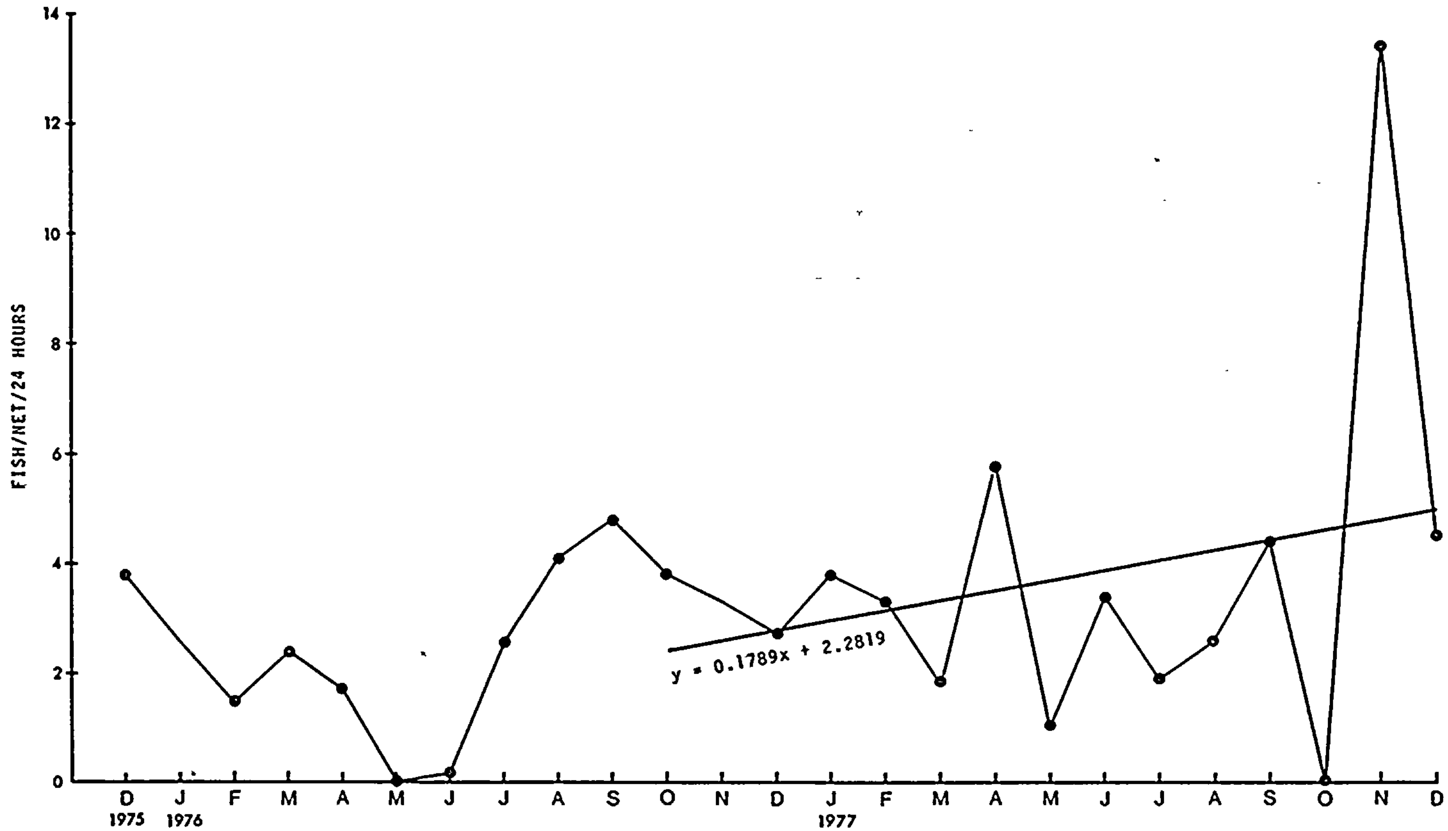

Figure B-6. Inshore (canal) gill net collections: fishes collected per net per 24 hours from the intake canal, St. Lucie Plant, December 1975-December 1977.

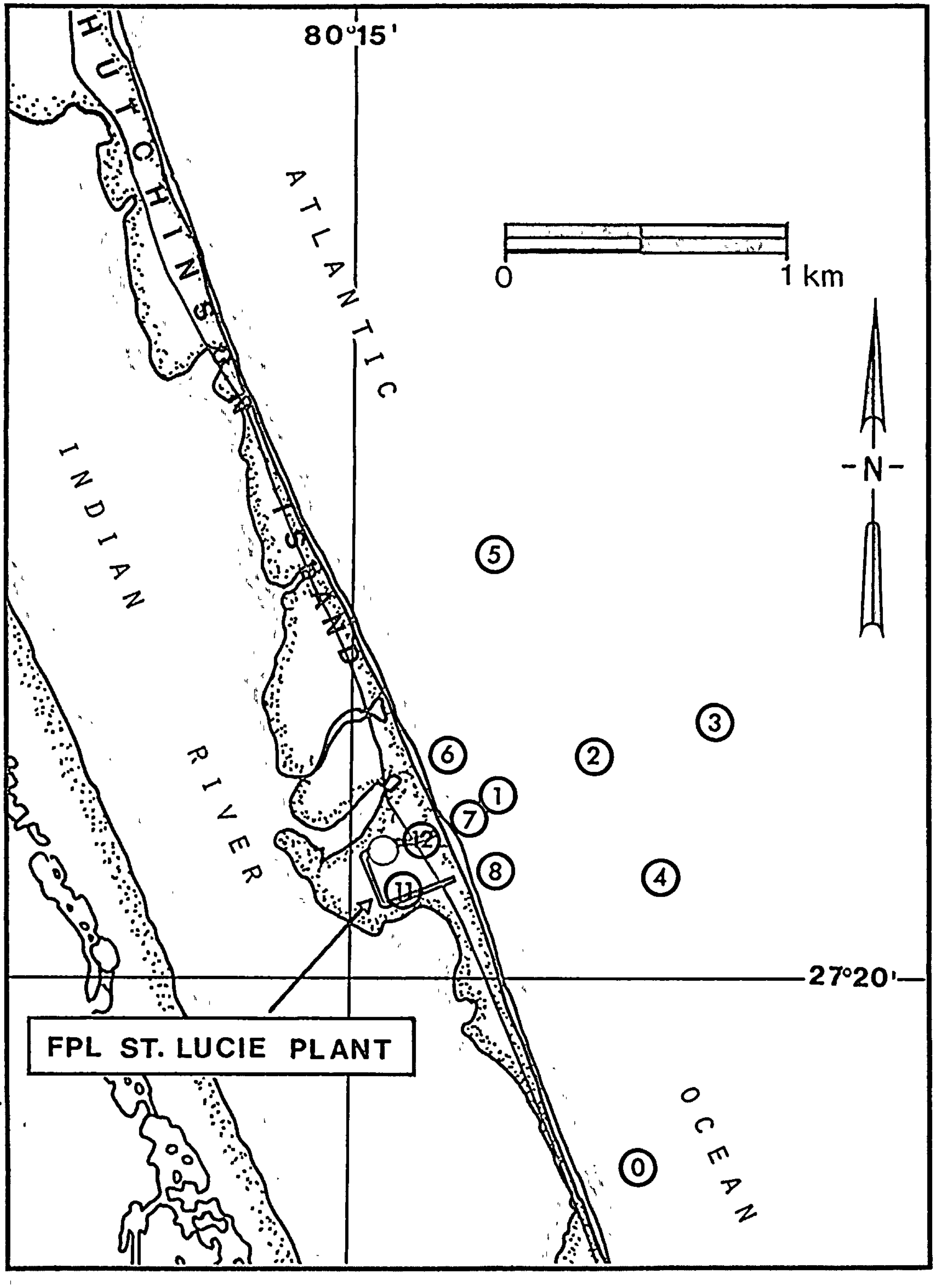

Figure B-7. Locations of fish sampling stations, 1977.

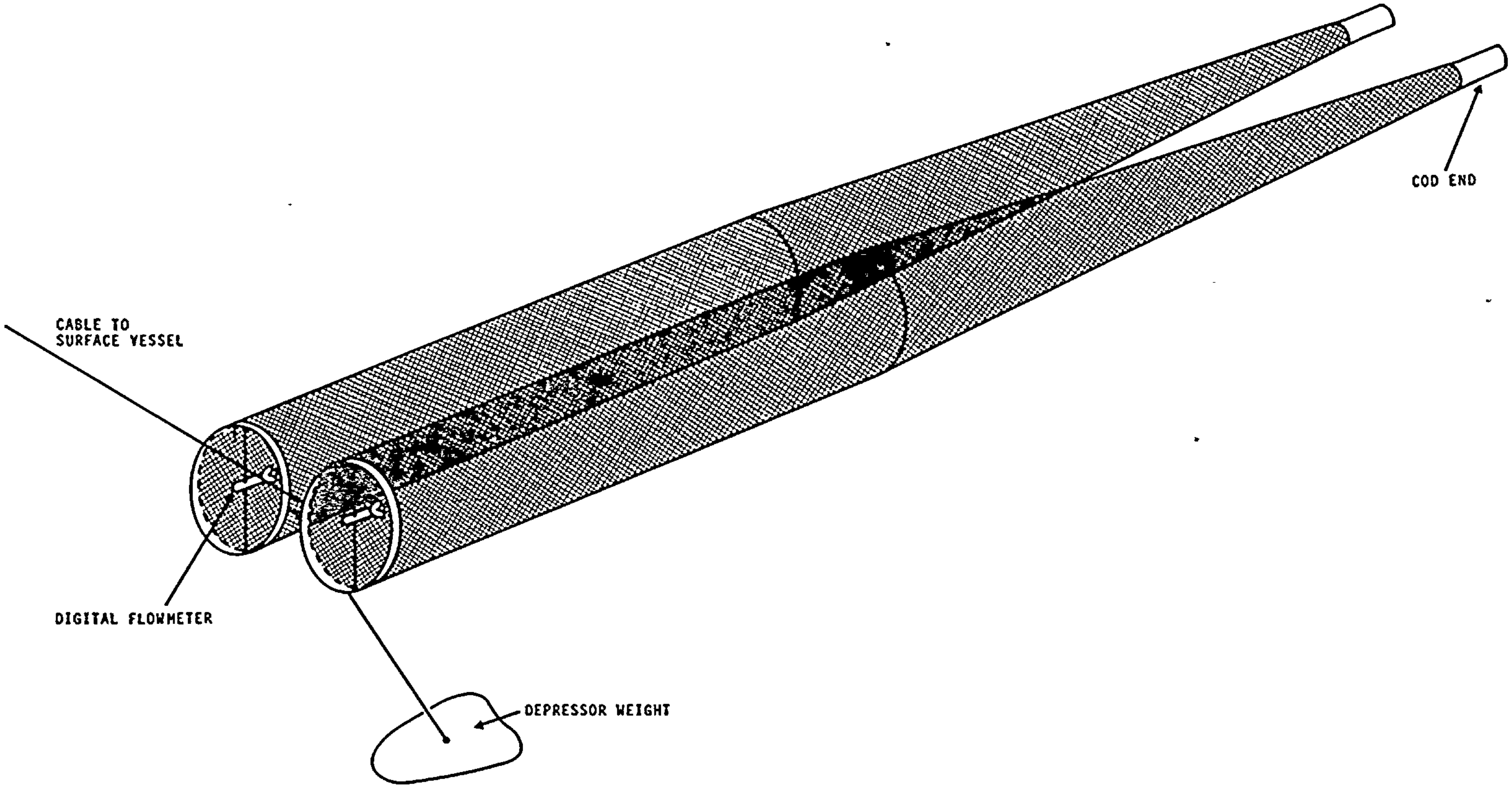

Figure B-8. Diagrammatic view of bongo nets used in ichthyoplankton sampling at the St. Lucie Plant.

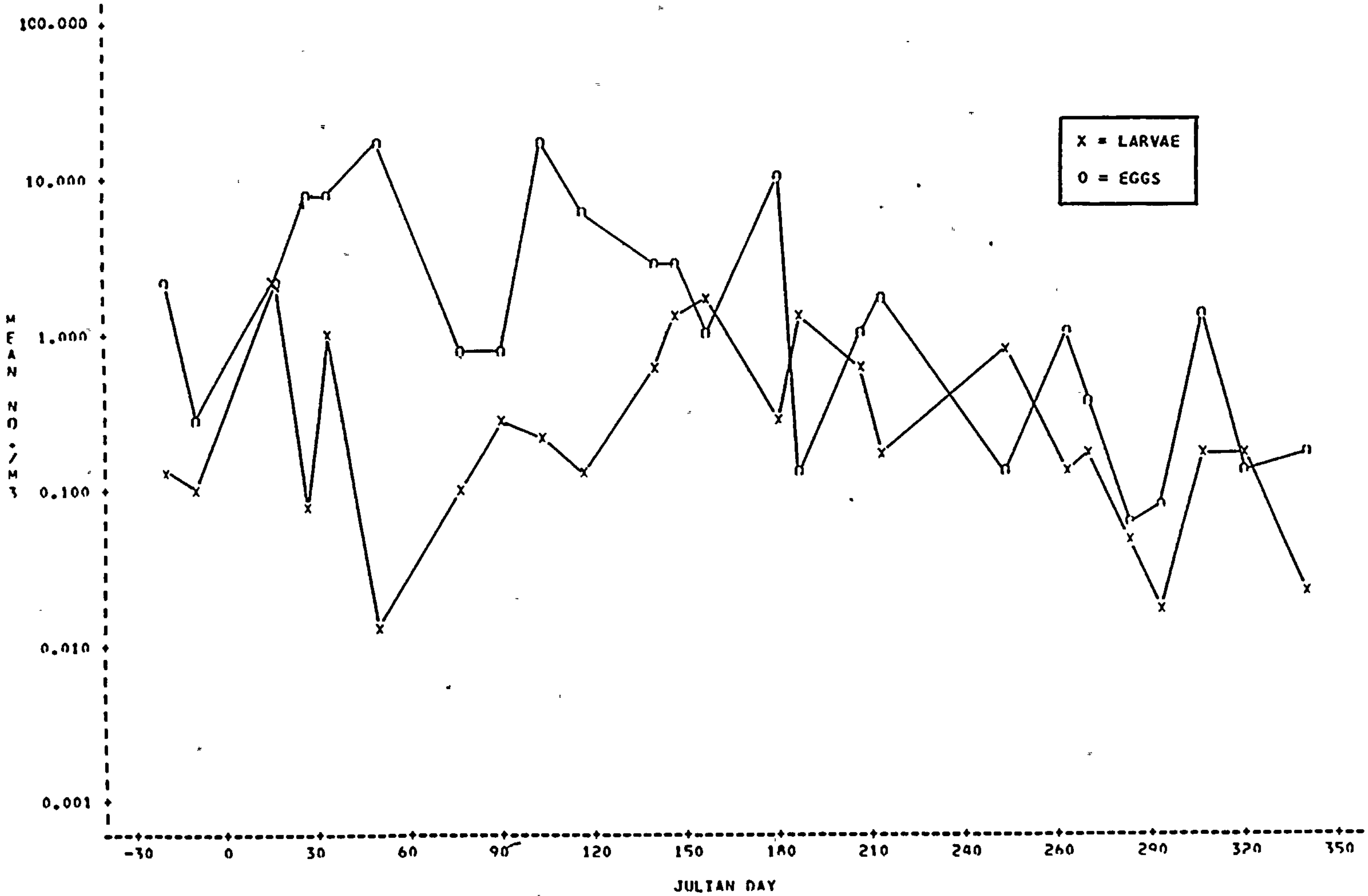

Figure B-9. Mean larval and egg densities (number/m³) by Julian (calendar) day, Stations 0 through 5, St. Lucie Plant, 12 December 1976 - 5 December 1977.

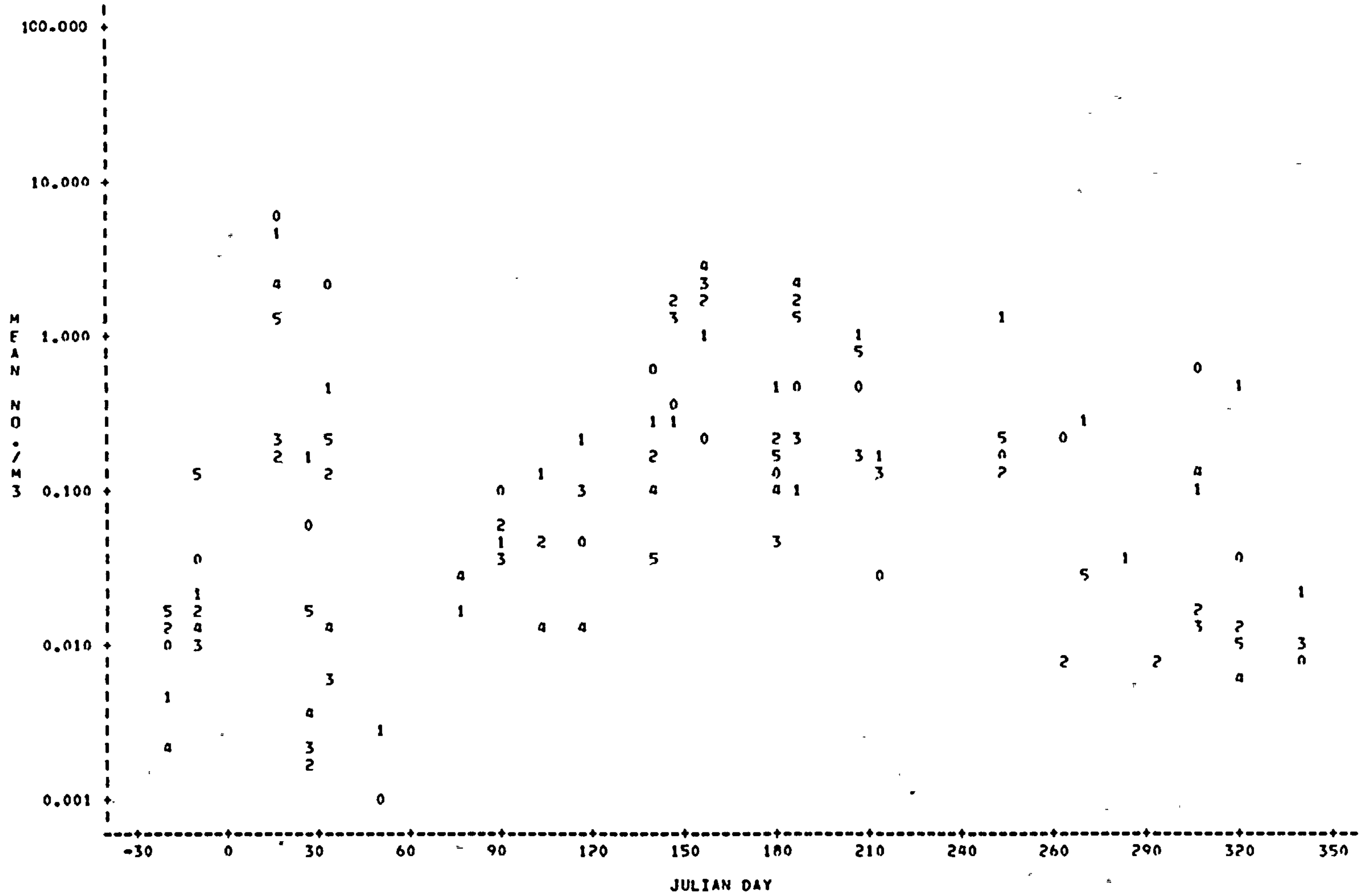

Figure B-10. Density of Clupeiformes larvae by Julian (calendar) day, Stations 0 through 5, St. Lucie Plant, 12 December 1976 - 5 December 1977.

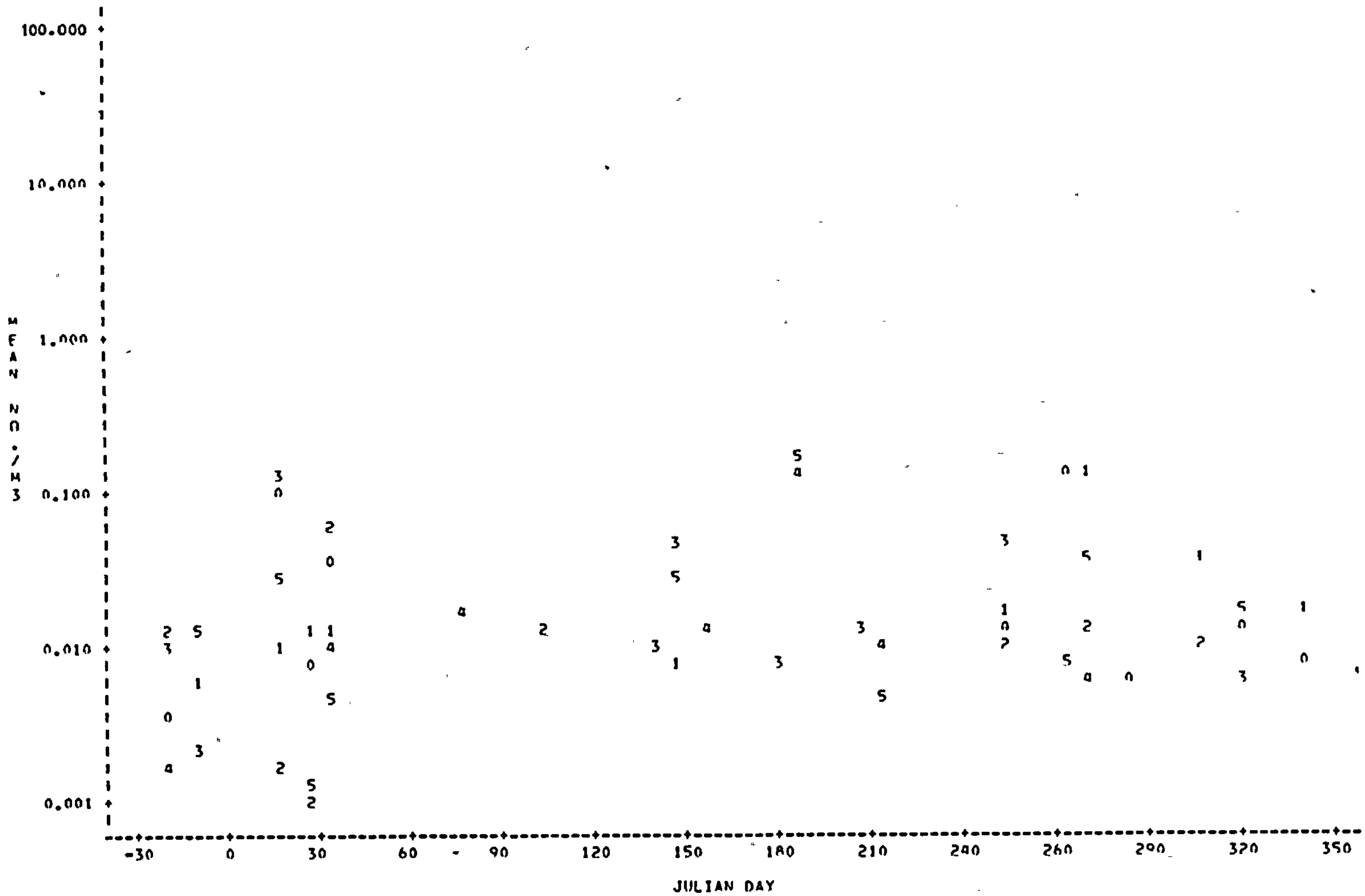

Figure B-11. Density of Sciaenidae larvae by Julian (calendar) day, Stations 0 through 5, St. Lucie Plant, 12 December 1976 - 5 December 1977.

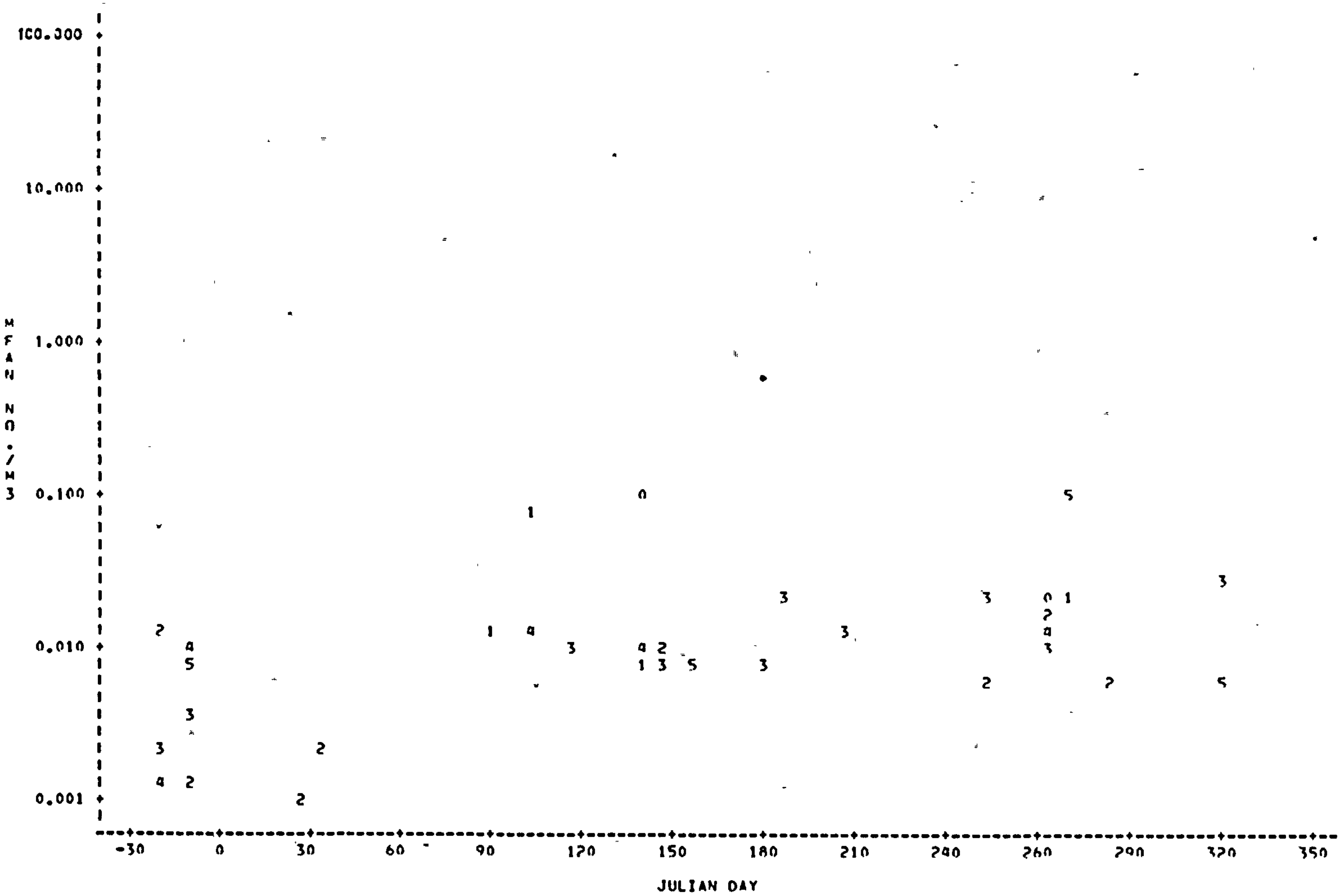

Figure B-12. Density of Carangidae larvae by Julian (calendar) day, Stations 0 through 5, St. Lucie Plant, 12 December 1976 - 5 December 1977.

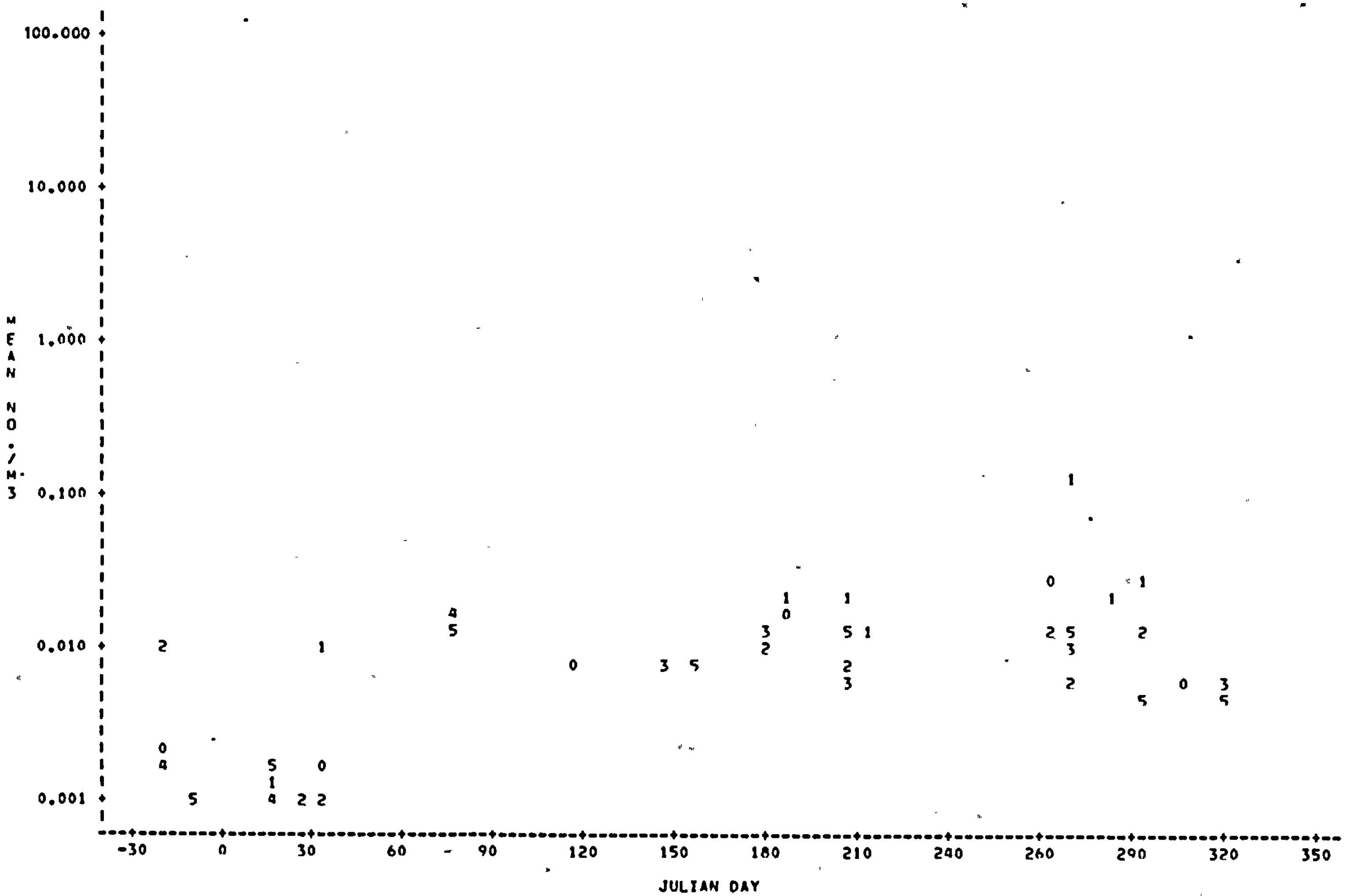

Figure B-13. Density of Bothidae larvae by Julian (calendar) day, Stations 0 through 5, St. Lucie Plant, 12 December 1976 - 5 December 1977.

TABLE B-1

NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category	3-4 JAN		6-7 JAN		10-11 JAN		13-14 JAN		17-18 JAN		20-21 JAN		24-25 JAN		27-28 JAN	
	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	16	124	8	51	7	92	21	123	6	39	20	77	60	228[c]	143	272
blue crab	10	282	9	488	6	203	26	1616	13	693	16	596	8	377	6	368
stone crab	-	-	1	10	1	1	-	-	1	24	1	12	-	-	-	-
spiny lobster	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
shark, ray	-	-	-	-	1	145	-	-	-	-	-	-	-	-	-	-
herring	1	-[c]	1	2	-	-	-	-	-	-	-	-	2	62	11	96[c]
anchovy	2	2[c]	1	2	-	-	1	6	-	-	-	-	15	75	3	9
catfish	-	-	-	-	-	-	-	-	-	-	2	109	4	159	4	125
jack	2	28	1	2	1	7	-	-	3	19	21	107	178	1346	145	767
mojarra	-	-	2	7	1	1	-	-	2	4	7	40	3	77	6	238
grunt	5	84	1	3	2	9	-	-	2	17	3	46	4	65[c]	1	19
croaker	29	205	2	46	-	-	-	-	-	-	3	40	7	134	6	166
blenny, goby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	1	7	2	10	1	5	2	98	-	-	-	-	2	43	1	3
flounder, sole	-	-	2	20[c]	-	-	2	31	-	-	5	49	5	50	2	14
triggerfish, filefish	4	945	1	14	-	-	1	433	-	-	4	77	2	54	1	604
puffer, trunkfish	-	-	-	-	1	5	-	-	1	5	-	-	6	68[c]	7	674
other fish	-	-	1	21	1	5	3	224	-	-	8	631	12	627[c]	12	647
total shellfish	26	406	18	549	14	296	47	1739	20	756	38	687	68	605[c]	149	640
total fish	44	1271[c]	14	127[c]	8	177	9	792	8	45	53	1099	240	2760[c]	200	3366[c]

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

	31 JAN-1 FEB		3-4 FEB		7-8 FEB		10-11 FEB		14-15 FEB		17-18 FEB		22-23 FEB		24-25 FEB	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	32	99	13	25	45	57	309	1073	111	315	24	27	15	67	17	42
blue crab	7	401	3	102	3	76	8	175	11	353	11	690	5	88	3	91
stone crab	1	1	1	1	1	10	-	-	-	-	2	3	-	-	-	-
spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
shark, ray	-	-	1	73	-	-	-	-	2	1026	1	252	1	530	-	-
herring	1	2	2	22	-	-	17	221	40	74	-	-	64	287	1	1
anchovy	1	8	5	24	2	3	36	110	2011	2394	11	19	686	990	331	487
catfish	1	56	1	32	2	115	4	150	1	29	1	29	-	-	-	-
jack	-	-	47	800	1	4	64	972	53	796	-	-	9	1559	8	1985
mojarra	1	3	-	-	3	23	-	-	-	-	-	-	1	2	8	73
grunt	-	-	31	1661	-	-	2	12	2	15	-	-	1	8	-	-
croaker	1	21	73	1901	1	1	2	207	13	1331	5	517	2	254	3	8
blenny, goby	1	3	38	275	1	1	1	1	2	5	1	2	-	-	1	4
cutlassfish	-	-	1	28	-	-	2	770	2	85	-	-	-	-	-	-
scorpionfish, searobin	-	-	2	230	-	-	5	268	3	339	-	-	2	156	-	-
flounder, sole	1	5	1	26	3	102	15	272	9	24	4	89	1	26	-	-
triggerfish, filefish	1	1	19	3408	-	-	1	1	3	1100	2	980	-	-	-	-
puffer, trunkfish	4	341	4	302	3	410	6	417	10	1298	1	89	2	471	-	-
other fish	-	-	24	963	4	297	30	655[c]	17	992	2	19	4	42	-	-
total shellfish	40	501	17	128	49	143	317	1248	122	668	37	720	20	155	20	133
total fish	12	440	249	9745	20	956	185	4056[c]	2168	9508	28	1996	773	4325	352	2558

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category	28 FEB-1 MAR		3-4 MAR		7-8 MAR		10-11 MAR		14-15 MAR		17-18 MAR		21-22 MAR		24-25 MAR	
	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	13	45	24	168	6	64	15	143	18	171	7	43	7	40	59	342
blue crab	4	380	3	118	5	212	2	118	4	248	3	230	5	141	7	503
stone crab	2	61	1	3	1	2	-	-	2	10	-	-	-	-	2	13
spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
shark, ray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	84	434	12	89	3	4	295	890	-	-	2	11	36	257	31	127
anchovy	539	841	261	374	36	50	1735	2339	14	27	17	37	15	27	49	44
catfish	-	-	-	-	-	-	-	-	-	-	2	87	-	-	-	-
jack	8	1356	7	1022	9	3962	39	121	6	2755	7	5078	200	4819	9	890
mojarra	2	10	1	4	-	-	5	39	1	3	144	708	145	1351	357	2884
grunt	-	-	-	-	1	4	4	37	3	30	-	-	1	17	1	4
croaker	3	397	9	1316	1	8	18	712	2	168	4	22	1	18	4	87
blenny, goby	-	-	-	-	-	-	1	1	-	-	-	-	1	4	-	-
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	-	-	-	-	-	-	-	-	-	-	1	4	1	29	1	5
flounder, sole	1	9	1	21	-	-	2	20	6	107	9	168	4	65	2	47
triggerfish, filefish	-	-	1	564	1	37	-	-	-	-	-	-	-	-	1	400
puffer, trunkfish	-	-	-	-	2	38	-	-	2	23	1	22	3	44	1	19
other fish	5	87	1	13	2	3	6	364	4	50	6	116	5	4	8	495
total shellfish	19	486	28	289	12	278	17	261	24	429	10	273	13	182	68	858
total fish	642	3134	293	3403	55	4106	2105	4523	38	3163	193	6253	412	6635	464	5002

[a] Number of individuals. [b] Total weight in grams.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category	28-29 MAR		31 MAR-1 APR		11-12 APR		14-15 APR		19-20 APR		24-25 APR		25-26 APR		28-29 APR	
	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	19	128	2	3	33	121	8	8[c]	13	23	8	16	7	14	3	5
blue crab	2	364	3	94	12	535	2	147	11	158	9	108	2	52	1	4
stone crab	2	3	3	12	1	74	1	16	-	-	-	-	-	-	1	2
spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
shark, ray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	2	3	-	-	2	6	1	6	-	-	-	-	-	-	-	-
anchovy	1	2	5	8	9	17	9	16	-	-	-	-	-	-	-	-
catfish	-	-	-	-	-	-	-	-	1	52	-	-	-	-	-	-
jack	2	823	4	1133	9	3017	14	1974	1	773	-	-	2	488	-	-
mojarra	74	655	59	328	269	2049	61	299	19	42	-	-	-	-	-	-
grunt	-	-	1	6	3	44	1	6	1	97	-	-	-	-	-	-
croaker	-	-	3	10	1	6	-	-	-	-	-	-	-	-	-	-
blenny, goby	1	3	-	-	-	-	-	-	1	2	4	30	-	-	-	-
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	2	8	1	44	3	64	3	12	2	14	-	-	2	13	-	-
flounder, sole	5	91	-	-	18	290	8	52	6	12	15	119	6	10	4	5
triggerfish, filefish	-	-	-	-	2	388	-	-	-	-	-	-	-	-	-	-
puffer, trunkfish	-	-	-	-	1	20	2	25	2	30	1	136	1	3	-	-
other fish	2	19	3	8	61[d]	1195[c]	33[d]	778	19[d]	135	19[d]	24	4	4	2	173
total shellfish	23	495	8	109	46	730	11	171[c]	24	181	17	124	9	66	5	11
total fish	89	1604	76	1537	378	7096[c]	132	3168	52	1157	39	309	15	518	6	178

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments. [d] Primarily pinfish.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Dates	2-3 MAY		5-6 MAY		9-10 MAY		12-13 MAY		16-17 MAY		19-20 MAY		23-24 MAY		26-27 MAY	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt. f	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	9	14	12	9	4	6	70	127	29	32	30	43	9	15	12	22
blue crab	2	113	2	149	2	43	8	51	-	-	-	-	3	207	2	205
stone crab	-	-	1	5	-	-	-	-	-	-	2	34	-	-	-	-
spiny lobster	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-
shark, ray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
anchovy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jack	4	2031	8	5230	8	5501	10	5216[c]	15	10249	15	10159	12	7726	9	5651
mojarra	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
grunt	-	-	4	3	2	2	1	1	1	1	1	2	-	-	-	-
croaker	-	-	-	-	-	-	1	35	-	-	-	-	-	-	-	-
blenny, goby	1	1	1	1	1	1	-	-	-	-	2	4	2	5	2	3
cutlassfish	-	-	-	-	-	-	1	748	-	-	-	-	-	-	-	-
scorpionfish, searobin	4	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
flounder, sole	5	31	4	6	1	15	2	34	2	9	-	-	1	13	1	1
triggerfish,filefish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
puffer, trunkfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
other fish	-	-	7	12	-	-	1	3	1	2	4	11	-	-	1	1
total shellfish	11	127	15	163	6	49	78	178	29	32	33	78	12	222	14	227
total fish	14	2069	24	5252	12	5519	16	6037[c]	20	10262	22	10176	15	7744	13	5656

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments. [d] Primarily pinfish.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Dates	31 MAY-1 JUN		2-3 JUN		6-7 JUN		9-10 JUN		13-14 JUN		16-17 JUN		23-24 JUN		24-25 JUN	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	30	52	48	92	24	34	17	27	22	30	7	10	8	11	12	16
blue crab	1	29	1	2	1	25	2	466	2	140	-	-	1	1	-	-
stone crab	-	-	-	-	-	-	1	25	-	-	-	-	1	23	1	1
spiny lobster	-	-	3	7	2	4	-	-	1	2	-	-	-	-	1	3
shark, ray	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
anchovy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jack	7	2458[c]	11	5619[c]	7	3606[c]	4	3088	3	218[c]	-	-	-	-	2	872
mojarra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
grunt	1	3	-	-	1	1	-	-	-	-	-	-	162	6397	9	246
croaker	-	-	-	-	-	-	-	-	-	-	-	-	2	82	-	-
blenny, goby	2	11	-	-	-	-	-	-	1	3	-	-	13	37	3	3
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
flounder, sole	3	6	3	8	-	-	1	1	-	-	-	-	-	-	-	-
triggerfish, filefish	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-
puffer, trunkfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
other fish	2	5	2	4	1	5	3	841	1	1	-	-	1	2	-	-
total shellfish	31	81	52	101	27	63	20	518	25	172	7	10	10	35	14	20
total fish	15	2483[c]	16	5631[c]	10	3614[c]	8	3930	5	222[c]	-	-	178	6518	14	1121

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
JULY-DECEMBER 1977

Dates	27-28 JUN		30 JUN-1 JUL		5-6 JUL		7-8 JUL		11-12 JUL		14-15 JUL		18-19 JUL		21-22 JUL	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	27	45	32	55	34	51	48	73	50	64	339	520	195	259	92	91
blue crab	2	17	5	26	-	-	1	77	-	-	-	-	1	12	2	21
stone crab	1	60	-	-	-	-	-	-	3	105	-	-	-	-	-	-
spiny lobster	-	-	-	-	-	-	-	-	-	-	2	13	-	-	-	-
shark	-	-	-	-	-	-	-	-	-	-	1	311	-	-	-	-
herring	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
anchovy	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
catfish	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
jack	1	1	5	1618	1	426	-	-	-	-	-	-	-	-	-	-
mojarra	1	-[c]	-	-	-	-	1	2	-	-	1	2	24	67	3	6
grunt	-	-	-	-	-	-	-	-	-	-	1	3	1	6	-	-
croaker	-	-	-	-	-	-	-	-	-	-	-	-	4	5	9	8
blenny, goby	1	10	-	-	-	-	7	47	1	1	4	63	-	-	1	4
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
flounder sole	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-
triggerfish, filefish	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-
puffer, trunkfish	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-
other fish	6	1013	3	6	1	5	1	2	1	4	3	13	5	15	1	8
total shellfish	30	122	37	81	34	51	49	150	53	169	341	533	196	271	94	112
total fish	9	1024[c]	9	1625	3	432	9	51	3	10	10	392	37	99	14	26

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category / Dates	25-26 JUL		28-29 JUL		1-2 AUG		4-5 AUG		8-9 AUG		11-12 AUG		15-16 AUG		17-18 AUG		22-23 AUG	
	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	121	153	112	160	140	201	96	149	422	595	1057	1408	317	395	87	101	83	119
blue crab	-	-	12	182	12	100	2	17	3	25	4	37	34	362	17	104	25	266
stone crab	-	-	-	-	2	6	-	-	-	-	1	2	1	6	-	-	-	-
spiny lobster	2	18	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
shark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
anchovy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jack	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
mojarra	-	-	4	7	7	31	1	1	28	38	1	2	5	8	1	4	-	-
grunt	-	-	2	8	-	-	-	-	118	892	6	29[c]	50	230	523	3019	31	197
croaker	-	-	-	-	-	-	-	-	6	8	4	12	2	9[c]	9	16	-	-
blenny, goby	-	-	2	7	1	4	1	1	3	34[c]	-	-	2	20	-	-	2	8
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	930	-	-
scorpionfish, searobin	-	-	1	9	2	4[c]	3	4	2	3	3	3	2	27	-	-	-	-
flounder, sole	-	-	2	3	-	-	1	6	1	4	-	-	-	-	-	-	2	18
triggerfish, filefish	1	1	-	-	1	2	1	2	-	-	-	-	-	-	1	7	1	2
puffer, trunkfish	1	2	-	-	-	-	1	1	-	-	-	-	-	-	1	4	1	4
other	3	12	4	160	3	5	3	14	3	132	4	8	5	24	1	2	-	-
total shellfish	123	171	124	342	154	307	98	166	425	620	1062	1447	353	765	104	205	108	385
total fish	5	15	15	194	15	47[c]	11	29	161	1111[c]	18	54	66	318	537	3982	38	232

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Dates	25-26 AUG		29-30 AUG		1-2 SEP		6-7 SEP		8-9 SEP		12-13 SEP		15-16 SEP		19-20 SEP		22-23 SEP	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	34	45	394	863	125	254	243	530	41	87	77	167	69	132	28	52	16	29
blue crab	4	31	138	952	28	332	14	43	7	156	5	38	5	44	-	-	2	25
stone crab	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1
spiny lobster	-	-	1	15	-	-	-	-	1	30	1	3	-	-	-	-	-	-
shark	-	-	-	-	-	-	1	11	-	-	-	-	-	-	-	-	-	-
herring	-	-	1	3	-	-	2	17	-	-	-	-	-	-	-	-	-	-
anchovy	-	-	2	5	1	1	9	9	13	16	1	1	-	-	1	2	-	-
catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jack	-	-	1	4	1	2	1	7	1	10	1	1	-	-	-	-	-	-
mojarra	1	4	12	49	11	75	65	322	12	66	1	4	5	13	1	1	-	-
grunt	318	2019	7520	44448	1262	18529	136	498	124	451	87	454	59	334	117	685	124	702
croaker	3	16	12	40	34	833	1	2	1	2	3	29	-	-	-	-	1	541
blenny, goby	1	3	5	52	85	896	2	14	2	.7	1	9	-	-	-	-	2	48
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	-	-	-	-	1	12	1	5	-	-	-	-	-	-	-	-	-	-
flounder,sole	1	10	2	7	1	2	-	-	-	-	-	-	-	-	-	-	-	-
triggerfish, filefish	-	-	1	4	2	343	1	14	2	22	-	-	-	-	-	-	-	-
puffer, trunkfish	1	9	-	-	2	196	1	4	-	-	2	14	-	-	-	-	-	-
other fish	2	14	11	84	27	1053	14	55[c]	7	42	9	131	7	37	-	-	1	-[c]
total shellfish	38	76	533	1830	154	587	257	573	49	273	83	208	74	176	28	52	19	55
total fish	327	2075	7567	44696	1427	21942	234	958[c]	162	615	105	643	71	384	119	688	128	1291[c]

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category	Dates 11-12 OCT		13-14 OCT		17-18 OCT		20-21 OCT		24-25 OCT		27-28 OCT		31 O-1 NOV		3-4 NOV		7-8 NOV	
	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	5	16	18	54	21	62	9	25	22	126	7	21	8	23	73	228	96	178
blue crab	2	24	1	15	3	50	-	-	8	113	12	150	1	16	8	100	9	221
stone crab	-	-	1	1	-	-	-	-	-	-	1	1	-	-	-	-	1	1
spiny lobster	-	-	1	32	1	1	-	-	-	-	1	2	-	-	1	1	1	1
shark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	-	-	-	-	-	-	-	-	-	-	1	3	-	-	1	4	1	1
anchovy	-	-	21	25	-	-	1	2	7	11	17	45	3	4	26	34	58	107
catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	343
jack	-	-	-	-	1	1	17	3	3	2	-	-	-	-	1	1	6	55
mojarra	1	4	-	-	2	6	1	1	24	112	-	-	10	48	1	7	3	14
grunt	1	8	5	120	2	33	1	6	12	86	3	9	1	6	5	19	5	26
croaker	1	2	-	-	-	-	-	-	-	-	-	-	-	-	2	4	22	44
blenny, goby	1	16	1	6	-	-	-	-	-	-	1	4	-	-	1	7	2	32
cutlassfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	-	-	-	-	1	17	-	-	-	-	-	-	-	-	2	6[c]	62	272
flounder,sole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	19	2	8
triggerfish, filefish	-	-	-	-	1	1	-	-	1	2	-	-	-	-	2	2	1	2
puffer, trunkfish	2	26	3	25	-	-	-	-	-	-	-	-	-	-	1	11	-	-
other fish	2	10	4	375[c]	1	1	-	-	5	18[c]	3	19[c]	2	10	11	48	41	1867[c]
total shellfish	7	40	21	102	25	113	9	25	30	239	21	174	9	39	82	329	107	401
total fish	8	66	34	551[c]	8	59	20	12	52	231[c]	25	80[c]	16	68	55	162[c]	204	2771[c]

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Dates	10-11 NOV		14-15 NOV		17-18 NOV		21-22 NOV		22-23 NOV		28-29 NOV		1-2 DEC		5-6 DEC		8-9 DEC	
Category	No.[a]	Wt.[b]	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
shrimp	25	62	40	75	32	103	28	56	31	64	5	12	10	17	7	12	30	79
blue crab	2	36	7	138	7	152	6	99	3	51	1	59	-	-	-	-	5	143
stone crab	2	8	-	-	-	-	-	-	2	32	2	35	1	29	1	1	2	33
spiny lobster	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
shark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
herring	-	-	-	-	-	-	-	-	1	7	-	-	-	-	-	-	-	-
anchovy	4	8	-	-	2	3	1	1	1	4	-	-	-	-	-	-	-	-
catfish	1	103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
jack	-	-	4	51	7	8	-	-	-	-	-	-	-	-	-	-	-	-
mojarra	9	55	1	7	3	8	2	5	7	22	2	3	-	-	1	3	3	8
grunt	10	57	18	94	13	87	2	10	7	40	2	14	2	17	-	-	-	-
croaker	2	11	3	43	4	12	1	6	1	11	1	9	-	-	-	-	1	9
blenny, goby	-	-	1	1	-	-	-	-	1	3	-	-	-	-	-	-	1	38
cutlassfish	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
scorpionfish, searobin	8	284	3	7	1	2	3	13	1	2	-	-	1	4	-	-	-	-
flounder,sole	-	-	1	10	-	-	-	-	-	-	-	-	-	-	-	-	1	12
triggerfish, filefish	1	2	1	5	4	15	-	-	-	-	1	3	-	-	-	-	-	-
puffer, trunkfish	4	283	2	176	-	-	1	23	-	-	-	-	-	-	-	-	-	-
other fish	2	22	2	8	5	29[c]	-	-	1	73	-	-	4	112	1	3	2	7
total shellfish	30	107	47	213	39	255	34	155	36	147	8	106	11	46	8	13	37	255
total fish	41	825	36	402	40	165[c]	10	58	20	162	6	29	7	133	2	6	8	74

[a] Number of individuals. [b] Total weight in grams. [c] Includes fragments.

TABLE B-1
(continued)
NUMBER AND BIOMASS OF SHELLFISHES AND FISHES COLLECTED
DURING 24-HOUR IMPINGEMENT SURVEYS AT THE ST. LUCIE PLANT
1977

Category	Dates 13-14 DEC No.[a]	Wt.[b]	14-15 DEC No.	Wt.	19-20 DEC No.	Wt.	22-23 DEC No.	Wt.	27-28 DEC No.	Wt.	29-30 DEC No.	Wt.	Total Number	Percentage Composition	Total Weight	Percentage Composition
shrimp	100	194	50	142	31	103	11	62	11	33	9	25	6390	88.7	12955	42.1
blue crab	42	407	14	382	6	82	4	249	8	101	8	16	727	10.1	16913	54.9
stone crab	1	23	2	5	2	14	-	-	-	-	-	-	59	0.8	710	2.3
spiny lobster	1	2	-	-	-	-	-	-	-	-	1	86	26	0.4	227	0.7
shark	-	-	-	-	-	-	-	-	-	-	-	-	8	0.1	2348	0.9
herring	-	-	1	10	-	-	-	-	-	-	-	-	618	2.9	2644	1.0
anchovy	66	97	3	5	-	-	2	4	4	7	10	16	6049	28.0	8319	3.1
catfish	-	-	-	-	1	274	-	-	-	-	-	-	26	0.1	1663	0.6
jack	-	-	-	-	-	-	-	-	-	-	2	25	1019	4.7	108062	40.9
mojarra	4	14	1	2	-	-	1	2	2	12	-	-	1435	6.6	9876	3.7
grunt	12	51	1	5	1	5	1	6	8	45	12	62	10855	50.3	82150	31.1
croaker	-	-	2	65	-	-	2	20	-	-	-	-	327	1.5	9449	3.6
blenny, goby	1	2	-	-	1	1	-	-	-	-	1	2	217	1.0	1754	0.7
cutlassfish	-	-	-	-	-	-	-	-	-	-	1	11	9	0.1	2573	1.0
scorpionfish, searobin	8	434	4	15	1	8	6	18	-	-	-	-	157	0.7	2507	0.8
flounder, sole	1	1	1	21	1	1	-	-	2	26	-	-	182	0.8	2001	0.7
triggerfish, filefish	1	10	-	-	-	-	-	-	-	-	-	-	71	0.3	9449	3.6
puffer, trunkfish	1	2	-	-	-	-	-	-	1	12	-	-	87	0.4	5236	2.0
other fish	4	25	1	1	2	449	-	-	1	4	3	6	544	2.5	16423	6.3
total shellfish	144	626	66	529	39	199	15	311	19	134	18	127	7202	100.0	30805	100.0
total fish	98	636	14	124	7	738	12	50	18	106	29	122	21604	100.0	264454	100.0

[a] Number of individuals. [b] Total weight in grams.

TABLE B-2

TOTAL NUMBER OF INDIVIDUALS, WEIGHT IN GRAMS AND PERCENTAGE COMPOSITION BY TAXON OF SHELLFISHES AND FISHES COLLECTED DURING IMPINGEMENT SAMPLING ST. LUCIE PLANT 1976 - 1977

	1976[a]				1977[b]			
Taxon	No. of individuals	% by numbers	Weight (g)	% by weight	No. of individuals	% by numbers	Weight (g)	% by weight
shrimp	2525	78.1	8499	23.9	6390	88.7	12955	42.1
blue crab	690	21.4	26821	75.3	727	10.1	16913	54.9
stone crab	13	0.4	265	0.7	59	0.8	710	2.3
spiny lobster	4	<0.1	17	0.1	26	0.4	227	0.7
herring	152	0.9	623	1.2	618	2.9	2644	1.0
anchovy	8776	54.4	12327	22.9	6049	28.0	8319	3.1
jack	4962	30.8	6575	12.2	1019	4.7	108062	40.9
mojarra	365	2.3	2918	5.4	1435	6.6	9876	3.7
grunt	453	2.8	5743	10.7	10855	50.3	82150	31.1
croaker	309	1.9	2444	4.6	327	1.5	9449	3.6
cutlassfish	458	2.8	2423	4.5	9	<0.1	2573	1.0
flatfish[c]	112	0.7	1562	2.9	182	0.8	2001	0.7
other fish	542	3.4	19149	35.6	1110	5.1	39380	14.9
TOTAL SHELLFISH	3,232	100.0	35,602	100.0	7,202	100.0	30,805	100.0
TOTAL FISH	16,129	100.0	53,764	100.0	21,604	100.0	264,454	100.0

[a] Total of 45 24-hour sampling periods.
[b] Total of 97 24-hour sampling periods.
[c] Flounder, sole, tonguefish.

TABLE B-3

TOTAL NUMBER OF FISHES COLLECTED BY GILL NET[a] AT INSHORE (CANAL) STATIONS
ST. LUCIE PLANT
1977

	Date and station																		
	27-28 Jan				28-29 Jan				16-17 Feb				17-18 Feb				22-23 Mar		
Taxon	13	14	15	16	13	14	15	16	13	14	15	16	13	14	15	16	13	14	15
shark, ray		1			1				10		15			1	1				
jack										1									1
snapper	1	4											1					2	
mojarra				1															
grunt		2																5	
porgy	3		1		1	1	2		1						1		5	2	
croaker	2	2	4		3		1		1										
spadefish	1	1			2		1							1				3	
mullet																		1	
other fish	5	1	3		1		1		1	1	1		1	1	2				
TOTAL	12	11	8	1	8	1	5	0	13	2	16	0	2	3	4	0	5	13	1

[a] Combination of two nets per station per 24-hour period.

TABLE B-3
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY GILL NET[a] AT INSHORE (CANAL) STATIONS
ST. LUCIE PLANT
1977

	Date and station																	
	23-24 Mar			26-27 Apr			27-28 Apr			19-20 May			20-21 May			8-9 Jun		
Taxon	13	14	15	13	15	16	13	15	16	13	15	16	13	15	16	13	15	16
shark, ray								1										
jack	1			2	2			1									2	
snapper				1						1								
mojarra																		
grunt				1	1									3				
porgy														2		1	1	
croaker																	1	
spadefish				19	7		10			2						1	10	
mullet	1																	
other fish					1												2	
TOTAL	2	0	0	23	11	0	10	2	0	3	0	0	0	5	0	2	16	0

[a] Combination of two nets per station per 24-hour period.

TABLE B-3
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY GILL NET[a] AT INSHORE (CANAL) STATIONS
ST. LUCIE PLANT
1977

	Date and station																	
	9-10 Jun			13-14 Jul			14-15 Jul			17-18 Aug			18-19 Aug			19-20 Sep		
Taxon	13	15	16	13	15	16	13	15	16	13	15	16	13	15	16	13	15	16
shark, ray					1											1		
jack		1		2	6					1						1		
snapper				1	1						6			1		8		
mojarra																		
grunt											3					4	1	
porgy																1		
croaker					1						1			1				
spadefish		8			3					1	2					6	4	
mullet											2			1		1		
other fish											2					1		
TOTAL	0	9	0	3	12	0	0	0	0	2	16	0	0	3	0	23	2	0

[a] Combination of two nets per station per 24-hour period.

TABLE B-3
(continued)

TOTAL NUMBER OF FISHES COLLECTED BY GILL NET[a] AT INSHORE (CANAL) STATIONS
ST. LUCIE PLANT
1977

	Date and station																	
	20-21 Sep			17-18 Oct			18-19 Oct			7-8 Nov			8-9 Nov			7-8 Dec		
Taxon	13	15	16	13	15	16	13	15	16	13	15	16	13	15	16	13	15	16
shark, ray											1		1					
jack										6	22		3	1		2		
snapper	1	1									15		2	1			1	
mojarra																1		
grunt										4	6		4	2		1	3	
porgy	3									2	2		6	5		6		
croaker										1	2			2			1	
spadefish		1											1					
mullet										3	5			3		8		
other fish	1									2	4			1		3		
TOTAL	5	2	0	0	0	0	0	0	0	18	57	0	17	15	0	21	5	0

[a] Combination of two nets per station per 24-hour period.

TABLE B-3
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY GILL NET[a] AT INSHORE (CANAL) STATIONS
ST. LUCIE PLANT
1977

	Date and station								
	8-9 Dec.			Total by station				Total by	Percentage
Taxon	13	15	16	13	14[b]	15	16	taxon	composition
shark, ray				13	2	19	0	34	8.4
jack	1			19	1	36	0	56	13.9
snapper	1			17	6	26	0	49	12.2
mojarra	2			3	0	0	1	4	1.0
grunt		1		14	7	20	0	41	10.2
porgy		1		29	3	15	0	47	11.7
croaker				7	2	14	0	23	5.7
spadefish				43	5	36	0	84	21.0
mullet	2	1		15	1	12	0	28	7.0
other fish	1			16	3	17	0	36	8.9
TOTAL	7	3	0	176	30	195	1	402	100.0

[a] Combination of two nets per station per 24-hour period.
[b] Sampled three months only.

TABLE B-4

TOTAL NUMBER OF INDIVIDUALS AND PERCENTAGE COMPOSITION
BY TAXON OF FISHES COLLECTED BY CANAL GILL NET AT
INSHORE STATIONS
ST. LUCIE PLANT
1976 - 1977

Taxon	1976[a] No. of individuals	1976[a] % composition	1977[b] No. of individuals	1977[b] % composition
shark, ray	2	0.4	34	8.4
jack	38	7.7	56	13.9
snapper	62	12.6	49	12.2
mojarra	10	2.0	4	1.0
grunt	80	16.2	41	10.2
porgy	16	3.2	47	11.7
croaker	125	25.3	23	5.7
spadefish	2	0.4	84	21.0
mullet	97	19.6	28	7.0
other fish	62	12.6	36	8.9
TOTAL FISH	494	100.0	402	100.0

[a] Total of 33 sampling periods.
[b] Total of 24 sampling periods.

TABLE B-5

TOTAL NUMBER OF FISHES COLLECTED BY GILL NET AT OFFSHORE STATIONS[a]
ST. LUCIE PLANT
1977

Taxon	Date and station																							
	27 Jan						24 Feb						25 Mar						25 Apr					
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
Spanish mackerel	8	5	1				1	1									1		15	6				
bluefish	139	166				1																1		
Atlantic bumper														37					13					
blue runner								3					2	3				1	1	1	1		3	1
crevalle jack																								
other fish	6	6	2	1		13			1		1			14			1	3			2	2	1	7
TOTAL FISH	153	177	3	1	0	14	1	4	1	0	1	0	2	54	0	0	2	4	29	7	3	3	4	8

Taxon	Date and station																							
	20 May						9 Jun						15 Jul						18 Aug					
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
Spanish mackerel	4		1																					
bluefish																								
Atlantic bumper																								
blue runner		1	1				4					1	3	12	2			1		3				3
crevalle jack																								
other fish		1				1				5	1		4	1	1			1					32	
TOTAL FISH	4	2	2	0	0	1	4	0	0	5	1	1	7	13	3	0	0	2	0	3	0	0	32	3

[a] One 30-minute set per station per month.

TABLE B-5
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY GILL NET AT OFFSHORE STATIONS[a]
ST. LUCIE PLANT
1977

Taxon	Date and station 20 Sep 0	1	2	3	4	5	26 Oct 0	1	2	3	4	5	Nov (2 Dec)[b] 0	1	2	3	4	5	9 Dec 0	1	2	3	4	5
Spanish mackerel							31	12	172	1	2	71								9	66			
bluefish							1	9	2		2	10												
Atlantic bumper							19	41	38			63												
blue runner	2	2				1			3			1	7	4	3					1				
crevalle jack								3	1			1												
other fish							23	9	6		11	17	22		1					1				
TOTAL FISH	2	2	0	0	0	1	74	74	222	1	15	163	29	4	4	0	0	1	0	11	66	0	0	0

Taxon	Date and station Total by station 0	1	2	3	4	5	Total by taxon	% composition
Spanish mackerel	59	33	240	1	3	71	407	33.3
bluefish	140	175	2	1	2	11	331	27.1
Atlantic bumper	32	78	38	0	0	63	211	17.2
blue runner	19	30	10	0	3	9	71	5.8
crevalle jack	0	3	1	0	0	1	5	0.4
other fish	55	32	13	8	47	43	198	16.2
TOTAL FISH	305	351	304	10	55	198	1,223	100.0

[a] One 30-minute set per station per month.
[b] Delayed due to inclement weather.

TABLE B-6

TOTAL NUMBER OF INDIVIDUALS AND PERCENTAGE COMPOSITION BY TAXON OF FISHES COLLECTED BY GILL NET OFFSHORE ST. LUCIE PLANT 1976 - 1977

Taxon	1976[a] No. of individuals	1976[a] % composition	1977[b] No. of individuals	1977[b] % composition
Spanish mackerel	179	10.3	407	33.3
blue fish	91	5.2	331	27.1
Atlantic bumper	557	32.2	211	17.2
blue runner	273	15.7	71	5.8
crevalle jack	327	18.9	5	0.4
other fish	307	17.7	198	16.2
TOTAL FISH	1,734	100.0	1,223	100.0

[a] Total of 10 sampling periods.
[b] Total of 12 sampling periods.

TABLE B-7

TOTAL NUMBER OF FISHES COLLECTED BY TRAWL
(ONE 15-MINUTE TRAWL PER STATION PER MONTH)
ST. LUCIE PLANT
1977

Taxon	Date and station																													
	6 Jan						22 Feb						16 Mar						26 Apr						17 May					
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
seatrout																														
other croakers																									3					1
flatfish[a]		1	2	1	2	1					1					9		19						1	6	1	3	7	1	1
grunt	1					4	1	1			2			1				1								2				
searobin, scorpionfish			3		5	2					3					1					1	1		3	1	3	2	4		
sand perch																										9		1	2	1
mojarra																										2				
cusk-eel		2				2					1					3									1			1		
lizardfish	1		3	1	2	1				1												1								
other fish	1	5				1		22		1	4			4		2		3		1	3				1	3	4		5	2
TOTAL FISH	3	8	8	2	9	11	1	23	0	2	11	0	0	5	0	15	0	23	0	1	4	2	0	4	12	20	9	13	8	5

[a] Flounder, sole, tonguefish.

TABLE B- 7
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY TRAWL
(ONE 15-MINUTE TRAWL PER STATION PER MONTH)
ST. LUCIE PLANT
1977

	Date and station																													
	20 Jun						20 Jul						24 Aug						19 Sep						20 Oct					
Taxon	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
seatrout																														
other croakers					1																			1						
flatfish[a]		2	9	8	10	3	5	4	25	10			2	4	7	3	1	1	1		4	5	1	4		1	1	4	3	1
grunt		1					11	69						5					30	14				20						2
searobin, scorpionfish			4	6	4	2	3	1	2	1			1		7		1	2	1		4	3	2	7			1	1	3	7
sand perch	1		19		11	11	12	4	15		1	3			2	1		2	1		12		3	20						5
mojarra	6	1			4		16	1					3	2					81	9				2						
cusk-eel			1	3		1	1	4	1		1								1				1					1		
lizardfish				1				1	2	1				1		3					3	4	3				1	2	1	1
other fish		6	4	2	5	1	3	5	7		6	9	2	10	4	2	4	3	6		1	1	2	12		8	4			7
TOTAL FISH	7	10	37	20	35	18	51	89	52	12	8	12	8	22	20	9	6	8	121	23	24	13	12	66	0	9	7	8	7	23

[a] Flounder, sole, tonguefish.

TABLE B-7
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY TRAWL
(ONE 15-MINUTE TRAWL PER STATION PER MONTH)
ST. LUCIE PLANT
1977

	Date and station																	
	9 Nov						14 Dec						Total by station					
Taxon	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
seatrout	16	536				54							16	536	0	0	0	54
other croakers	9	232					3						15	232	0	0	1	2
flatfish[a]	2	11	2	7	2	2	2		1	7	3	6	18	24	54	61	24	39
grunt	1	1				6	2	2				1	46	96	0	0	2	34
searobin, scorpionfish		17	1		2	29	3	8	3	5	3	7	9	29	28	22	23	59
sand perch		1				4							14	14	48	2	17	46
mojarra		1			1	10							106	16	0	0	5	12
cusk-eel	2	13				1		1	3	1		1	5	20	5	9	3	5
lizardfish	1			2						6	1	1	2	2	9	22	7	3
other fish	3	12	1	3		44	3	4	3			3	19	80	31	11	26	85
TOTAL FISH	34	824	4	12	5	150	13	15	10	19	7	19	250	1049	175	127	108	339

[a] Flounder, sole, tonguefish.

TABLE B-7
(continued)
TOTAL NUMBER OF FISHES COLLECTED BY TRAWL
(ONE 15-MINUTE TRAWL PER STATION PER MONTH)
ST. LUCIE PLANT
1977

Taxon	Total by taxon	Percentage composition
seatrout	606	29.6
other croakers	250	12.2
flatfish[a]	220	10.7
grunt	178	8.7
searobin, scorpionfish	170	8.3
sand perch	141	6.9
mojarra	139	6.8
cusk-eel	47	2.3
lizardfish	45	2.2
other fish	252	12.3
TOTAL FISH	2,048	100.0

[a] Flounder, sole, tonguefish.

TABLE B-8

TOTAL NUMBER OF INDIVIDUALS AND PERCENTAGE COMPOSITION BY TAXON OF FISHES COLLECTED BY TRAWL ST. LUCIE PLANT 1976-1977

Taxon	1976[a] No. of individuals	1976[a] % composition	1977[b] No. of individuals	1977[b] % composition
seatrout	0	0.0	606	29.6
other croakers	13	2.0	250	12.2
flatfish[c]	129	19.6	220	10.7
grunt	61	9.3	178	8.7
searobin, scorpionfish	129	19.6	170	8.3
sand perch	86	13.1	141	6.9
mojarra	26	4.0	139	6.8
cusk-eel	72	11.0	47	2.3
lizardfish	9	1.4	45	2.2
other fish	131	20.0	252	12.3
TOTAL FISH	656	100.0	2,048	100.0

[a] Total of 10 sampling periods.
[b] Total of 12 sampling periods.
[c] Flounder, sole, tonguefish.

TABLE B-9

TOTAL NUMBER OF SHELLFISH AND FISHES COLLECTED BY BEACH SEINE[a]
ST. LUCIE PLANT
1977

	Date and station																				
	7 Jan			17 Feb			18 Mar			29 Apr			16 May			16 Jun			27 Jul		
Taxon	6	7	8	6	7	8	6	7	8	6	7	8	6	7	8	6	7	8	6	7	8
speckled crab			1														2	3	3	1	1
sand drum							1			6	5	1	1	1	3	60	4	1	12	7	
kingfish	2					2	1			12	1		7	2	3			2	7	20	
herring						1								2		13	1		11	35	38
mojarra										1						3					8
anchovy										2	12					46					
Atlantic bumper																					
Florida pompano						1							1	4		5	2		1		
other jacks														1		1					
other fish				2						15	3					1	1		2		
TOTAL FISH	2	0	0	2	0	4	2	0	0	36	21	1	9	10	6	129	8	3	33	62	46

[a] Combination of three replicates per station per month.

TABLE B-9
(continued)
TOTAL NUMBER OF SHELLFISH AND FISHES COLLECTED BY BEACH SEINE[a]
ST. LUCIE PLANT
1977

Taxon	26 Aug 6	26 Aug 7	26 Aug 8	23 Sep 6	23 Sep 7	23 Sep 8	27 Oct 6	27 Oct 7	27 Oct 8	9 Nov 6	9 Nov 7	9 Nov 8	15 Dec 6	15 Dec 7	15 Dec 8	Total/station 6	Total/station 7	Total/station 8	Total by taxon	% composition
speckled crab	3			1	1		1	3	1				2	2		10	9	6	25	100.0
sand drum	9	11	2	35	4	1	8							1		132	33	8	173	21.1
kingfish	29	12		14	10		27	7	2	2	1		4	2	3	105	55	12	172	21.0
herring	69							1								93	39	39	171	20.9
mojarra				9	31	24							4		1	17	31	33	81	9.9
anchovy																48	12	0	60	7.3
Atlantic bumper										12			32			44	0	0	44	5.4
Florida pompano			1					3	3		1					7	10	5	22	2.7
other jacks	2		2		23	2	2	5			2	1			1	5	31	6	42	5.1
other fish	1		15	3				3	3	1		1		2	1	25	9	20	54	6.6
TOTAL FISH	110	23	20	61	68	27	37	19	8	15	4	2	40	5	6	476	220	123	819	100.0

[a] Combination of three replicates per station per month.

TABLE B-10

TOTAL NUMBER OF INDIVIDUALS AND PERCENTAGE COMPOSITION BY TAXON OF FISHES COLLECTED BY BEACH SEINE ST. LUCIE PLANT 1976-1977

	1976[a]		1977[b]	
Taxon	No. of individuals	% composition	No. of individuals	% composition
sand drum	105	8.7	173	21.1
kingfish	108	8.9	172	21.0
spot	101	8.3	0	0.0
herring	510	42.1	171	20.9
mojarra	8	0.7	81	9.9
anchovy	159	13.1	60	7.3
Atlantic bumper	28	2.3	44	5.4
Florida pompano	43	3.6	22	2.7
other jacks	73	6.0	42	5.1
other fish	76	6.3	54	6.6
TOTAL FISH	1,211	100.0	819	100.0

[a] Total of 10 sampling periods.
[b] Total of 12 sampling periods.

TABLE B-11

ANALYSIS OF VARIANCE: GENERAL LINEAR MODELS PROCEDURE
DIFFERENCES IN CAPTURE RATES OF PAIRED BONGO NETS
ST. LUCIE PLANT, 1977

EGGS

Source	DF	Sum of squares	Mean square	
Model	6	1277.78002015	212.9633369	
Error	291	64249.99914364	220.79037506	
Corrected Total	297	65527.77916379		
Source	**DF**	**Type I SS**	**F Value**	**PR > F**
Station	5	1248.17174117	1.13	0.3440
Replicate	1	29.60827898	0.13	0.7145

LARVAE

Source	DF	Sum of squares	Mean square	
Model	6	3.43440290	0.57240048	
Error	290	474.81099787	1.63727930	
Corrected Total	296	478.24540077		
Source	**DF**	**Type I SS**	**F value**	**PR > F**
Station	5	3.43280641	0.42	0.8365
Replicate	1	0.00159650	0.00	0.9751

* Significant at $\alpha = 0.10$.

TABLE B-12

EXAMPLES OF THE VARIABLES, CLASS VARIABLES AND MODELS USED WITH THE GENERAL LINEAR MODELS PROCEDURE
ST. LUCIE PLANT
1977

VARIABLES			
(Y_1) Density	($X_{1,2}$) Station	($X_{3,4}$) Replicate	(X_0) Intercept
Yi_1	1	A	1
Yi_1	1	B	1
Yi_1	2	A	1
Yi_1	2	B	1

CLASS VARIABLES			
Station		Replicate	
1	2	A	B
X_{i1}	X_{i2}	X_{i3}	X_{i4}
1	0	1	0
1	0	0	1
0	1	1	0
0	1	0	1

MODELS

For station and replicate effects:

$$Y_i = B_0X_0 + B_1X_{i1} + B_2X_{i2} + B_3X_{i3} + B_yX_{i4} + \Sigma_i$$

For station effects:

$$Y_i = B_0X_0 + B_1X_{i1} + B_2X_{i2} + \Sigma_i$$

where: B is the respective slope
Σ_i is the error term.

TABLE B-13

ANALYSIS OF VARIANCE:
COMPARISON OF CAPTURE RATE AT STATIONS 0 THROUGH 5
ST. LUCIE PLANT
1977

EGGS

Source	DF	Sum of squares	Mean square	
Model	5	1248.17174117	249.63434823	
Error	292	64279.66742262	220.13564186	
Corrected Total	297	65527.77916379		
Source	DF	Type I SS	F value	PR > F
Station	5	1248.17174117	1.13	0.3422

LARVAE

Source	DF	Sum of squares	Mean square	
Model	5	3.43280641	0.68656128	
Error	291	474.81259437	1.63165840	
Corrected Total	296	478.24540077		
Source	DF	Type I SS	F value	PR > F
Station	5	3.43280641	0.42	0.8355

* Significant at $\alpha = 0.10$.

TABLE B-14

ANALYSIS OF VARIANCE:
EGG DISTRIBUTION AT STATIONS 0 - 5 BY SEASON
ST. LUCIE PLANT
1977

Season	Source	DF	Sum of squares	Mean square
Winter	Model	5	2450.23066326	490.04613265
	Error	66	20805.87951359	315.24059869
	Corrected total	71	23256.11017685	

Source	DF	Type I SS	F value	PR > F
Station	5	2450.23066326	1.55	0.1843

Season	Source	DF	Sum of squares	Mean square
Spring	Model	5	2596.51143285	519.30228657
	Error	65	23831.11567317	366.63254882
	Corrected total	70	26427.62710602	

Source	DF	Type I SS	F value	PR > F
Station	5	2596.51143285	1.42	0.2293

Season	Source	DF	Sum of squares	Mean square
Summer	Model	5	1823.34219367	364.66843873
	Error	54	9338.11900295	172.92812968
	Corrected total	59	11161.46119662	

Source	DF	Type I SS	F value	PR > F
Station	5	1823.34219367	2.11*	0.0777

Season	Source	DF	Sum of squares	Mean square
Fall	Model	5	9.44608719	1.88921744
	Error	88	126.95678021	1.44269068
	Corrected total	93	136.40286740	

Source	DF	Type I SS	F Value	PR > F
Station	5	9.44608719	1.31	0.2666

* Significant at $\alpha = 0.10$.

TABLE B-15

DUNCAN'S MULTIPLE-RANGE TEST:
SUMMER DISTRIBUTION OF EGGS AT STATIONS 0-5
ST. LUCIE PLANT
1977

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=54 MS=0.336318

GROUPING	MEAN	N	STA
A	16.220653	10	0
B	2.004158	10	2
B			
B	1.903364	10	5
C	1.350259	10	4
C			
C	1.212331	10	1
C			
C	0.861241	10	3

TABLE B-16

CORRELATION COEFFICIENTS BETWEEN DENSITIES OF EGGS AND LARVAE AND FOUR PHYSICAL PARAMETERS
ST. LUCIE PLANT
1977

	EGGS	LARVAE	DO	TURB	TEMP	SALINITY
EGGS	1.00000	-0.04155	0.18020*	-0.11094*	-0.24271*	0.01413
	0.0000	0.4757	0.0033	0.0558	0.0001	0.8093
	298	297	264	298	286	294
LARVAE		1.00000	-0.21176*	0.13605*	-0.07265	-0.04909
		0.0000	0.0005	0.0190	0.2214	0.4024
		297	264	297	285	293
DO			1.00000	0.14501*	-0.57923*	-0.04255
			0.0000	0.0184	0.0001	0.4946
			264	264	252	260
TURB				1.00000	-0.20870*	-0.10261
				0.0000	0.0004	0.0790
				298	286	294
TEMP					1.00000	0.11628*
					0.0000	0.0511
					286	282
SALINITY						1.00000
						0.0000
						294

*Significant at $\alpha = 0.05$.

TABLE B-17

ANALYSIS OF VARIANCE:
LARVAL DISTRIBUTION AT STATIONS 0 - 5 BY SEASON
ST. LUCIE PLANT
1977

Season	Source	DF	Sum of squares	Mean square
Winter	Model	5	31.78464144	6.35692829
	Error	66	214.78128866	3.25426195
	Corrected total	71	246.56593010	

Source	DF	Type I SS	F value	PR > F
Station	5	31.78464144	1.95*	0.0964

Season	Source	DF	Sum of squares	Mean square
Spring	Model	5	1.18766380	0.23753276
	Error	64	37.97546783	0.59336668
	Corrected total	69	39.16313164	

Source	DF	Type I SS	F value	PR > F
Station	5	1.18766380	0.40	0.8479

Season	Source	DF	Sum of squares	Mean square
Summer	Model	5	18.21219054	3.64243811
	Error	54	113.00258667	2.09264049
	Corrected total	59	131.21477721	

Source	DF	Type I SS	F value	PR > F
Station	5	18.21219054	1.74	0.1401

Season	Source	DF	Sum of squares	Mean square
Fall	Model	5	2.08539346	0.41707869
	Error	88	17.99035855	0.20443589
	Corrected total	93	20.07575201	

Source	DF	Type I SS	F value	PR > F
Station	5	2.08539346	2.04*	0.0799

* Significant at $\alpha = 0.10$.

TABLE B-18

DUNCAN'S MULTIPLE-RANGE TEST:
WINTER AND FALL DISTRIBUTION OF LARVAE AT STATIONS 0-5
ST. LUCIE PLANT
1977

WINTER 1976-1977

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=66 MS=3.25426

GROUPING		MEAN	N	STA
	A	2.033758	12	0
	A			
B	A	1.321229	12	1
B	A			
B	A	0.740972	12	4
B	A			
B	A	0.478467	12	5
B				
B		0.206096	12	2
B				
B		0.168346	12	3

FALL 1977

ALPHA LEVEL=.05 DF=88 MS=4.0E-04

GROUPING	MEAN	N	STA
A	0.520724	16	1
B	0.314102	15	0
B			
B	0.313313	16	3
C	0.193173	15	5
D	0.098756	16	2
D			
D	0.096680	16	4

TABLE B-19

PERCENTAGE COMPOSITION OF THE MAJOR CATEGORIES OF FISH LARVAE
BY STATION
ST. LUCIE PLANT
WINTER (DECEMBER 1976–FEBUARY 1977)

CATEGORY	STATION 0	1	2	3	4	5	11	12
GERREIDAE	1.3	0.3	5.4	6.4	0.9	2.2	7.7	5.3
SCIAENIDAE	1.4	0.7	9.1	22.7	0.6	2.7	19.2	5.3
BLENIIDAE	0.8	0.6	5.5	6.2	1.4	1.0	26.9	47.4
TETRAODONTIDAE	0.0	0.0	0.5	0.3	0.0	0.2	0.0	0.0
CLUPEIFORMES	95.0	96.2	70.3	49.4	93.6	89.8	23.1	26.3
CARANGIDAE	0.0	0.0	0.9	0.8	0.2	0.2	0.0	0.0
GOBIIDAE	0.4	0.4	0.5	0.8	0.4	1.2	7.7	5.3
BOTHIDAE	0.1	0.2	0.3	0.1	0.1	0.4	0.0	0.0
GOBIESOCIDAE	0.0	0.0	0.7	0.0	0.0	0.1	0.0	0.0
OPHIDIIDAE	0.2	0.1	2.1	5.6	0.9	0.9	0.0	0.0
SERRANIDAE	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0
SCORPAENIDAE	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
ATHERINIDAE	.	.	.	.	.	.	.	.
ALL OTHER LARVAE	0.8	1.5	4.4	7.2	1.6	1.2	15.4	10.5

TABLE B-20

PERCENTAGE COMPOSITION OF THE MAJOR CATEGORIES OF FISH LARVAE
BY STATION
ST. LUCIE PLANT
SPRING (MARCH 1977-MAY 1977)

CATEGORY	STATION 0	1	2	3	4	5	11	12
GERREIDAE	8.8	20.6	12.4	8.7	10.5	24.7	0.0	0.0
SCIAENIDAE	0.0	0.0	3.4	1.1	2.0	0.0	0.0	0.0
BLENIIDAE	2.2	1.9	1.5	7.5	14.7	34.1	0.0	0.0
TETRAODONTIDAE	5.5	2.9	7.2	6.3	5.9	1.0	0.0	0.0
CLUPEIFORMES	40.3	59.4	37.1	57.2	22.0	24.7	94.6	100.
CARANGIDAE	5.5	1.4	0.0	0.7	2.4	0.0	5.4	0.0
GOBIIDAE	0.0	0.0	1.8	0.9	1.5	2.5	0.0	0.0
BOTHIDAE	0.8	0.0	0.0	0.0	2.2	2.0	0.0	0.0
OPHIDIIDAE	7.5	0.0	1.8	0.7	2.4	0.0	0.0	0.0
SERRANIDAE	1.3	2.5	3.1	3.7	2.1	2.6	0.0	0.0
SCORPAENIDAE	2.7	0.0	14.7	1.4	0.0	0.0	0.0	0.0
ATHERINIDAE	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL OTHER LARVAE	24.1	11.3	17.0	11.8	34.5	8.5	0.0	0.0

TABLE B-21

PERCENTAGE COMPOSITION OF THE MAJOR CATEGORIES OF FISH LARVAE
BY STATION
ST. LUCIE PLANT
SUMMER (JUNE 1977-AUGUST 1977)

CATEGORY	STATION 0	1	2	3	4	5	11	12
GERREIDAE	2.8	0.9	0.9	3.3	3.9	1.9	0.0	0.0
SCIAENIDAE	0.0	0.2	0.0	1.1	2.1	3.3	0.0	0.0
BLENIIDAE	1.4	0.5	0.9	1.0	0.5	0.8	0.0	0.0
TETRAODONTIDAE	2.3	1.5	0.8	1.8	1.8	0.5	0.0	0.0
CLUPEIFORMES	82.9	81.1	93.0	74.8	87.1	85.5	92.3	94.7
CARANGIDAE	0.0	0.0	0.1	0.8	0.3	0.2	0.0	0.0
GOBIIDAE	3.1	4.4	1.8	5.4	1.8	2.2	0.0	5.3
BOTHIDAE	0.9	2.0	0.2	0.4	0.3	0.4	7.7	0.0
GOBIESOCIDAE	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0
OPHIDIIDAE	0.0	1.5	0.4	0.4	0.0	0.3	0.0	0.0
SERRANIDAE	1.7	1.0	1.1	1.0	0.1	1.8	0.0	0.0
SCORPAENIDAE	0.0	2.3	0.0	0.6	0.2	0.2	0.0	0.0
ALL OTHER LARVAE	4.8	4.6	0.9	9.1	1.9	2.7	0.0	0.0

TABLE B-22

PERCENTAGE COMPOSITION OF THE MAJOR CATEGORIES OF FISH LARVAE
BY STATION
ST. LUCIE PLANT
FALL (SEPTEMBER 1977-NOVEMBER 1977)

CATEGORY	STATION 0	1	2	3	4	5	11	12
GERREIDAE	9.1	2.1	6.8	2.8	9.5	3.8	0.0	0.0
SCIAENIDAE	10.9	9.3	5.9	3.6	4.7	6.7	0.0	0.0
BLENIIDAE	2.2	0.2	3.9	1.5	1.2	1.4	0.0	0.0
TETRAODONTIDAE	2.8	1.7	5.8	0.3	8.4	4.3	0.0	0.0
CLUPEIFORMES	57.6	69.9	29.9	68.3	52.7	40.1	0.0	0.0
CARANGIDAE	1.9	1.4	6.4	5.7	3.2	10.5	0.0	0.0
GOBIIDAE	3.5	1.2	5.3	3.6	1.7	6.0	0.0	0.0
BOTHIDAE	2.5	9.0	5.7	0.8	1.4	2.6	100	100
GOBIESOCIDAE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPHIDIIDAE	5.3	2.9	17.8	6.1	10.9	8.0	0.0	0.0
SERRANIDAE	0.0	0.4	0.0	0.6	0.0	4.1	0.0	0.0
SCORPAENIDAE	1.2	0.7	3.1	0.0	0.0	6.4	0.0	0.0
ALL OTHER LARVAE	2.8	1.9	9.4	6.6	6.3	6.1	0.0	0.0

TABLE B-23

OCCURRENCE OF GRAVID FISH IN THE VICINITY OF THE
ST. LUCIE PLANT
JANUARY 1976-DECEMBER 1977

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
menhaden	✓					✓						
clupeid						✓						
cusk eel									✓			
striped mullet	✓	✓									✓	✓
white mullet								✓		✓		✓
lizardfish	✓											
black margate			✓	✓								
pinfish										✓		
pigfish	✓	✓	✓									✓
sea bream									✓			
sheepshead		✓										
silver porgy			✓									
spot	✓	✓								✓		✓
banded croaker										✓		
Atlantic croaker	✓	✓								✓		
silver seatrout										✓		
highhat		✓										
reef croaker			✓									✓
gulf kingfish							✓			✓		
searobins	✓	✓				✓			✓			✓
guaguanche							✓					
striped mojarra						✓						
gafftopsail catfish			✓									
oyster blenny		✓				✓						
seaweed blenny		✓							✓			
hairy blenny		✓										
Atlantic cutlass-fish					✓					✓		
bluefish										✓		
scad						✓				✓		
blue runner						✓		✓				
Atlantic bumper			✓	✓			✓		✓			
midshipman		✓										
sand perch				✓								
rock sea bass		✓	✓									
lane snapper				✓			✓					
frigate mackerel					✓		✓					
Spanish mackerel				✓	✓	✓						
spadefish				✓								
spotted whiff				✓								
dusky flounder							✓					

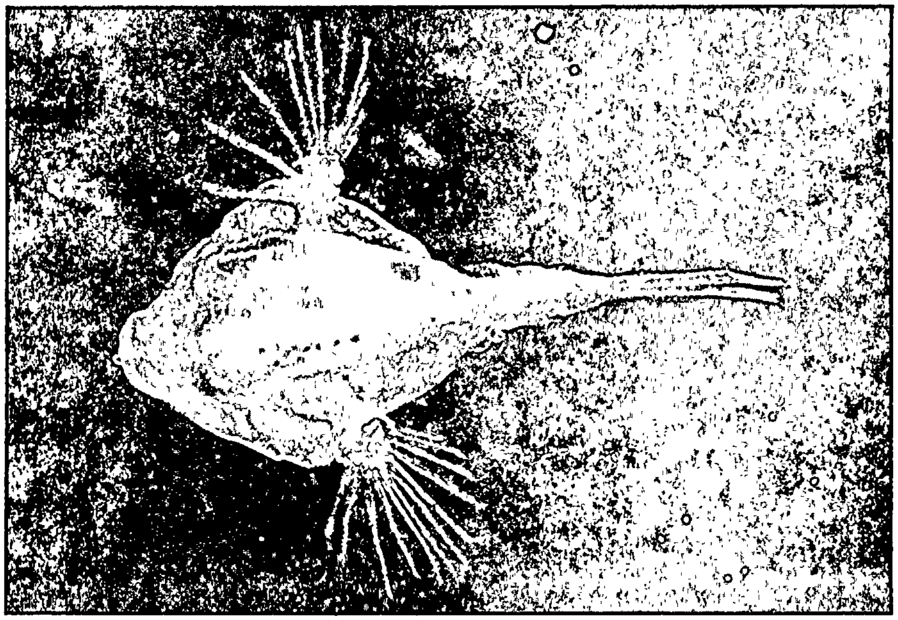

Plate 1. Unidentified larva, 4.7 mm total length.

Plate 2. Unidentified larva, 6.1 mm total length.

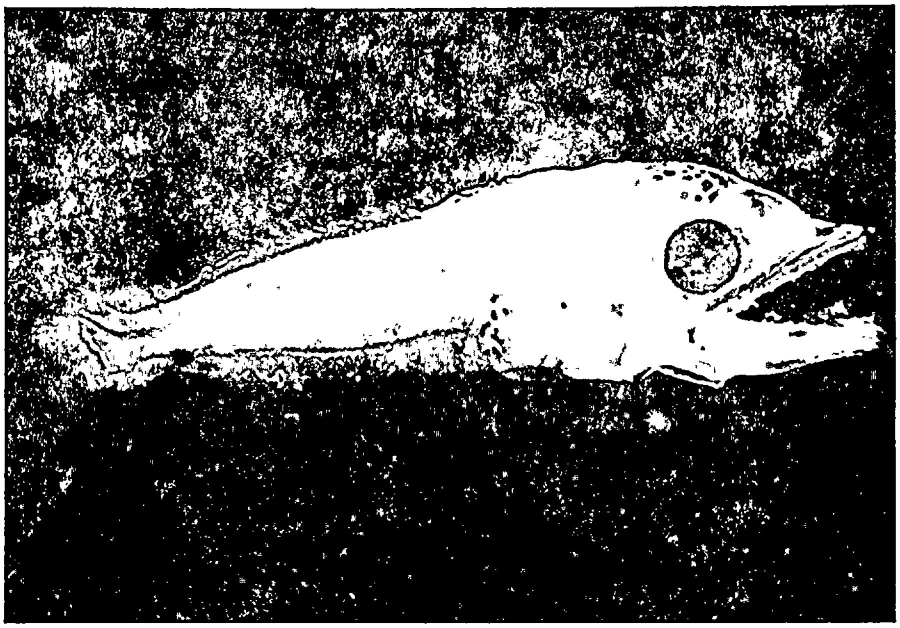

Plate 3. Larval scombrid, 7.7 mm total length.

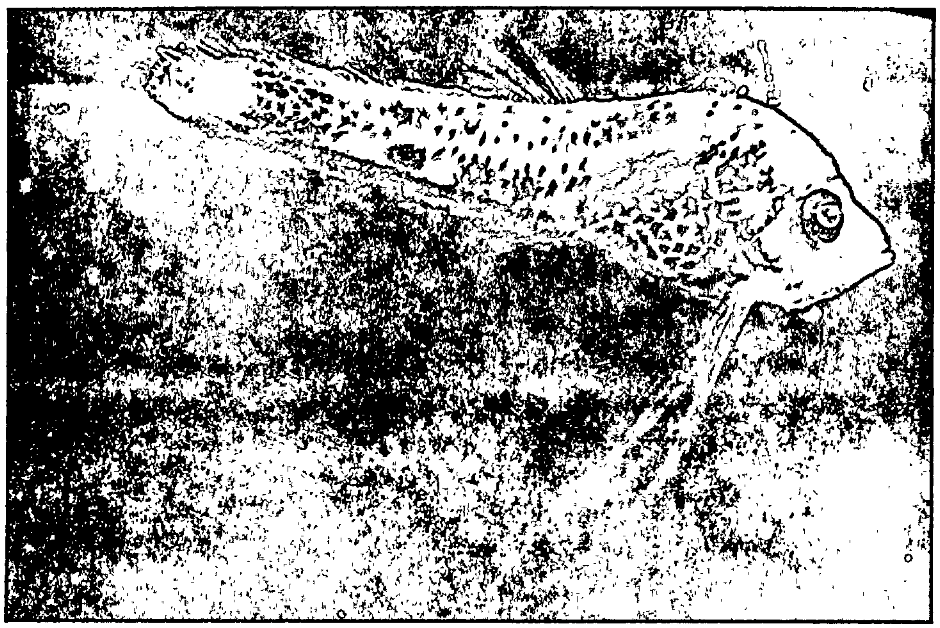

Plate 4. Antenna codlet, 9.0 mm total length.

Plate 5. Larval scorpionfish (scanning electron micrograph).

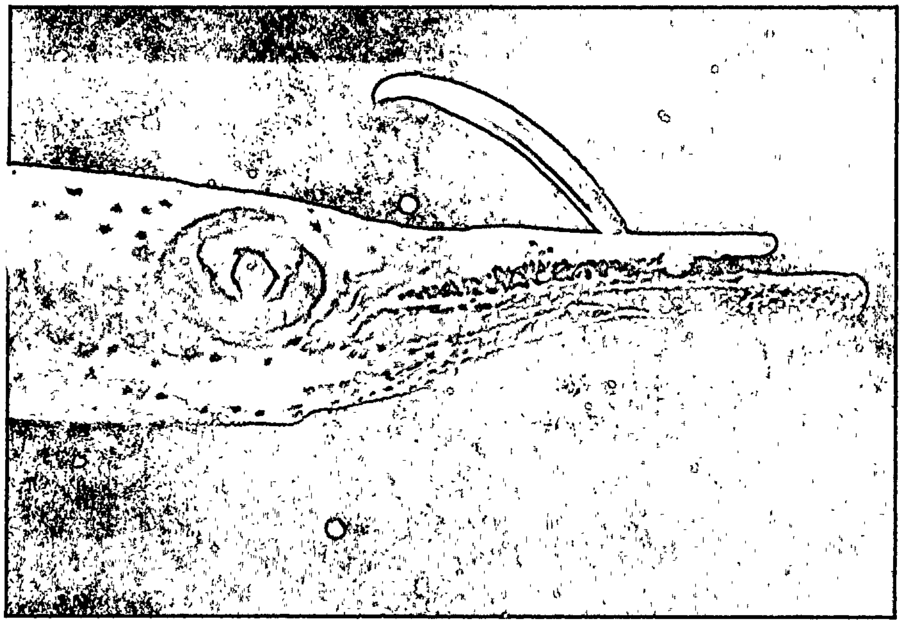

Plate 6. Post-larval barracuda with chaetognath in jaws.

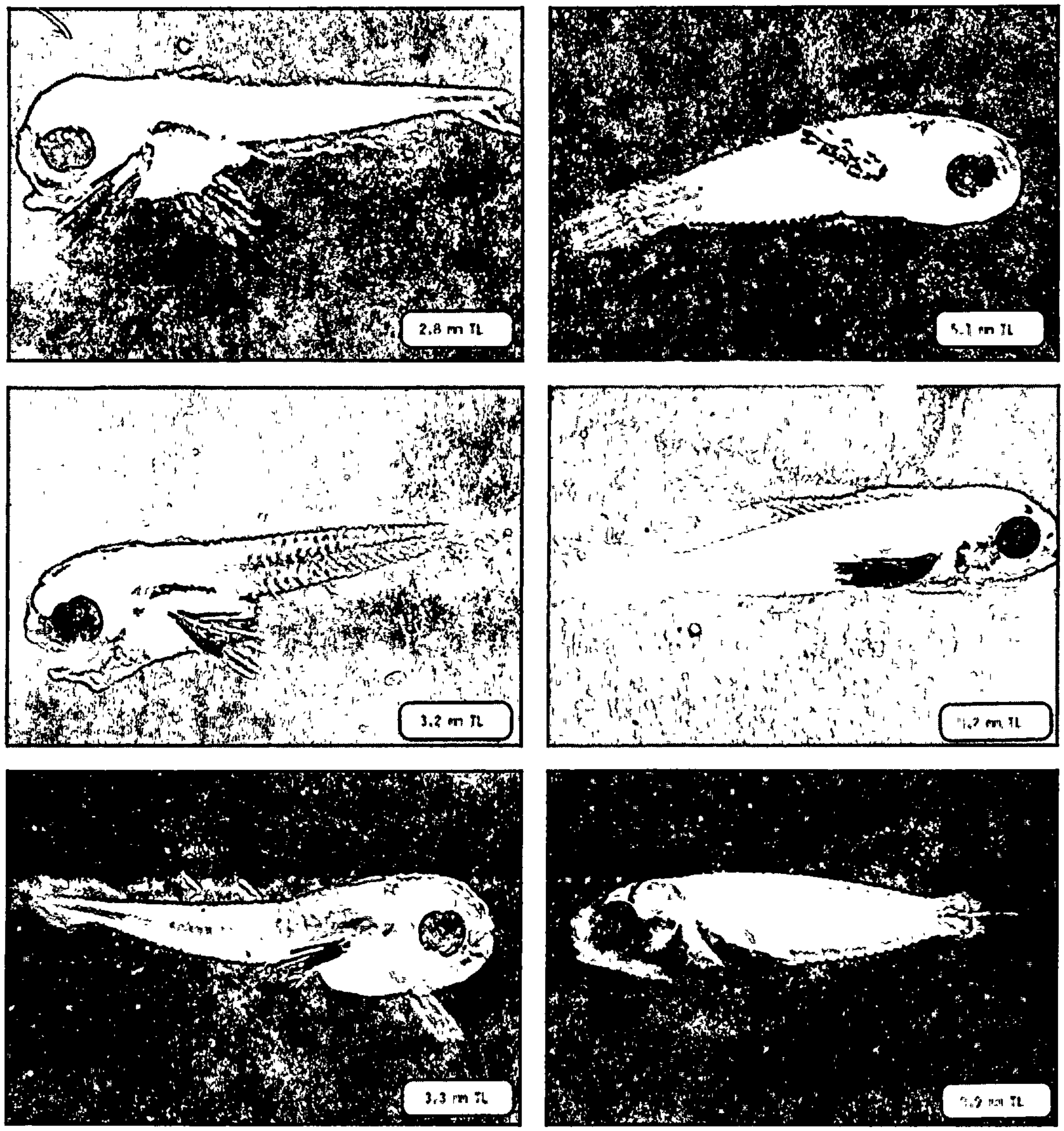

Plate 7. Feather blenny, developmental series.

C. MACROINVERTEBRATES

INTRODUCTION

Marine macroinvertebrates spend at least part of their lives on or within bottom sediments, pilings, rocks, or other substrates. Because their mobility is limited, these animals cannot avoid stressful conditions and therefore serve as useful indicators of environmental perturbations. Monitoring of marine macroinvertebrate communities in the St. Lucie Plant area provides information concerning the effects of power plant operation on the offshore ecosystem.

Three types of benthic communities are found in association with distinct sediment types in the vicinity of the St. Lucie Plant. The first of these is the depauperate, low-density macroinvertebrate fauna found on the beach terrace. This zone, which extends from shore to about 8 meters deep, has a fine sandy bottom. The 1977 Stations 0 and 1 are located on the beach terrace. A more diverse assemblage is found farther offshore where sediments of shell material provide habitats for macroinvertebrates, including a fouling community. Stations 2, 4, and 5 are located in this offshore trough. The third type of benthic community is found farther offshore on Pierce Shoal, where Station 3 is located. The medium sand substrate of the offshore bar supports another characteristic macroinvertebrate assemblage.

This report presents grab and trawl data collected from March 1976 through December 1977. Analyses of macroinvertebrate community abundance and diversity are discussed in relation to environmental parameters and community trophic levels. The data are also compared with the invertebrate larvae abundance and distribution results from the zooplankton sampling program. Comparisons of the present study with published baseline information (1971-1973) will be used to discern long-term trends.

MATERIALS AND METHODS

Two sampling programs designed to study macroinvertebrates in the oceanic environments near the St. Lucie Plant were conducted in 1976 and 1977. Except for minor changes, study methodologies remained the same during both years (see Table C-1). Bottom sediments and fauna living in and upon the sediments were collected with a Shipek benthic grab sampler. Trawl samples provided data on those macroinvertebrates living on or near bottom. Water temperature, salinity, dissolved oxygen concentration, and turbidity data were collected at surface, mid-depth, and bottom of each station during both trawl and grab sampling.

Shipek Grab Samples

Quarterly grab sampling for the smaller benthic infauna (organisms living within the substratum) and epifauna (organisms living on top of the substratum) began in March 1976 at six offshore locations

(Figure C-1, Table C-2). Stations 1 through 5, located near the plant discharge structure, corresponded to locations sampled during preliminary studies conducted from 1971 to 1974 by the Florida Department of Natural Resources (Gallagher and Hollinger, 1977). An additional station (Station 0), located 4.3 kilometers south of the plant discharge, served as a control for the 1976-1977 studies (Table C-2).

The Shipek grab sampler consists of two concentric half-cylinders. The inner half-cylinder (20 x 20 x 10 cm) rotates through 180° as the sampling scoop (Figure C-2). When the sampler is lowered to the bottom with winch and line, powerful helical springs close the two half-cylinders so that the sample cannot escape.

Four replicate samples were taken quarterly at each offshore station. Each sample was preserved in a 10% buffered formalin-seawater solution and stained with rose bengal. Three of the four replicates taken at each station were washed through a No. 25 sieve to remove fine sediment and particulate matter. This screen size and procedure were used to conform with previous offshore benthic monitoring programs conducted by the Florida DNR (Gallagher and Hollinger, 1977). All material retained on the sieve was hand-sorted under low magnification in the laboratory, where the stained organisms were identified to the lowest practical taxon.

The fourth replicate was similarly sorted, but the organisms (exclusive of molluscan shells) were dried at 105°C for four hours, then weighed to provide an estimate of community biomass per unit area. Because the character of the substratum is a major determinant of benthic macroinvertebrate distribution, the substratum material of the fourth replicate was dried, disaggregated, and placed in a nest of nine sieves (mesh widths of 16, 8, 4, 2, 1, 0.5, 0.25, 0.125, and 0.063 mm). The nest was shaken for 15 minutes on a Tyler Ro-Tap sieve shaker. The substratum was then analyzed according to the method of Folk (1966) for mean particle diameter, sorting coefficient (standard deviation of mean particle size), and particle size distribution.

To assess the adequacy of three replicates to sample the species present in the study area, additional samples to determine species saturation were taken at two stations during the March 1977 sampling.

Trawl Studies

The trawl sampling program for invertebrates was conducted in conjunction with the fish sampling program (see Section B, Fish and Shellfish). Trawls were made at night to reduce net avoidance. One 15-minute tow was made with a 4.9-m semi-balloon otter trawl at each offshore station per month. The samples were preserved in 10% buffered formalin-seawater solution, labeled, and transported to the laboratory for sorting and identification to the lowest practicable taxon.

RESULTS AND DISCUSSION

Substrata

Many environmental parameters are known to affect the structure and distribution of marine benthic communities. Among the more important is substratum type. Sharp distinctions occur between fauna associated with hard and soft substrata. Hard substrata are usually represented by rock outcroppings and coral reefs; to a lesser extent they are also represented by large fragments of mollusc shell. These hard substrata generally support a wide variety of cryptic, boring and epifaunal species. Soft substrata, such as the biogenically derived sediment reported by Hathaway (1971) to be widespread on the nearshore continental shelf adjacent to Hutchinson Island, may be expected to support a somewhat lower infaunal biomass and species diversity (Abele, 1974).

Many researchers have correlated various sediment parameters such as grain size and material composition with the species distribution and diversity of benthic macroinvertebrates (Sanders, 1968; Lie, 1968; Lie and Kelley, 1970). Most of this work has focused on benthic communities associated with sand and mud substrata, and little effort has been expended studying the benthic macroinvertebrate community of a shell-hash habitat. Substratum analysis was needed to provide data for describing this little-studied benthic community.

Substratum samples were analyzed for mean particle size, particle size class distribution, and sorting coefficient. The sorting

coefficient, or standard deviation of the mean particle size, was used to describe the degree of sorting or homogeneity of sample particle size as follows:

Sorting Coefficient

0.35 ø	very well sorted
0.35-0.50 ø	well sorted
0.50-0.71 ø	moderately well sorted
0.71-1.0 ø	moderately sorted
1.0 -2.0 ø	poorly sorted
2.0 -4.0 ø	very poorly sorted
over 4.0 ø	extremely poorly sorted

As discussed in the baseline study (Gallagher, 1977) and the 1976 annual report on the present sampling program (ABI, 1977), the study area can be divided into three zones based on sediment characteristics (see Appendix Table L-1):

1. the beach terrace (Station 1)
2. the offshore trough (Stations 2, 4, and 5)
3. the offshore bar-Pierce Shoal (Station 3).

Station 0 was located in a trough-type substratum in 1976 but was moved inshore to a beach terrace-type substratum in 1977.

In 1977, beach terrace sediments were found to be fine to very fine, moderately well-sorted, gray, non-biogenic (quartz) sand. This sediment type was found at Stations 0 and 1 on the seaward edge of the terrace. Offshore trough sediments consisted of very poorly to extremely poorly sorted, very coarse particles. This sediment type is termed "shell hash" since it is composed almost entirely of broken

mollusc shells. Trough sediments characteristically exhibited large variations in mean particle size and sorting coefficient. A significant quantity, 14 to 33%, of gravel-sized shell particles (>2.0 mm) was typical of trough sediments. Large shell particles imparted heterogeneity, with resultant good porosity, to trough sediments. The substratum at Pierce Shoal was a well-sorted, medium, calcareous sand. The general homogeneity of the substratum at Station 3 probably results from storm-induced hydrological processes that selectively transport medium and fine particles to the shoal crest while removing the larger particles (Duane et al., 1972). This selective process resulted in a homogeneous substratum that, because of representative particles, probably retains good porosity.

Gallagher (1977) reported that mean grain sizes of all three substratum types exhibited temporal and spatial variation during the baseline study of 1971-73. Station 4 sediments were least varied. Significant textural changes were rarely observed in the beach terrace (Station 1) or Pierce Shoal (Station 3) sediments. Due to the homogeneity of sediments at these stations, however, relatively small compositional changes produced statistically significant differences. These textural changes were probably of insufficient magnitude to affect the distribution of the benthic fauna. Trough sediments exhibited the largest spatial variation, as indicated by large sorting coefficients and wide ranges in mean grain size. The substratum at

Station 5 had larger percentages of gravel and coarse shell particles than either Stations 2 or 4, although the differences were not statistically significant.

The Mann-Whitney U test (Elliott, 1971; Appendix Table L-2) was applied to mean grain size data from each station to determine if significant textural changes had occurred during the present studies. Sediments at Station 1 were found to be significantly different (P=0.05) between 1976 and the baseline study. Coarser mean grain size during December 1976 resulted from a quantity of broken shell particles that, considering their blackened color, had been buried for some time and recently uncovered. Mean grain sizes for remaining samples in 1976 were only slightly coarser compared to all other Station 1 sediment data (Figure C-3). Textural changes in 1976 could have been the result of installation of the plant discharge pipeline. Observed changes might also be a result of high-energy sediment transport. Such an assessment would be difficult to make due to the highly dynamic physical nature of this ecosystem. With continued plant operation during 1977, the sediment at Station 1 returned to a distribution typical of that found in the baseline study.

A large, though not statistically significant, change in mean particle size was observed at Station 5 in 1976 compared to

1971, 1973 and 1977. Differences in the gravel fraction, which averaged 18% in 1976, 34% during the baseline study, and 33% in 1977, were responsible for the observed differences. As expected, large variation was also noted at Station 0 because this station was moved in 1977.

Evaluation of Sample Adequacy for Species Accumulation

The number of replicate samples required to adequately describe the benthic community is predicated on the relative number of individuals and species inhabiting a given environment, the apportionment of individuals among the species, and the spatial distribution of the organisms present.

To determine the adequacy of three Shipek sample replicates, a short study was conducted to determine if additional bottom samples would produce significantly more species not previously encountered. Additional replicates were taken from Stations 1 and 5 during March 1977, and the data were graphed showing the number of species accumulated per replicate of increased sample effort (Figure C-4). These data produced irregular and erratic curves because of the chance ordering of haphazardly collected samples containing various numbers of taxa. These data were then compared with a theoretical population (generated by a statistical procedure developed by Gaufin et al., 1956; see Appendix Table L-2) that produces a smooth curve. From this curve, the proportion of species

in N samples can be estimated. The point at which the Gaufin cumulative curve becomes asymptotic is the point at which additional sample replicates will probably not produce additional species.

In relatively undisturbed environments, a few species are generally represented by large numbers of individuals while many species are represented by only a few (EPA, 1973). Longhurst (1959) suggested that in such a situation, the abundant species are usually adequately sampled well before the asymptote of the Gaufin cumulative curve is reached. Therefore, the benthic community may be satisfactorily described with fewer than the total number of samples needed to sample all species residing in the area.

Seven replicates were taken at Station 5, which typically yields a large number of species and individuals. Of the 203 species collected, 154 were contained in the first three replicates. The Gaufin cumulative curve predicted about 150 species as the average number of taxa expected from three replicates. These data suggest that, at shell-hash substrates similar to those at Station 5, three replicates are sufficient to sample about 75% of the taxa present. The relatively steep slope of the Gaufin cumulative curve indicated that substantially more than seven replicates would be needed before the curve would become asymptotic.

The slope of the Gaufin cumulative curve is positively

correlated with the total number of taxa in all samples (Longhurst, 1959). The presence of large numbers of taxa represented by single specimens would account for the relatively steep slope. Within the seven replicates taken at Station 5, 25% of the taxa were represented by only one specimen each. This agrees closely with the 26% value obtained for the entire 1977 study.

Ten replicates were taken at Station 1 on the beach terrace where fewer numbers of individuals and taxa exist. Of the 82 taxa collected, 51 were encountered in the first three replicates. However, the Gaufin cumulative curve indicated that on the average, only 39 of the taxa would be expected in that number of samples. This difference was due primarily to the sparse distribution of species on the beach terrace. Forty-five percent of the taxa in 10 replicates were represented by one specimen. Again, this is closely aligned with the 46% value obtained for the entire year (1977). Thus, beyond three replicates, most previously uncollected taxa would probably be represented by few individuals.

In summary, three replicates were demonstrated to be adequate in providing representative members of up to about 75% of the species that theoretically could be present in a greatly increased sample population.

Evaluation of Sample Adequacy for Diversity Indices

Closely related to the number of individuals and taxa is the concept of faunal diversity. Diversity indices are an additional tool for measuring the quality of the environment and the effect of induced stress on the structure of a community of macroinvertebrates. Their use is based on the generally observed phenomenon that in undisturbed environments, there will be relatively few species with large numbers of individuals and large numbers of species represented by only a few individuals. Many forms of stress tend to reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage.

Appendix Table L-2 outlines the Shannon-Weaver function (Lloyd et al., 1968) of diversity ($\bar{d}$) and its utility as an indicator of environmental stress. Cumulative diversity values were plotted for replicate samples taken at Stations 1 and 5 (Figure C-5). It becomes apparent that sampling effort beyond three replicates has little effect on faunal diversity values, since the curves become asymptotic at an early stage of collection. Sanders (1968) reiterates the usefulness of the Shannon-Weaver information function, stating that it has the critical characteristics of being relatively independent of sample size.

The equitability component (e) of diversity (Lloyd and Ghelardi, 1964) describes the apportionment of individuals among the taxa present and ranges from 0 to 1 (Appendix Table L-2). When the individuals in a sample are evenly distributed among the taxa, equitability is high. Cumulative equitability (e) values were plotted for the replicate samples taken at Stations 1 and 5 (Figure C-5). As this figure shows, equitability is reduced with increased replication. This situation is the result of continued acquisition of rare species coupled with large numbers of individuals of the dominant species. Thus, three replicates slightly overestimate the equitability component of diversity.

Seasonal Variation of Fauna in Benthic Grab Samples

Trends in community parameters measured from benthic grabs showed considerable seasonal variation. Generally, variations in the density of organisms were not accounted for by seasonal fluctuations in the population levels of any individual or group of taxa. Rather, the variable patterns exhibited were the result of cumulative fluctuations in a large number of taxa. Seasonal trends, however, were sometimes inconsistent from year to year.

The observed trends showed little continuity during the study at most stations (Table C-3 and Figure C-6). Diversity values were generally high and well above the levels that the Environmental Protection Agency suggests are indicative of healthy (non-polluted) environments (EPA, 1973). Station 3 was the only location at which equitability

exhibited an obvious relationship with number of taxa and density. In September when overall densities and numbers of taxa were highest, equitability was lowest. Most of the taxa were represented by relatively few individuals. When the dominant organisms decreased in abundance, the individuals were more evenly distributed among the taxa and equitability increased.

Only at Station 5 were biomass values significantly correlated with the density of organisms (Table C-4). Biomass is affected by both the absolute number of organisms present and by their relative sizes. The lack of correlation suggest that, in the study area, the average size of individuals within a taxon may be greater at less than maximum densities. However, biomass determinations were made from samples other than those used for species identification and enumeration. In patchy environments such as those encountered in the study area, large faunal variability between samples is often observed (Table C-3). The problem is further complicated when exceedingly large organisms, especially those which are infrequently collected, appear in the biomass sample.

Thus, seasonal trends of various community parameters, with few exceptions, showed little relationship with one another. Because of the dynamic nature of the environment, these parameters also show little congruity from year to year.

Critical Variables: Temperature and Substrate

Both temperature and substrate are known to be important in shaping benthic community structure (Sanders, 1968; Boesch, 1972). Substrate has previously been shown to be strongly related to faunal assemblages in the study area (ABI, 1977). However, no apparent seasonal fluctuations in substrates were detected through four years of sampling (including the baseline studies, previously discussed). Therefore, the observed seasonal fluctuation of the community parameters measured from benthic grab samples cannot be attributed to changes in substrate. Temperature, however, obviously varies through the seasons and affects benthic organisms in a number of ways, including the establishment of geographical boundaries of distribution.

Spearman rank correlation coefficients (r_s) were calculated for each station and for all stations combined to determine whether significant correlations existed between density and seasonal bottom water temperatures (Table C-4). The mean density for all stations combined displayed a trend similar to that observed for water temperature (Figure C-7) even though the two were not significantly correlated. Significant correlations between density and temperature were found only at Station 4. The lack of correlation at most stations suggests that recruitment of juvenile species is not restricted to a particular season but occurs sporadically throughout

the year. Some organisms probably spawn continuously while others require various fixed thermal regimes. The resultant staggered recruitment may account for the continuous presence of small individuals of many taxa throughout the year. Day et al. (1971) noted a similar phenomenon for shelf benthos off North Carolina, which has environmental characteristics similar to those of the present study area.

Zooplankton studies (see Section E) indicate that polychaete and mollusc larvae showed little seasonal pattern in abundance (Figure C-8). Although meroplankton and the underlying benthos are certainly related, it is not obvious from the sample data presented. One reason for the lack of similarity is that not all meroplankton will settle in the study area and those that do may have differential rates of survival. On an annual basis, it appears that the overall abundance of polychaete and mollusc larvae was higher during 1976, and this corresponds to higher densities of these groups in the adult population during that year.

Correlation coefficients between temperature and number of taxa collected at each station indicate that Stations 3 and 4 were the most seasonally predictable stations, both exhibiting significant positive correlations (Table C-4). No other stations exhibited this correlation, probably for reasons previously discussed.

Figure C-9 depicts mean monthly bottom temperatures at Stations 1 and 0. Thermal differences between the stations were not appreciable except during the summer months, when Station 1 was about 1°C higher than Station 0. Even though the total number of taxa and density of organisms at Station 1 exhibited little variation between years (Table C-3), these parameters displayed opposite trends, rising throughout the first year and declining the second (Figure C-6). It is doubtful that declining numbers of individuals and taxa were plant-related, since corresponding decreases were observed at Station 0 in a similar environment. Declining numbers of individuals and taxa during 1977 at these stations may reflect natural biological events occurring all along the beach terrace.

In summary, temperature as a critical variable showed little correlation with any community parameter at any station. This fact, coupled with the lack of appreciable thermal differences between stations, indicated little possibility of plant effect on seasonal benthic community parameters.

Plant Effects on Benthic Fauna Collected by Grabs: 1976-1977

Because of the dynamic seasonal nature of community parameters observed in the vicinity of the St. Lucie Plant, it is difficult to segregate natural variations from plant-induced ones, if any. Changes in the benthic community structure are not necessarily detrimental. In fact, environments that are seasonally dynamic are often found to be quite stable on a long-term basis (Livingston, 1976). Nevertheless, the effects of environmental perturbation can still be observed by various types of benthic community analysis (Heck, 1976).

Benthic community parameters analyzed were the number of taxa and number of individuals collected on a year-to-year basis. To test for significant differences in both of these parameters, each station was treated separately. Grab efficiency, which is defined here as depth of penetration, was also tested in a similar manner to delineate its effect on both numbers of taxa and numbers of individuals collected. Since no one transformation would adequately "normalize" these data for use with parametric statistics, the non-parametric Mann-Whitney U test (Elliott, 1971; Appendix Table L-2) was applied.

Results from Shipek sampler penetration data (Table C-5) indicates significant decreases in grab efficiency at Stations 0, 1

and 5 from 1976 to 1977. The decrease at Station 0 was, of course, concomitant with its relocation onto fine, hardpacked sand. The observed decreases at Station 1 and 5 are believed to be due to a shift in grain size composition (Appendix Table L-1). This factor, as well as the presence of obstacles such as shells, might have caused the observed decreased efficiency at Station 5 (see Christie, 1975).

Except for Station 0, no decreases were observed either in number of taxa or number of individuals collected at any station between 1976 and 1977 (Table C-5). In fact, the number of taxa significantly increased at Stations 2 and 5. Both number of taxa and number of individuals significantly increased at Station 5 between 1976 and 1977 even though grab efficiency decreased. These two community parameters remained stable between years at Stations 1, 3 and 4. Results of substrate analysis from Station 5 (Appendix Table L-1) indicate that the heterogeneity of the substrate is most likely responsible for the observed increases at that station from 1976 to 1977.

Mann-Whitney U tests were also applied to 1977 data for Station 1, at the plant discharge, and Station 0, which served effectively as a control in 1977. These results are thus of particular importance. No significant differences were observed between grab

efficiency, number of individuals captured or number of taxa collected. This indicates no significant reductions of these benthic infaunal community parameters during 1977 when the plant was essentially in full operation.

Comparison of Benthic Grab Diversity by Year

A graphic method was chosen to compare species diversity by station between 1976 and 1977. This technique, known as the rarefaction method (Sanders, 1968), essentially interpolates the number of species distributed among any given number of individuals less than the total derived from the sample (see Appendix Table L-2). In the rarefaction curves generated by this method, low diversity is indicated by fewer number of taxa per unit number of individuals (i.e., high degree of dominance by a few taxa). Rarefaction measures for Stations 1 through 5 for each year of benthic macroinvertebrate data show little change at Stations 3 and 4 but slight increases in overall diversity at the remaining stations (Figure C-10). Station 1 in 1977 actually appears more diverse (less tendency toward dominance) than its counterpart (Station 0) in the same year.

Dominant Benthic Grab Phyla and Taxa

Changes in the percentage composition of the major groups of benthic macroinvertebrates are known to be indicative of environ-

mental perturbation (Rosenberg, 1976). If significant perturbation occurred in 1977 when the plant was in full operation, major shifts in taxonomic groups would be expected to occur. In the shelly environment offshore from the St. Lucie Plant, annelids predominated (50%) over all other groups (Figure C-11). Sipunculids, molluscs and arthropods generally comprised less than 17% by groups at these stations. Echinoderms and cephalochordates (lancelets) usually comprised an even smaller percentage (<6%). The contribution to the total community by each group at Stations 2, 4 and 5 remained relatively stable from 1976 to 1977.

At Station 3, in the medium sand environment, molluscs comprised the majority of individuals collected (>58%). Juvenile recruitment of the bivalve *Crassinella duplinana* was primarily responsible for this observation. Annelids and arthropods were the second and third most encountered groups, respectively, at that station. Percentage contribution by these groups exhibited very little change from 1976 to 1977. The most notable change at Station 3 was the decrease in lancelet abundance in 1977. It appears that this station is an area where mostly juveniles are collected (Futch and Dwinell, 1977), and a decrease in the settlement of larvae that year was most likely responsible for decreased abundance.

In the fine sand at Station 1, annelids predominated (<40%), but not in as large a proportion as that found at the shelly stations. Arthropods and molluscs were the next most dominant, in order of decreasing percentages. Other minor phyla, primarily nemerteans, were the fourth major faunal component at Station 1. Nemerteans are found throughout the study area, but they may comprise a larger percentage at Station 1 because other phyla are less abundant at Station 1 than at the other stations. The composition of dominant macroinvertebrate phyla at Station 1 remained essentially constant from 1976 through 1977.

The composition of benthic macroinvertebrate phyla in 1977 at Station 0, which most closely resembles Station 1 in substrate composition and most reasonably serves as a control, was similar to that at Station 1 (1976 and 1977) except for an increased percentage of arthropod composition. A noticeable increase in abundance of cumaceans (Crustacea) during the first two quarters of sampling (March and June) was responsible for this disparity. Increased numbers of cumaceans were also found at Station 1 during this period, but not in the relative numbers collected at Station 0. Frankenburg (1971) found large increases in population density (3000/m^2) of the cumacean *Oxyurostylis smithi* between January and June in the nearshore environment off the Georgia coast. The semi-planktonic, motile nature of this group could be responsible for the uneven distribution of

these organisms along the beach terrace at a given point in time. Generally, however, all stations sampled continuously in the same location through the 2-year period showed relatively constant percentage composition by the same phyla.

Replacement of dominant species (or taxa) in a benthic community is known to be indicative of environmental stress; sequential change of dominating populations was recorded in an estuary following pollution abatement (Rosenberg, 1976). Dominance in this study was determined by McCloskey's (1970) index (Appendix Table L-2). This method ranks each taxon by abundance and frequency of occurrence. The sum of rank "scores" for a species indicates its dominance value at a station. This method was used to determine the 10 top-ranked species for 1976 and 1977 at each station (Table C-6). A total of 56 taxa were classified as dominants. Thirty of these were annelid worms, 24 of which were polychaetes; molluscs and crustaceans were each represented by 10 taxa, and echinoderms by three taxa. Several of the taxa ranked as dominants may represent more than one species (e.g., sipunculida and nemertina). As a result of Station 0's relocation, only one taxon remained in the top 10 between years there. Three taxa were in the top 10 both years at Station 1, but the gastropod, *Olivella floralia*, represented the only single species. At Station 2, only four single species were ranked in the top 10 in both 1976 and 1977. These were the

polychaetes, *Goniadides carolinea, Mediomastus californiensis, Filogranula* sp. and the gastropod, *Crepidula fornicata.* At Station 4, the annelid worms *G. carolinea, Marionina* sp. and *Filogranula* sp. were the only species ranked in the top 10 during 1976 and 1977. At Station 5, *Filogranula* sp. was the only species to remain a dominant through both years. Station 3 exhibited the most stability of the top-ranked dominants between 1976 and 1977 with a total of five single species. These included the molluscs *Crassinella duplinana, Dentalium calamus* and *Glycymerus spectralis.* The crustacean species ranked in the top 10 for both years were *Eurydice littoralis* and *Protohaustorius* sp. A.

The number of dominant taxa shared by Station 0 and Station 2 during 1977 was relatively high (five). These included the polychaeta *Mediomastus californiensis,* and crustaceans *Cyclaspsis pustula, C. varians* and *Synchelidium americanum.* Taxa such as nemerteans and sipunculids present taxonomic difficulties and each group probably represented more than one species. However, they appeared as dominant in both 1976 and 1977 at almost every station and are obviously a functionally significant part of the informal community in the study area.

The apparent lack of continuity between dominant taxa collected in 1976 and 1977 indicates that, although the relative percentage

composition of major groups remained constant (Figure C-11), the dominant components of these groups exhibited a great deal of variation. Fifty percent of the dominant taxa, however, were shared at the discharge station (1) and that which serves as a control (0) during 1977.

Analysis of Trophic Types

In order to provide characterization of the benthic community found at St. Lucie, the species collected there were segregated according to trophic level (location in the marine food chain). The trophic types of the fauna collected in the Shipek sampling program were divided into seven categories: suspension feeders, deposit-suspension feeders, deposit feeders, herbivores, omnivores, carnivores, and others (see Appendix Tables L-3 and L-4). The food of deposit feeders can be plankton (alive or dead) deposited on the bottom, dissolved organic matter, plant detritus, and bacteria distributed on or within the sediments. Suspension feeders ingest plankton, dissolved organic aggregates, and bacteria from the water column (Levinton, 1972).

All habitats sampled exhibited a preponderance of deposit feeders and suspension feeders (Figure C-12). Observed temporal fluctuations in suspension feeding population is attributed to fluctuations in food supply (Levinton, 1972). Carnivores were

usually the third most abundant in numbers. The other groups comprised relatively low proportions. The lack of herbivores is indicative of the sparse vegetation in the study area.

Interstation Comparisons

Interstation comparisons were performed on a year-to-year basis by using larger groups of stations to detect divergent characteristics within one or more of these areas due to differential plant effect. The most logical approach was to first statistically compare the largest group of stations with similar substrate composition for both years. Stations 2, 4 and 5 were tested for each year by the Kruskal-Wallis test (Sokal and Rohlf, 1969). This is another non-parametric test used to test for differences among three or more groups (see Appendix Table L-2). This test was also applied to grab penetration estimates, number of taxa collected per replicate, and number of individuals collected per replicate. No significant differences (P=0.05) were found between stations for any of these parameters in 1976, but significant differences were found for all parameters in 1977. As expected, Station 5 showed significantly less grab efficiency (penetration). However, number of taxa and number of individuals collected per replicate were significantly less at Station 4 during 1977 than during 1976.

Comparison of rarefaction curves supports these results (Figure C-13). They indicate a close clustering of Stations 2, 4 and 5 in 1976 and a large degree of separation in 1977. This separation is due to a slight increase in diversity at Station 2 and an even larger increase at Station 5 from 1976 to 1977.

A more rigorous method used for interstation comparisons is the Morisita (1959) index of community similarity ($C\lambda$). This index is based on the abundances of cojoint (shared) species of taxa, total abundance in each sample, and respective diversity (see Appendix Table L-2). For this reason, it is being used extensively in benthic analysis (Bloom et al., 1972; Heck, 1976 and 1977). $C\lambda$ represents degree of faunal similarities between stations with a value of 1.0 expected between samples from the same community. A dendrogram can be formed, which essentially reduces the data into clusters. The group-average sorting method (Lance and Williams, 1967) was used in the present analysis and resulted in the formation of the major groups (Figure C-14). The first group, Station 3, 1976-77, exhibited the highest similarity and therefore the greatest stability from year to year. The next major group was the shell-hash Stations 2, 4, 5 and 0 in 1976. Stations 2, 4 and 5 exhibited a tendency toward yearly continuity, although Station 5 in 1976 formed a separate subgroup. This finding supports statistical data and rarefaction results previously discussed for that station in 1977.

The beach terrace stations (1 in 1976-1977 and 0 in 1977) formed the third major group, although less faunal similarity was shown among these samples than among those of other groups. This is most likely due to the natural instability of the area. Previous studies of benthic arthropod fauna in this area indicated it to be inhabited primarily by transient species (Camp et al., 1977).

The only other major divergence found between years was observed at Station 5, which exhibited increased diversity and decreased similarity ($C\lambda$) in 1977. Those changes resulted from significant increases in both number of taxa and individuals collected. Concomitant increases in sediment mean grain size and sorting coefficient were also detected at this station, even though they were not significantly correlated (Spearman ranks, $P=0.05$) with the above parameters.

The above analyses indicate little unexpected change in station grouping from year to year which might be attributable to plant effect. The divergences observed are a result of increases in various community parameters at certain stations. These changes are most likely indicative of sediment heterogeneity rather than plant effect.

Comparisons With Baseline Benthic Studies

Baseline benthic studies were conducted during 1971 through 1973 at the same locations as the present study. These studies examined distributions of lancelets (primitive fish-like organisms; Futch and Dwinell, 1977) and some aspects of the Arthropods, for the most part a crustacean community (Camp et al., 1977).

No significant differences were observed at any stations between studies. Similar tests were applied to benthic arthropod densities and diversities ($\overline{d}$). Data from both studies were modified to exclude mieofaunal forms (i.e., Ostracoda, Halicarida, Copepoda and the isopod *Microcerberus* sp.) which, because of their small size, were not quantitatively sampled. The only changes observed in these parameters were increases in density at Stations 1 and 5 during 1976-1977 and an increase in diversity ($\overline{d}$) at Station 2 (Table C-7). These data suggest little long-term change (1971-1977) in benthic fauna from grab samples following plant construction and start-up. The changes noted are in the form of increases.

Benthic Trawl Data

The following data are based on 22 months of otter trawl collections at benthic Stations 0-5 from March 1976 through December 1977. During this period, 14,963 macroinvertebrates comprising 209 taxa were identified. Of those, 5,923 individuals (164 taxa) were

collected in 1977 and the remaining 9,040 specimens (156 taxa) were collected in 1976 (Appendix Table L-5).

Total numbers of taxa collected at each station during the 10-month period in 1976 and the same period in 1977 are presented in Figure C-15. In 1976, collections from Stations 0 and 5 produced the highest numbers of taxa, 94 and 92, respectively. Station 3 produced the least with 33 taxa. Intermediate numbers of taxa were observed at Stations 1, 2 and 4. During 1977, Station 5 was again highest in number of taxa collected with 94 and Station 3 the lowest with 43. Stations 0 and 1 were comparable in 1977 with 69 and 63 taxa, respectively. Shell-hash stations (2, 4, 5 and 0 in 1976) exhibited a higher species richness in 1976 and 1977 than any of the other stations. Total species richness increased at all stations (except Station 0, which was moved between 1976 and 1977).

Total abundances of macroinvertebrates at each station in 1976 and 1977 are presented in Figure C-16. Station 4 yielded the greatest number of organisms in 1976 with 3754, and Station 3 the least with 354. Station 1 also produced relatively low numbers, while numbers at trough Stations (0, 2 and 5) were relatively high. During 1977, Station 5 produced the greatest number of individuals with 1867. Station 3 was again lowest with 354 organisms collected. Stations 0 and 1 were comparable in 1977 with 703 and 813 specimens,

respectively. The number of organisms at four of the six benthic stations were similar in 1977; Stations 3 and 5 were the exceptions. A substantial increase in abundance between 1976 and 1977 was observed at Station 1. It is not known whether this increase was caused by natural population cycles, by differences in collection techniques or by the plant discharge acting as an attractant (e.g., by increasing food supplies). The total number of individuals collected at Stations 2 and 4 decreased in 1977 compared to 1976. These declines are not considered unusual since they probably reflect normal fluctuations in density of the dominant taxa.

The large seasonal variations in observed species richness (Figures C-17 through C-22) are attributable to the diversity, patchiness, and motility of benthic macroinvertebrate fauna and to the qualitative aspects of trawl collections. Although seasonal patterns varied among stations, maximum species richness usually occurred during the summer months of both 1976 and 1977. The pattern was marked somewhat by late fall and winter increases at Stations 4 and 5 in 1977 and at Stations 0 and 5 in 1976. Except for these anomalous increases, trends of species richness at all stations generally followed observed patterns of bottom water temperature. Seasonal species richness at Station 3 most closely paralleled trends of mean bottom water temperatures. Species richness at that station was very similar between years, probably

indicating the presence of a more persistent, though less diverse, fauna than was found at the trough stations. Of the trough stations, Station 2 showed the least seasonal variation between years.

The most noticeable difference between years at Station 1 (Figure C-18) was a decline in species richness during late summer (August and September) of 1977. This is the period when water temperatures reach seasonal maxima (Worth and Hollinger, 1977). In 1977 Station 0, which is similar in water depth and substrate type to Station 1 but is 4.7 km south of it, showed no late summer decline in species abundance (Figure C-17). It is not known whether the observed disparity in species richness between Stations 0 and 1 was related to plant operation or to natural biological events.

Year-to-year differences in number of macroinvertebrate taxa collected were tested (Mann-Whitney U Test) at the six St. Lucie benthic stations. Numbers of taxa collected during 10 months of sampling in 1976 (March through December) at each benthic station were compared with trawl data from the same period in 1977. No significant differences between years were found at any benthic station.

Included among the taxa collected during 1976 and 1977 were seven species of commercially important shellfish (Table C-8). Trawl catches of these species indicate, however, that they are represented by small populations which vary little from year to year.

The penaeid shrimp, *Trachypenaeus constrictus*, was collected in large numbers and does occasionally occur in commercial catches of bait shrimp. However, it is usually of minor commercial importance. *T. constrictus* abundance data from trawl collections in 1976 and 1977 were pooled by station and are presented in Figure C-23. A definite decrease in abundance was observed at all stations in 1977 compared to 1976. It is probable that the observed decreases were a result of natural changes in population density. Juvenile recruitment occurred at Station 1 throughout the 2-year study period.

Monthly abundance data for *T. constrictus* indicate that six increases of abundance occurred at Station 1, but no definite seasonal patterns were evident when 1976 was compared to 1977 (Figure C-24). Seasonal abundance of *T. constrictus* was similar at Stations 0 and 1 in 1976 and 1977.

Dominant species at each of the six offshore stations were determined by using the "biological index value" of McCloskey

(1970; Appendix Table L-2). To facilitate comparisons with 1976 data, values for January and February 1977 were excluded from ranking calculations. The five most dominant taxa, as well as their ranks by abundance and frequency at each station, are presented in Table C-9.

In most cases, taxa ranked among the top five by McCloskey's index were also ranked in the top five by abundance and frequency. Dominant species in trawl collections (as in grab collections) showed a high degree of replacement from year to year. However, the dominant species (*Trachypenaeus constrictus*) at the discharge and the control stations remained a dominant through both years of sampling. Plant discharge, therefore, has not enhanced a change of the most dominant epibenthic macroinvertebrate species in the surrounding area.

McCloskey's index values were compared at each station. Stations 0, 1 and 3 were highly dominated by one or two species while Stations 2, 4 and 5 exhibited a more gradual decrease through the top-ranked taxa, indicating a more equitable distribution of dominance (Table C-9).

Dominance-diversity curves (Whittaker, 1965) depend solely on the abundance of each species in a sample. Greater dominance (low

diversity) is shown by a steeper slope of the upper portion of the curve. The dominance-diversity curves (Figures C-25 through C-30) produced a slightly different station relationship than McCloskey's index. These figures show that degree of dominance at all stations changed between 1976 and 1977. Dominance at Station 3 remained relatively constant in abundance over the two years of sampling. A high degree of dominance was indicated for Station 4 due to the numerical dominance of *Mellita quinquiesperforata*[a]. Minor changes in dominance at Stations 2 and 4 probably reflect normal yearly abundance variations of dominant faunal components (*Crepidula fornicata* and *Anomia simplex* at Station 2 and *M. quinquiesperforata* at Station 4) in conjunction with the qualitative aspects of trawl collections. The change in steepness of the curves for Station 0 reflects the loss of the dominant hard substrate fauna after the station was relocated.

A major change was noted in the degree of dominance at Station 1 between years. The curves show only a small increase in total number of species between 1976 and 1977, but striking differences were noted in the abundances within the taxa. Undoubtedly, some of the increases in abundance and number of species were attributable to large amounts of drift algae collected at Station 1 during the summer months of 1977.

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[a] Wilcox and Gamble (1974) discuss reasons for the high populations of *M. quinquiesperforata* on Pierce Shoal, near which Station 4 is located (Figure C-1).

The dominance curves for Station 5 were similar during 1976 and 1977. An increase in the abundance of individuals in 1977 may have resulted from a situation similar to that described previously at Station 1. With the exception of the above-discussed disparities, trawl macroinvertebrate dominance-diversity at each station showed little variation between 1976 and 1977. This indicates few possible changes in this parameter that could be associated with plant effect.

The Morisita index of community similarity ($C\lambda$) was also used to compare 1976 and 1977 trawl station data. The dendrogram formed using group-average sorting (Lance and Williams, 1967) indicated little faunal similarity during either year between Station 4 and all other stations (Figure C-31). In 1976, the trough stations (0, 2 and 5) formed a major group, with Stations 0 and 5 displaying the highest degree of similarity between any two stations. The lack of similarity between Station 4 and the other trough stations was due primarily to large numbers of the sand dollar (*M. quinquiesperforata*) collected at Station 4. A dendrogram formed by excluding this species (Figure C-32) showed that, during 1976, Station 4 joined the major group of trough stations and showed a very high degree of similarity with Station 5. Stations 1 and 3 in 1976 formed another major group and displayed low similarity with the trough stations.

Consistent with their location in similar habitat and water depth, Stations 0 and 1 showed a very close similarity in 1977 (Figure C-31). A major perturbation at either station would be expected to alter the fauna, thereby decreasing the magnitude of the index value. Station 3 was also grouped with Stations 0 and 1 but had a relatively low similarity to either station. In 1977, trough Stations 2 and 5 formed another major group, although the similarity between the stations was considerably lower than it was in 1976. The displacement of Station 4 is presumed to be due to the same phenomenon discussed for 1976.

Morisita's similarity index was used to determine the degree of similarity between years at the same station. Station 4 had the highest similarity index (0.84) between years, probably because of the large and persistent sand dollar population. Stations 2 (0.35) and 5 (0.34) exhibited the lowest similarity values as a result of very diverse faunal assemblages with low numbers of shared species between years. Stations 0 (0.69), 1 (0.71) and 3 (0.76) formed a group with slightly lower values than that at Station 4. The faunal similarity index between years at Station 1 was comparatively high (0.71), indicating that community structure changed little during the first year of plant operation.

SUMMARY

Continued quarterly grab and monthly trawl sampling for benthic macroinvertebrates was conducted at six offshore stations in the vicinity of the St. Lucie Plant. The first year of sampling was conducted in 1976 during the intermittent plant operation. During the following year, 1977, the plant was operating most of the time. Any plant-induced effects would therefore be observable by comparing data from the two study years. Additional sediment data from older baseline studies, conducted in 1971-1973 were compared with the present study.

Macroinvertebrate composition by major taxonomic group exhibited little change from 1976 to 1977. If plant effects were significant, the composition would be expected to change. Although the dominant species fluctuated from year to year at all stations, a relatively large portion of top-ranked species was shared by discharge and control stations in 1977 when the plant was in full operation. This situation would not be expected if the discharge area were significantly stressed.

In the number of individuals or number of species collected, no significant reductions were observed from 1976 to 1977. Some increases were noted.

Shipek grab data showed great seasonal variations in community structure (e.g., densities, number of species and biomass). Only Stations 3 and 4 exhibited recurring seasonal structural trends. The number of taxa shows significant positive correlation with density in the study area. Density trends for all stations (excluding 0) tend to be directly associated with mean bottom water temperature, although no significant correlation was determined. During 1977, densities and numbers of taxa declined at both the discharge and the control stations, indicating that variability on the beach terrace was normal rather than plant-induced.

Trawl sampling indicated that commercially important shellfish were represented by very small populations which showed little variation in numbers collected between 1976 and 1977. The penaeid shrimp, *Trachypenaeus constrictus*, of little commercial importance, was the dominant species collected by trawling at both the discharge and control stations.

Three distinct substrate types were observed, each with a characteristic benthic faunal assemblage. Station 1 was the only permanently sampled station to exhibit a significant change in sediment composition from baseline (1971-1973) through present studies. This change was an increased mean grain size during 1976. Although this might be attributed to discharge pipe construction, it

is more likely a result of high-energy sediment transport on the beach terrace.

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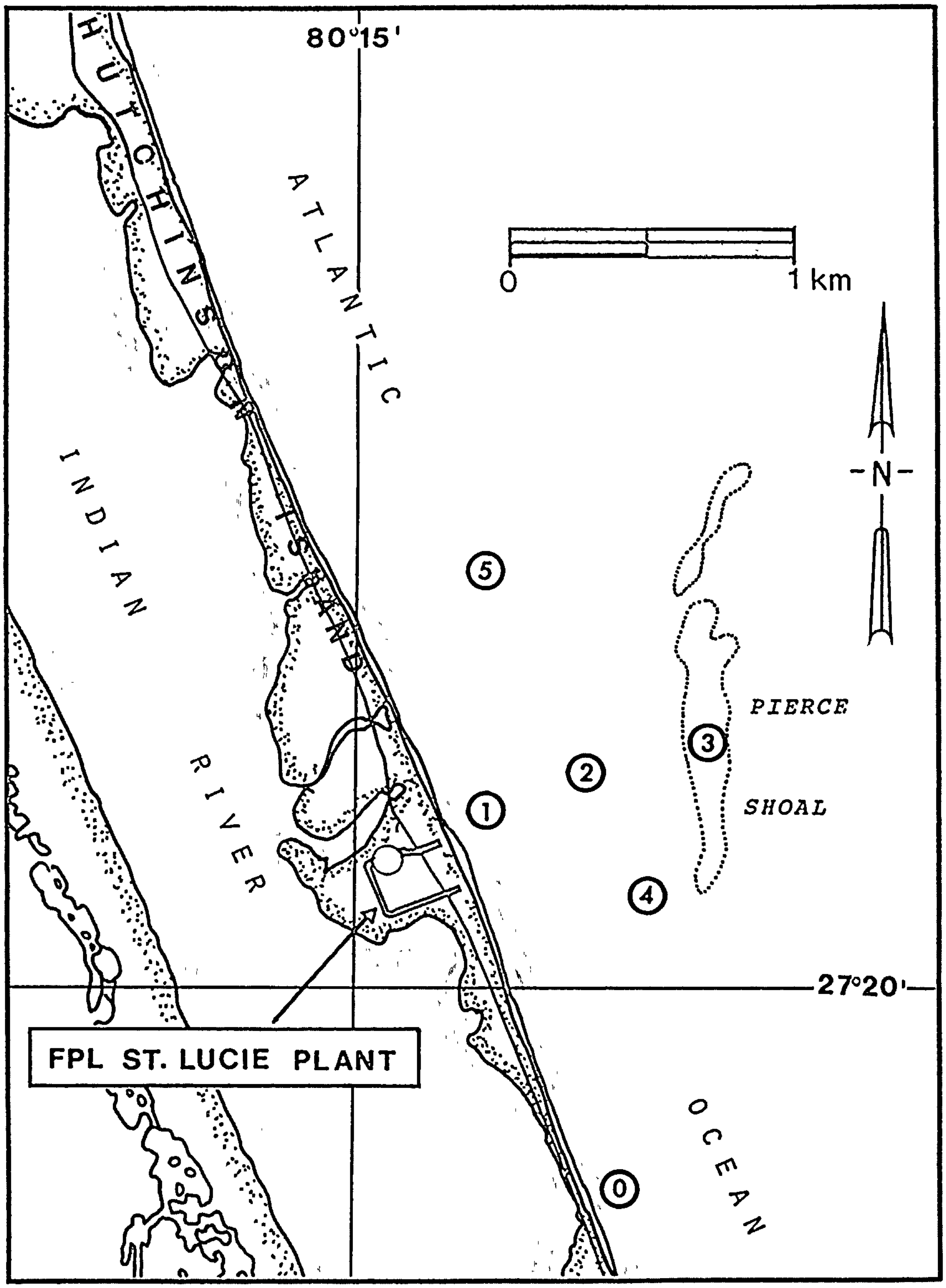


Figure C-1. Locations of benthic macroinvertebrate sampling stations, 1977.

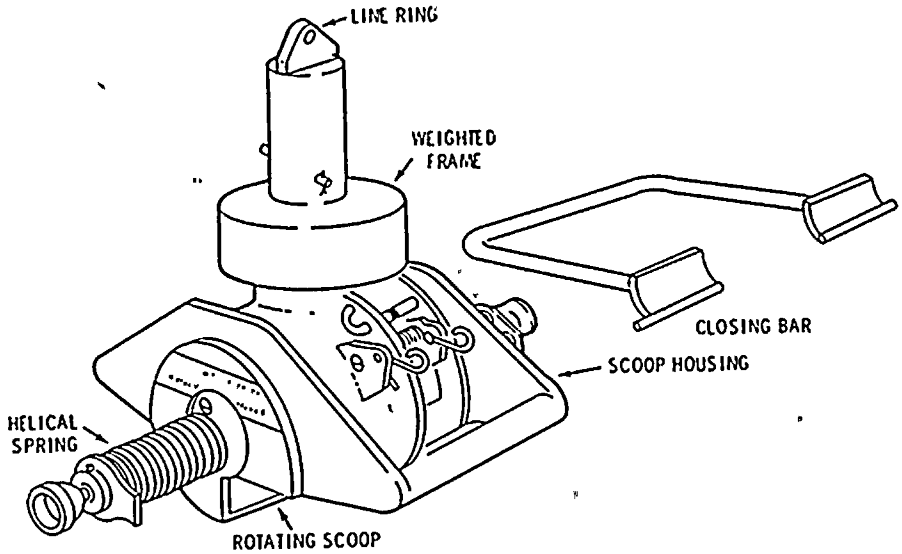


Figure C-2. Shipek grab sampler.

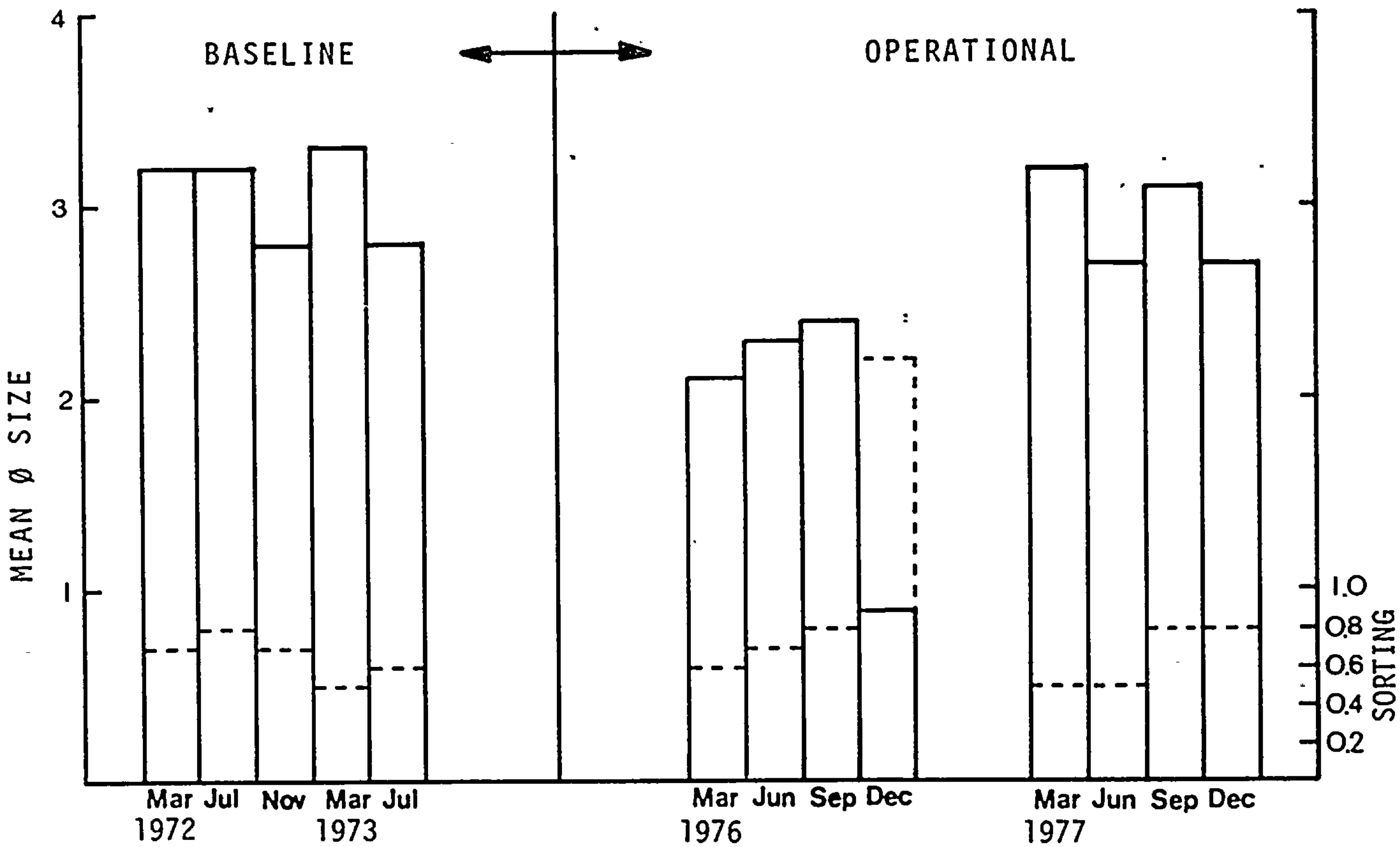
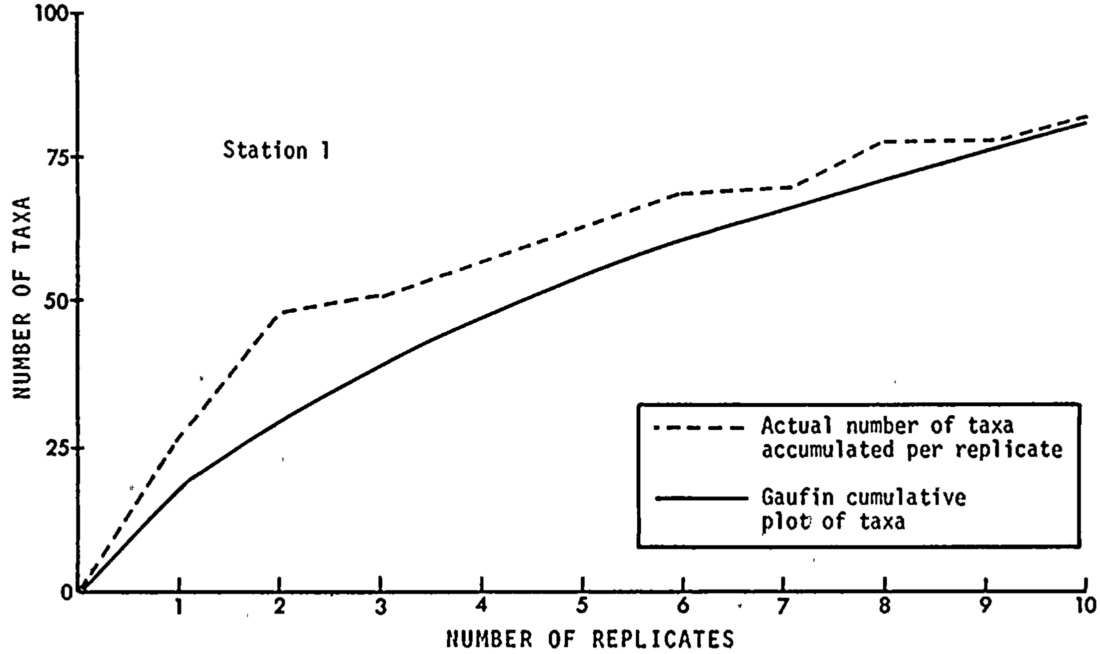


Figure C-3. Mean Ø sizes and sorting coefficients of particle-size distributions for sediment samples taken at Station 1 in 1972-1973 and in 1976-1977, St. Lucie Plant.



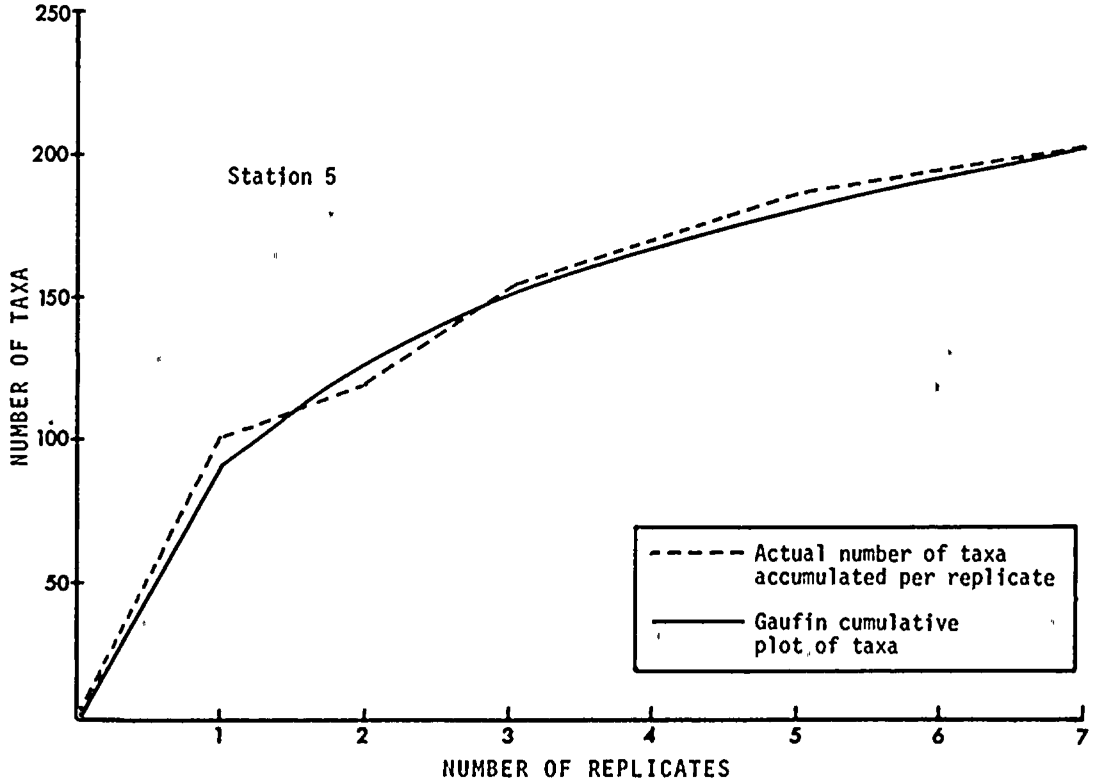


Figure C-4. Species saturation curves for benthic macro-invertebrates collected by Shipek grab at Stations 1 and 5, St. Lucie Plant, March 1977.

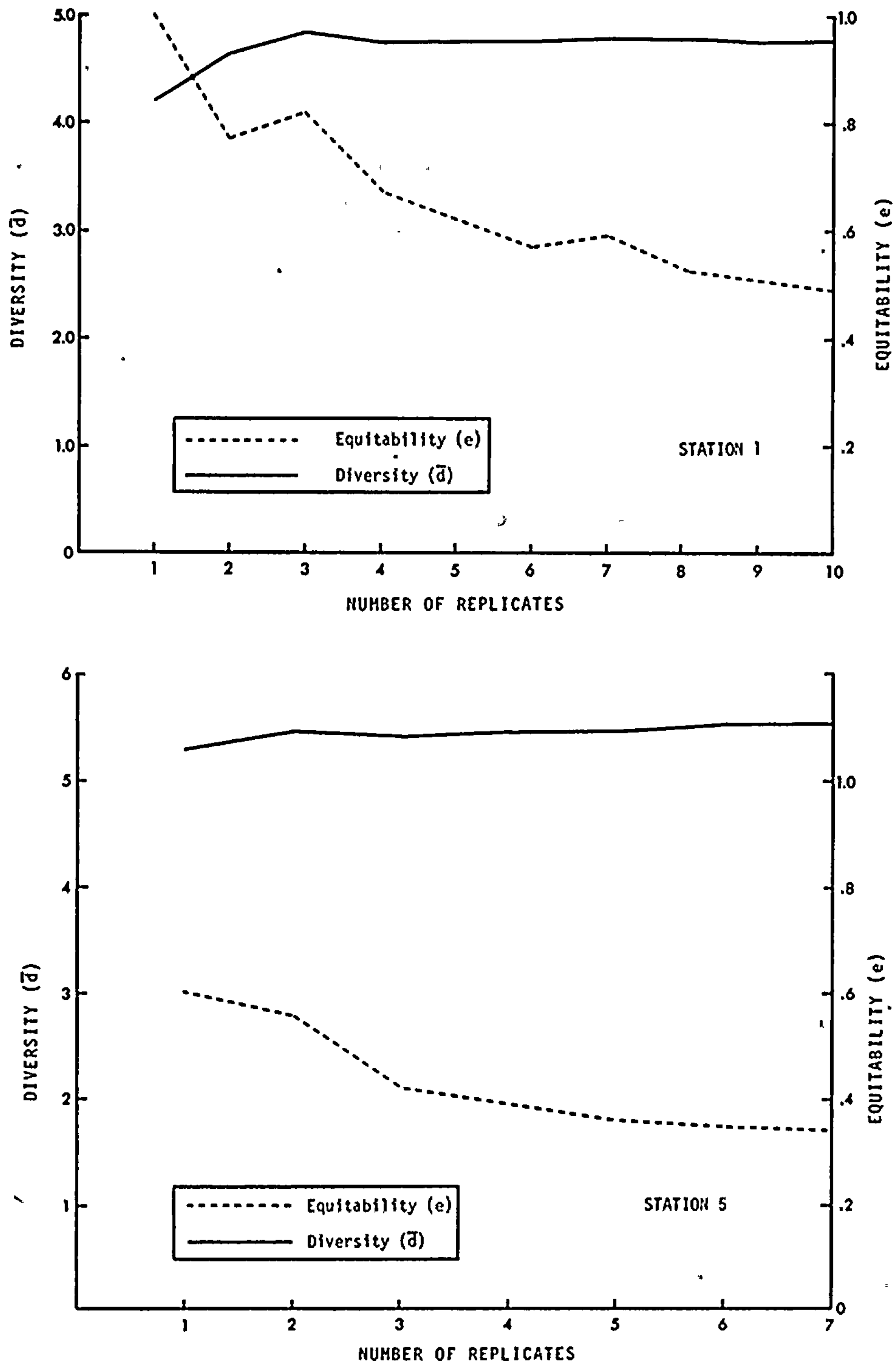


Figure C-5. Cumulative diversity (d̄) and equitability (e) for increased grab sampling at Stations 1 and 5, St. Lucie Plant, March 1977.

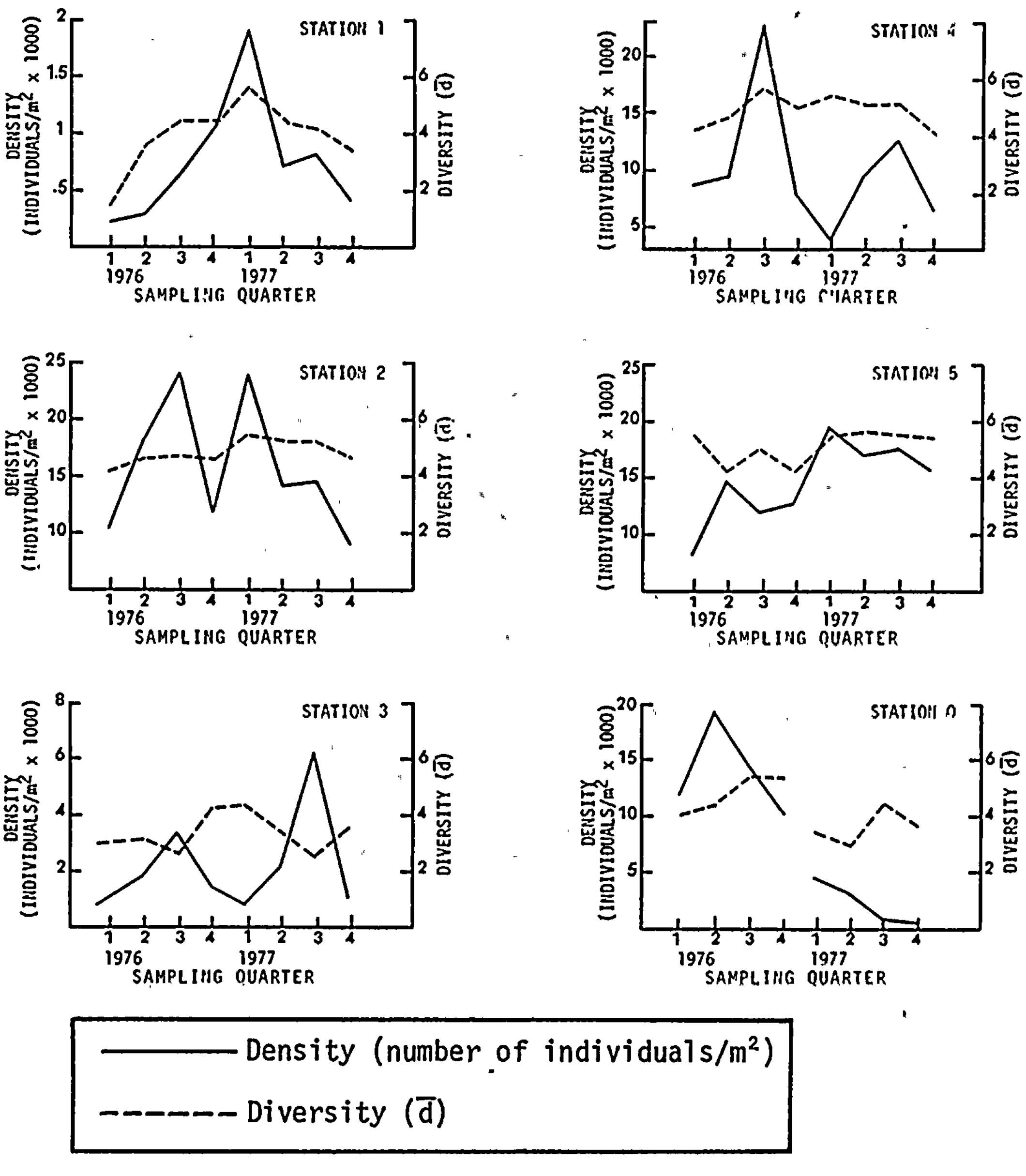


Figure C-6. Density and diversity of benthic macroinvertebrates collected by grabs at each of the six offshore sampling stations, St. Lucie Plant, 1976-1977. (Station 0 was relocated March 1977.)

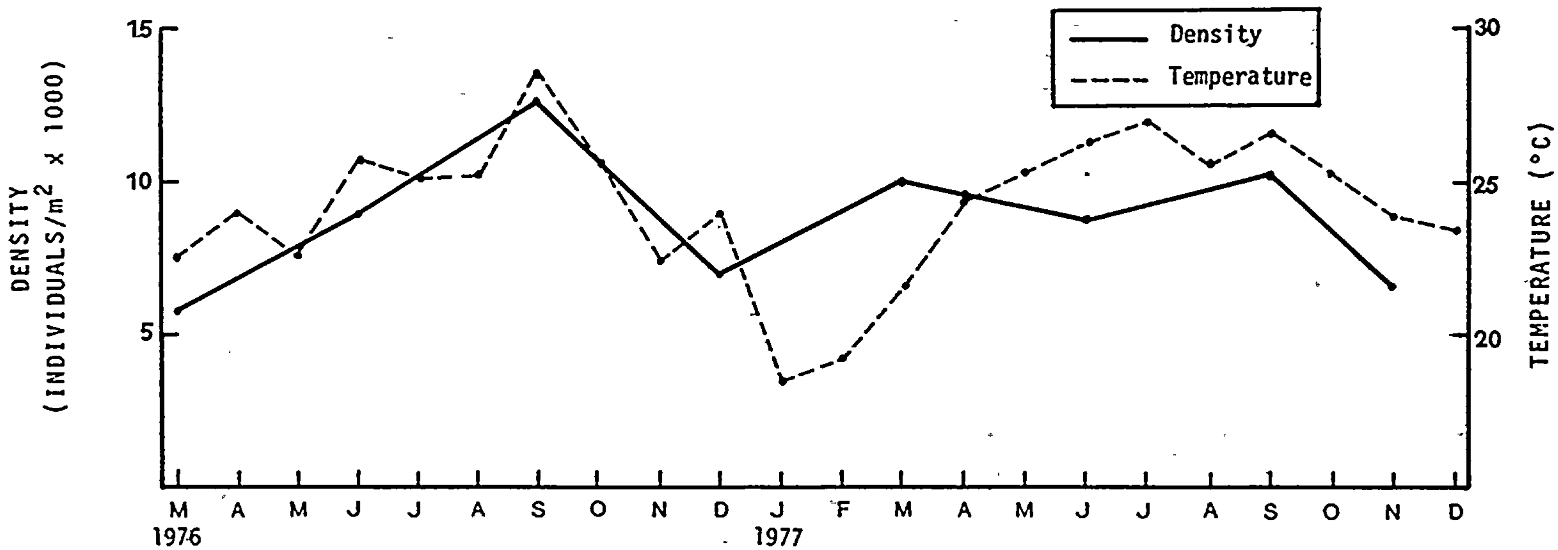


Figure C-7. Mean bottom temperature and mean density of macroinvertebrates collected by grab sampling at all offshore stations (excluding Station 0), St. Lucie Plant, 1976-1977.

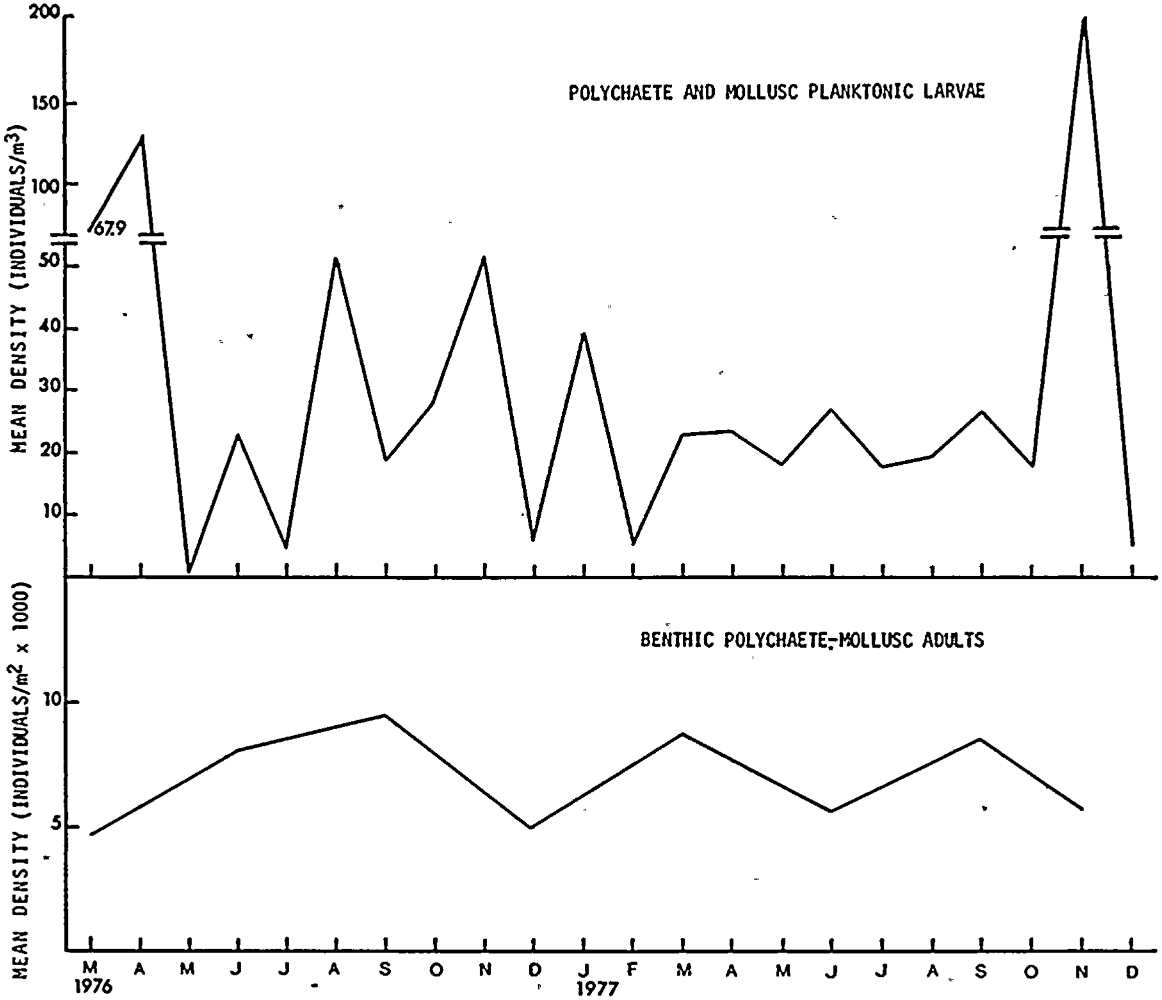


Figure C-8. Mean benthic polychaete-mollusc densities collected by grabs at all stations (excluding Station 0) and meroplankton densities from surface and bottom net collections, St. Lucie Plant, 1976-1977.

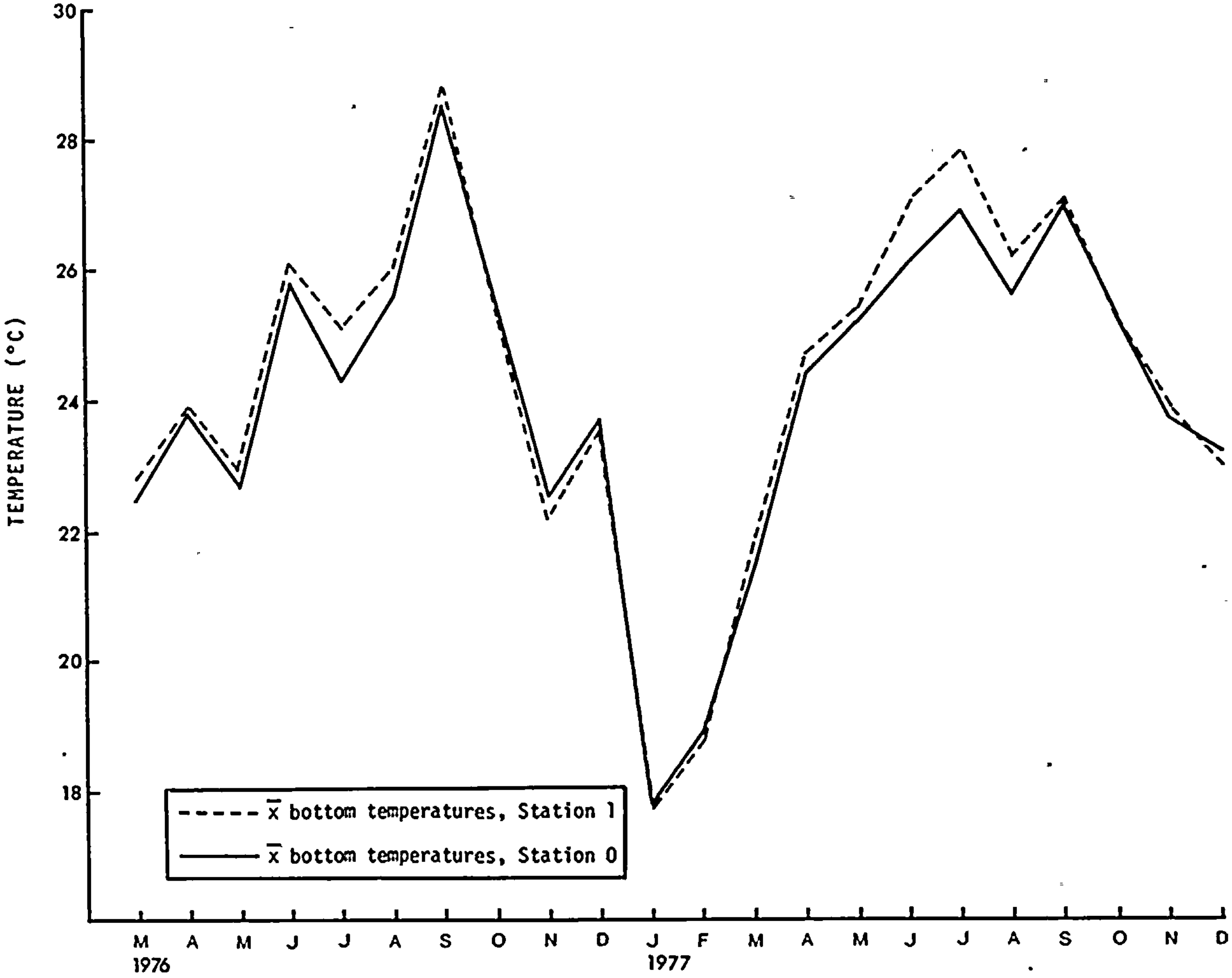


Figure C-9. Mean monthly bottom temperatures at Stations 1 and 0, St. Lucie Plant, 1976-1977.

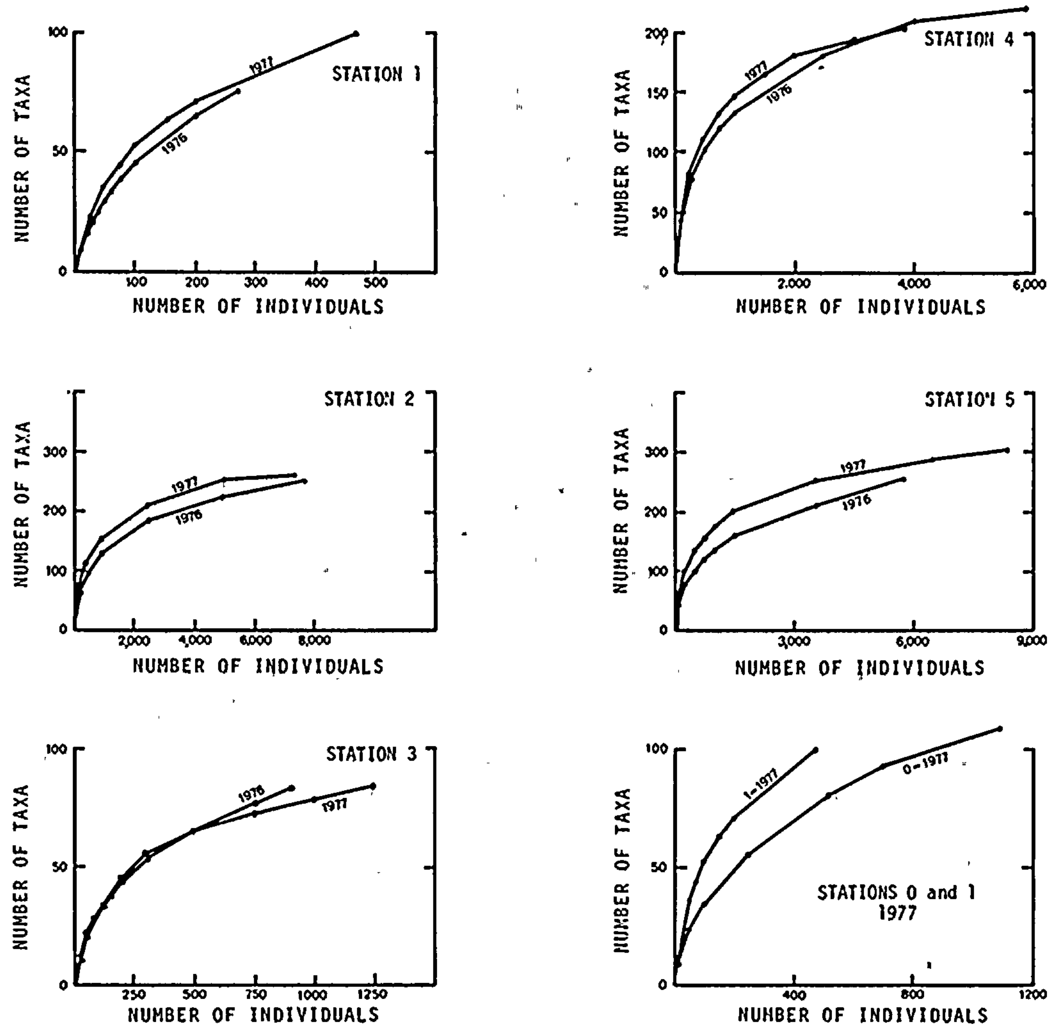


Figure C-10. Rarefaction curves for offshore grab sampling stations indicating number of expected taxa for various population levels of benthic macroinvertebrates, St. Lucie Plant, 1976-1977.

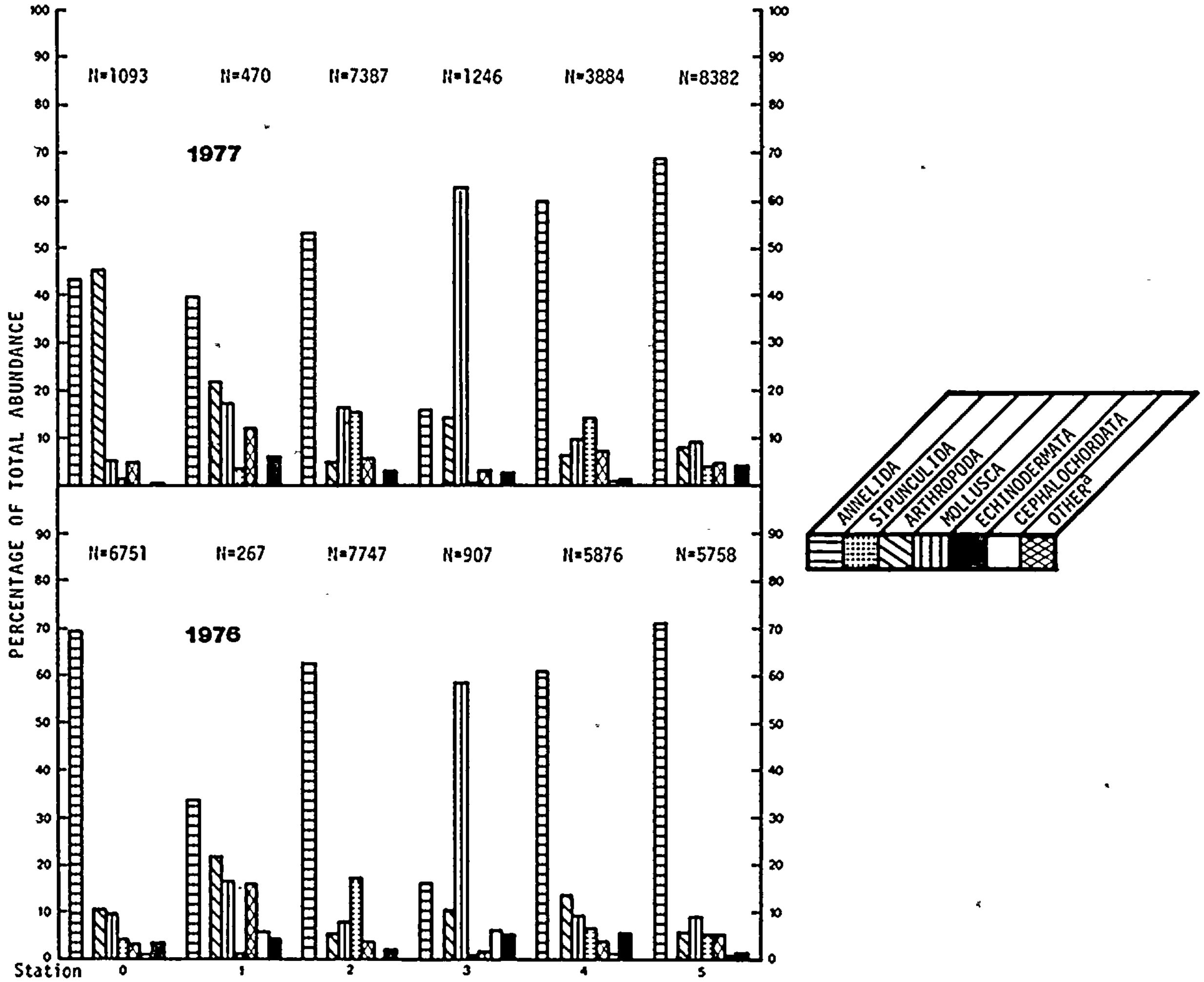


Figure C-11. Distribution by group of benthic macroinvertebrates collected by grabs, St. Lucie Plant, 1976-1977.

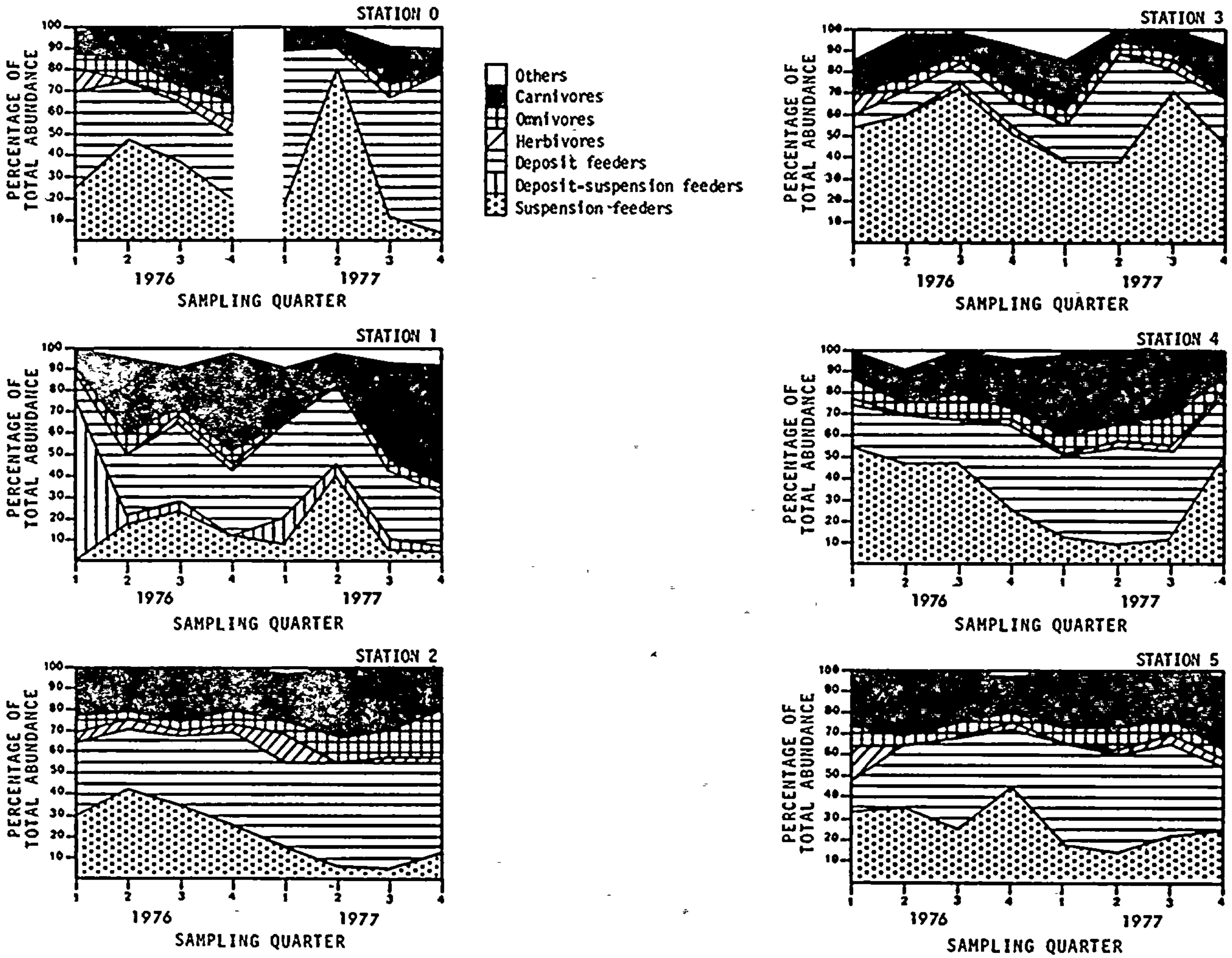


Figure C-12. Quarterly percentage composition of macrofaunal feeding types collected by benthic grabs, St. Lucie Plant, 1976-1977.

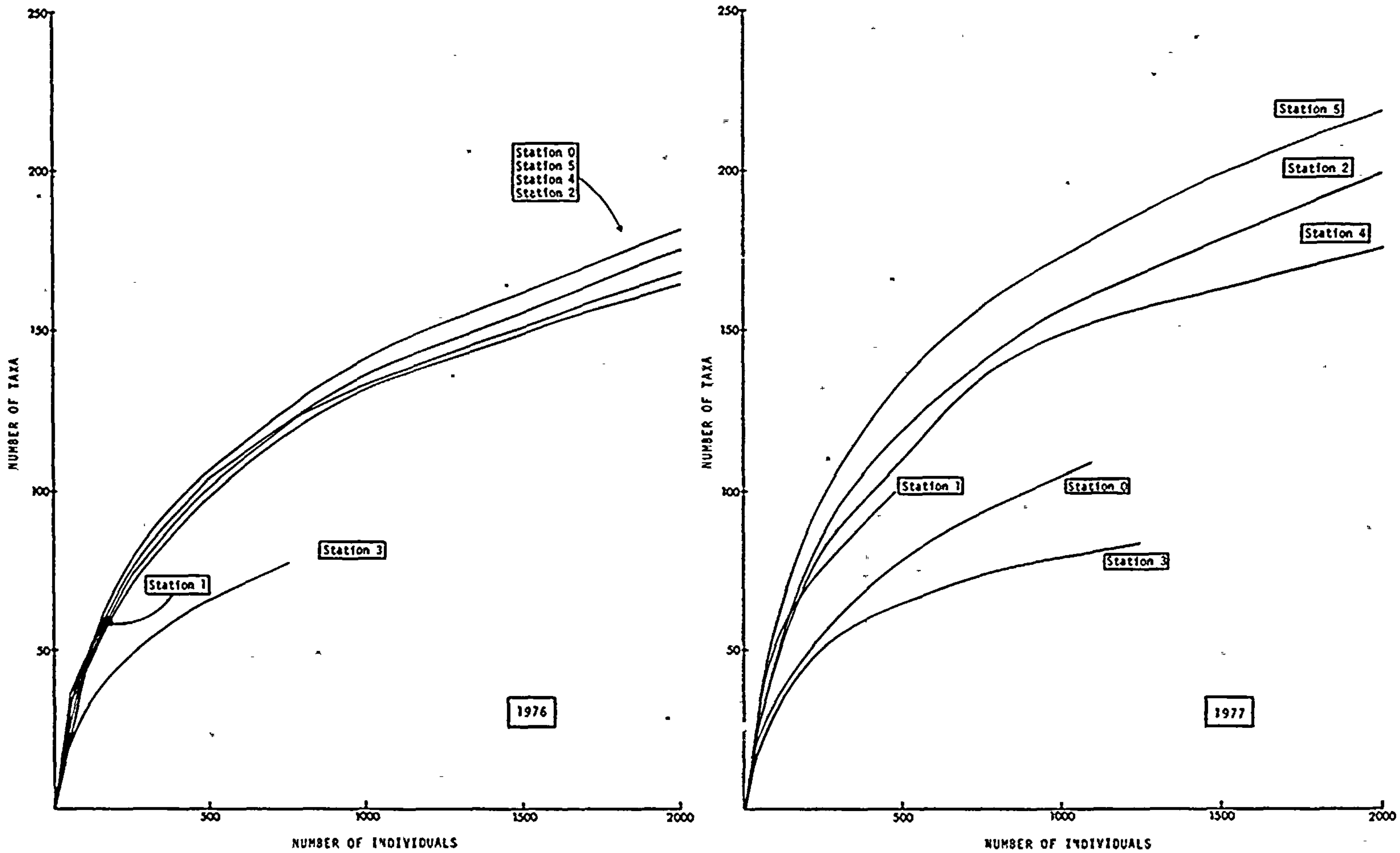


Figure C-13. Rarefaction curves for the six offshore grab sampling stations indicating the number of expected taxa for various population densities of benthic macroinvertebrates, St. Lucie Plant, 1976-1977.

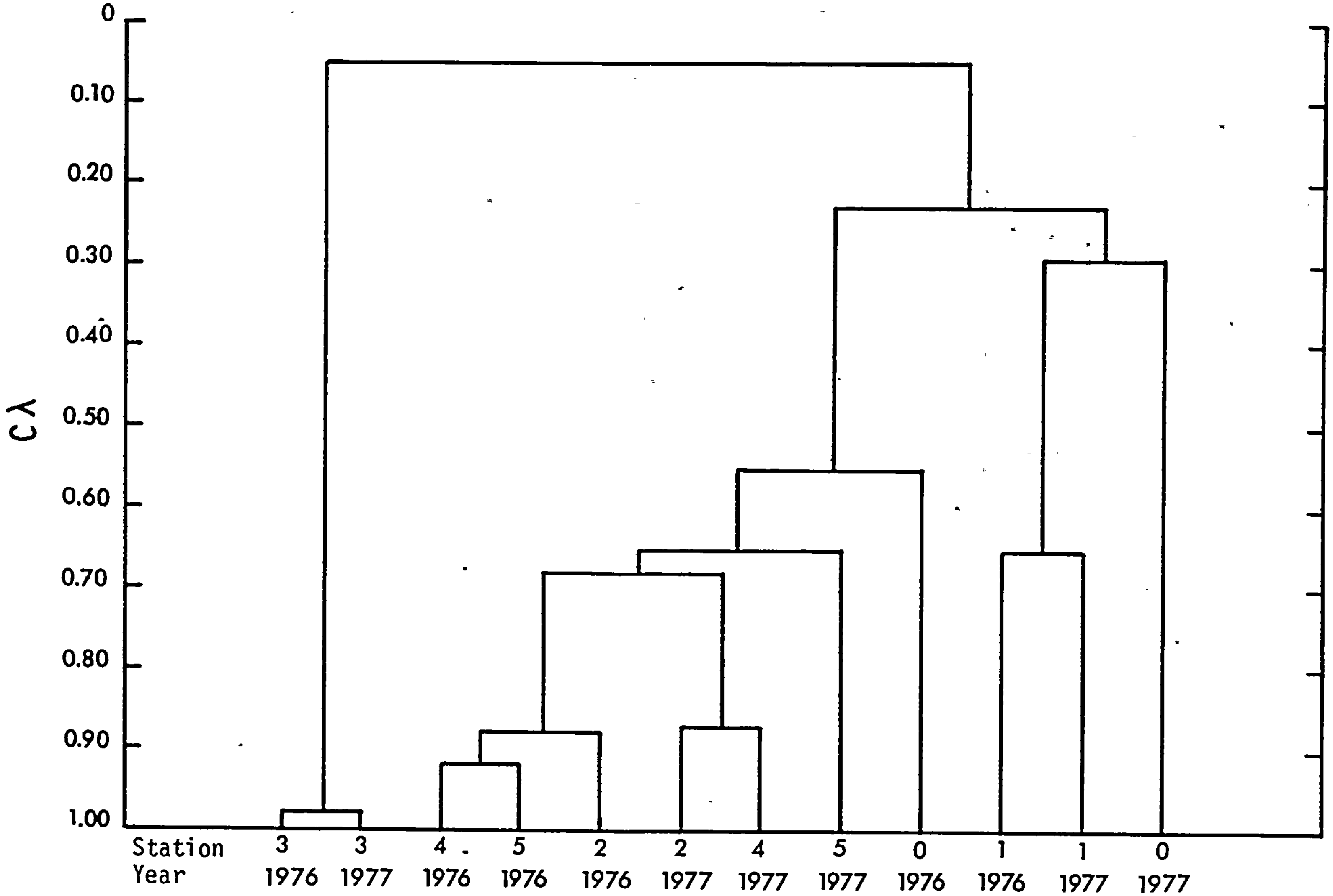


Figure C-14. Dendrogram of similarities (Cλ) between station data for each year of benthic grab sampling. Group-average sorting was used to produce the observed clusters.

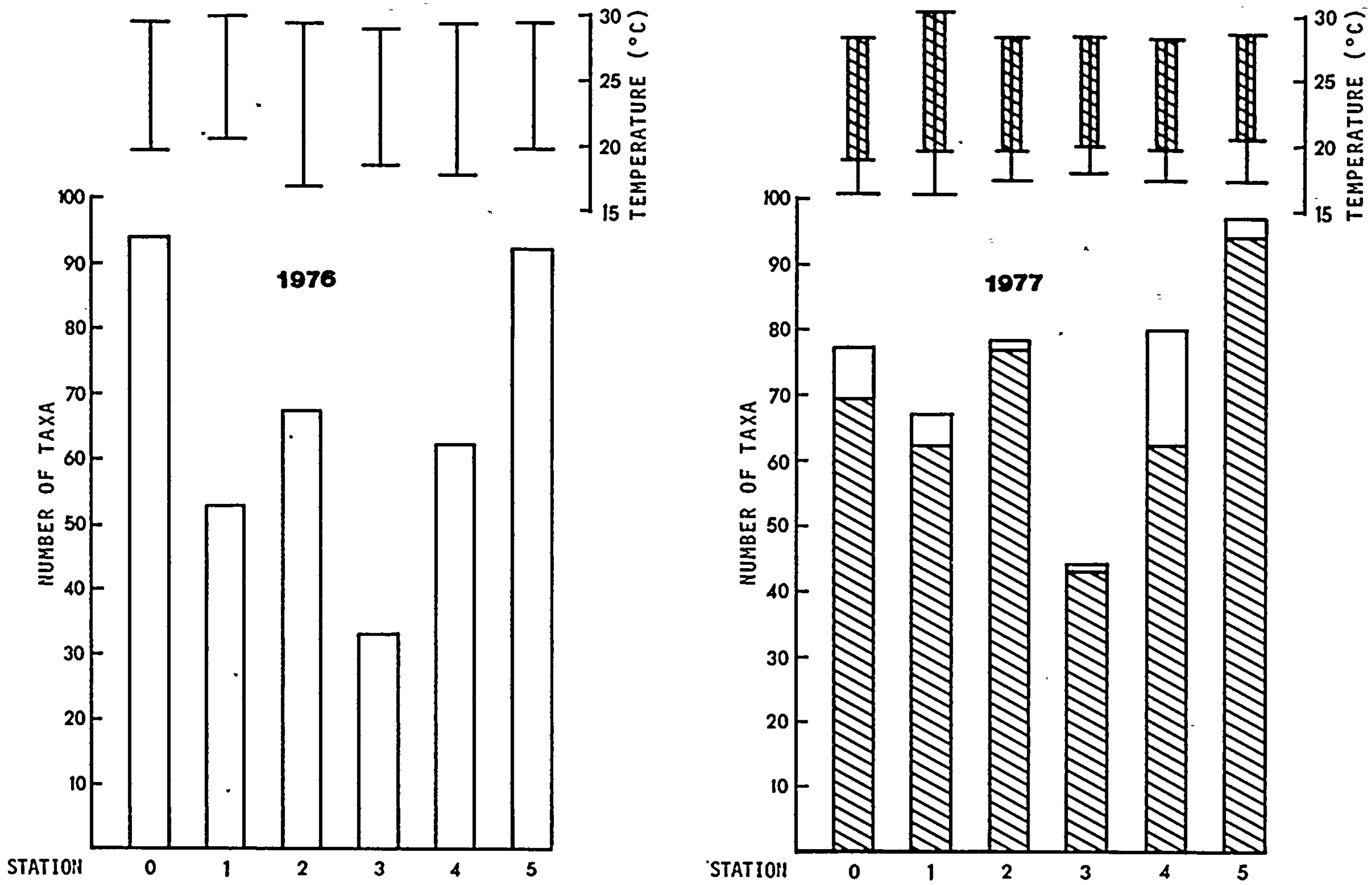


Figure C-15. Total number of macroinvertebrate taxa collected by otter trawl at each offshore station, St. Lucie Plant, March-December 1976 and all months of 1977. Shaded areas represent number of taxa collected from March through December 1977. Ranges of bottom water temperatures measured for each year are indicated by station. Shaded areas represent ranges between March and December 1977.

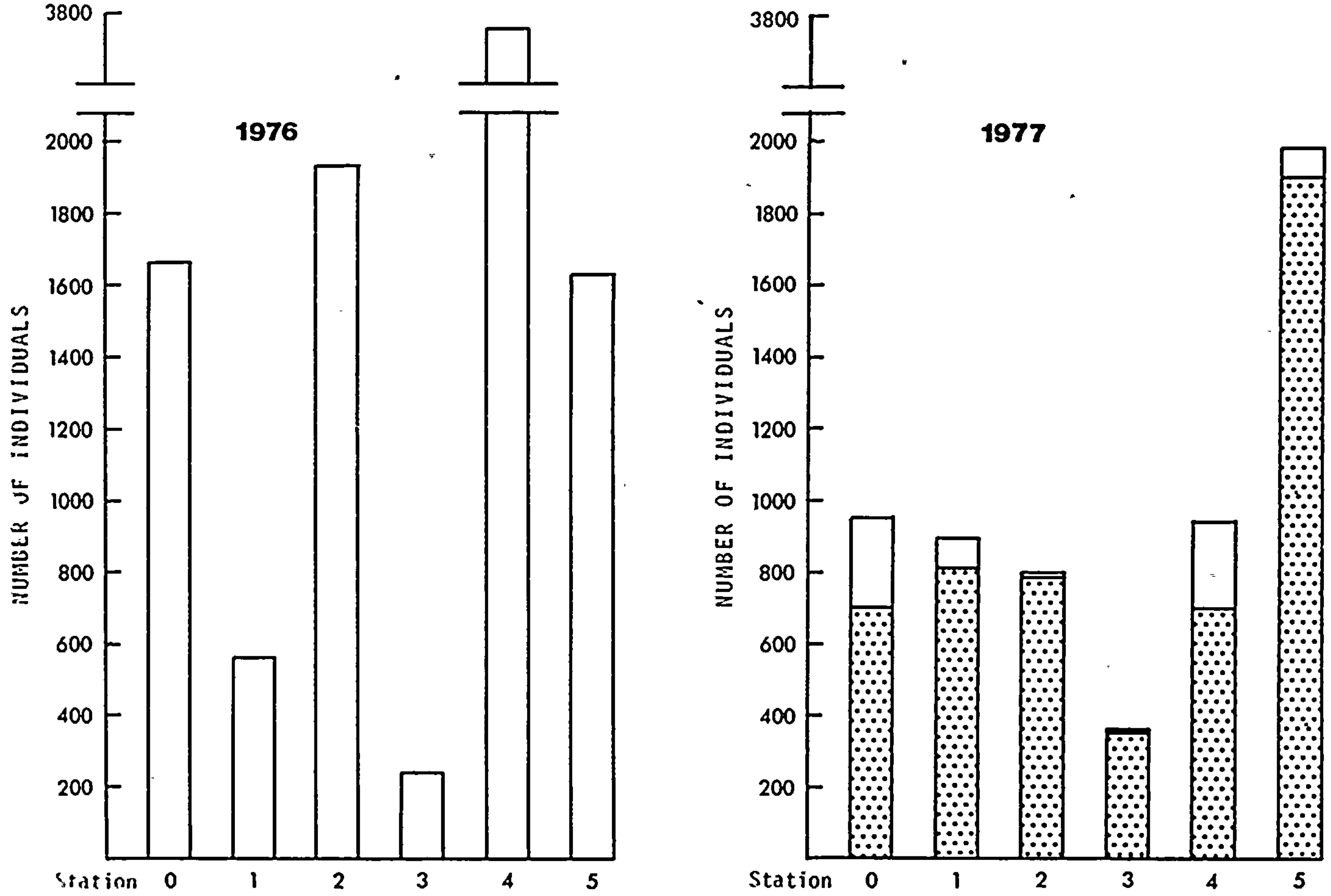


Figure C-16. Total number of macroinvertebrates collected by otter trawl at each offshore station, St. Lucie Plant, March-December 1976 and all months of 1977. March-December 1977 are shaded for comparisons with 1976.

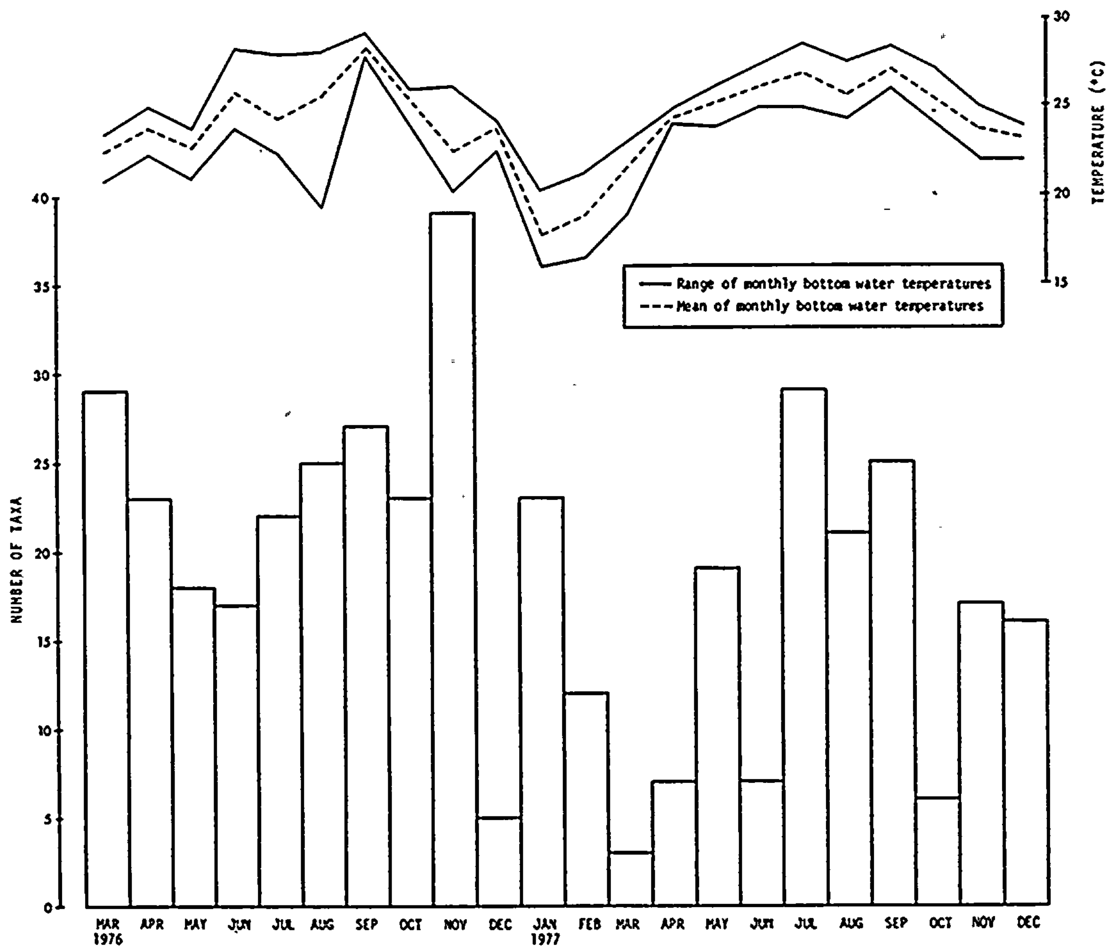


Figure C-17. Total number of macroinvertebrate taxa collected by monthly otter trawls with mean and range of bottom water temperatures at Station 0, St. Lucie Plant, March 1976 through December 1977.

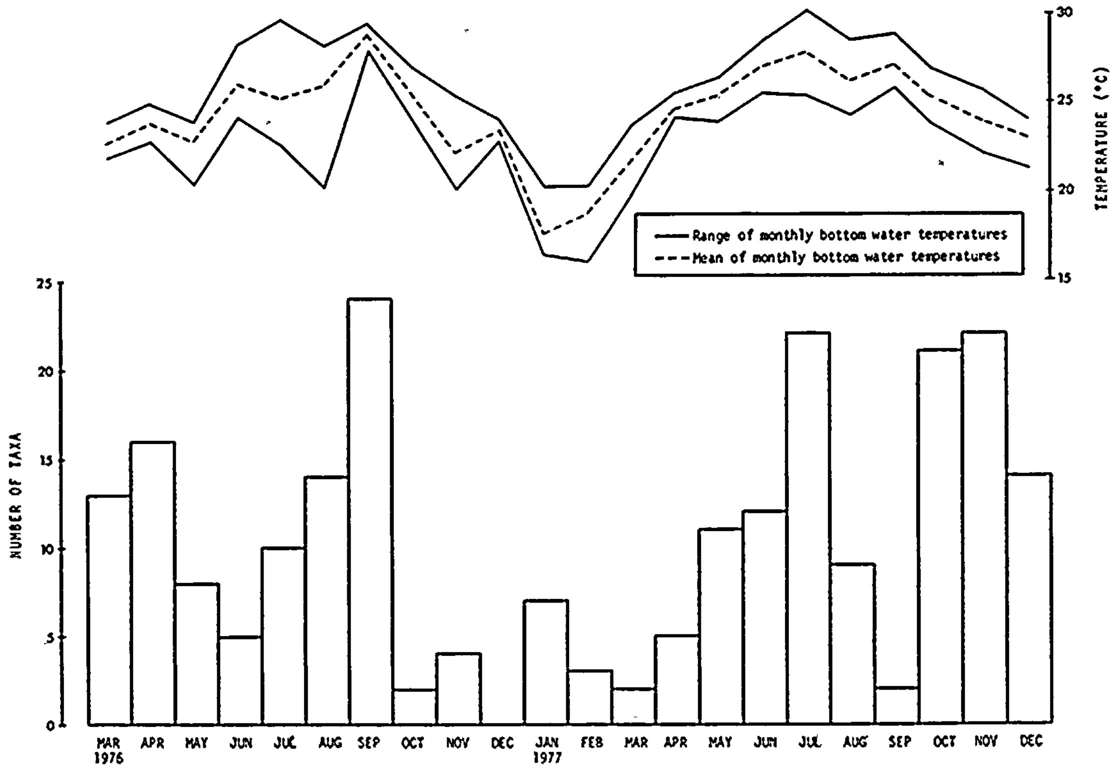


Figure C-18. Total number of macroinvertebrate taxa collected by monthly otter trawls with mean and range of bottom water temperatures at Station 1, St. Lucie Plant, March 1976 through December 1977.

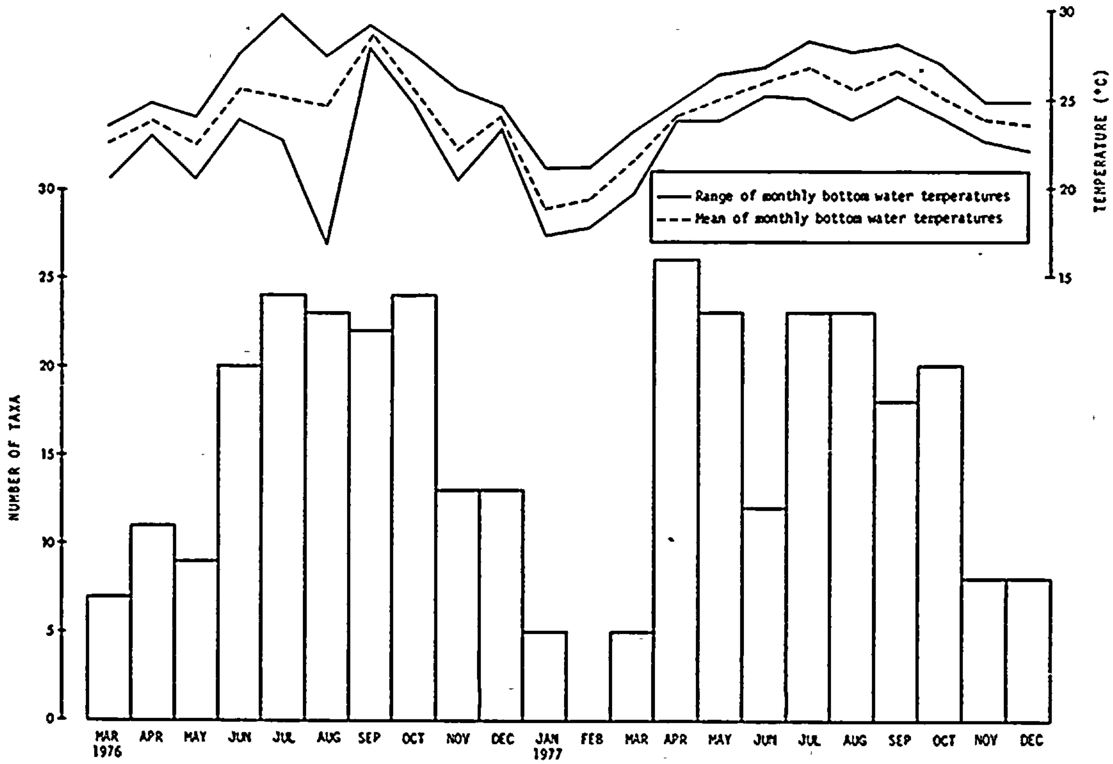


Figure C-19. Total number of macroinvertebrate taxa collected by monthly otter trawls and mean and range of bottom water temperatures at Station 2, St. Lucie Plant, March 1976 through December 1977.

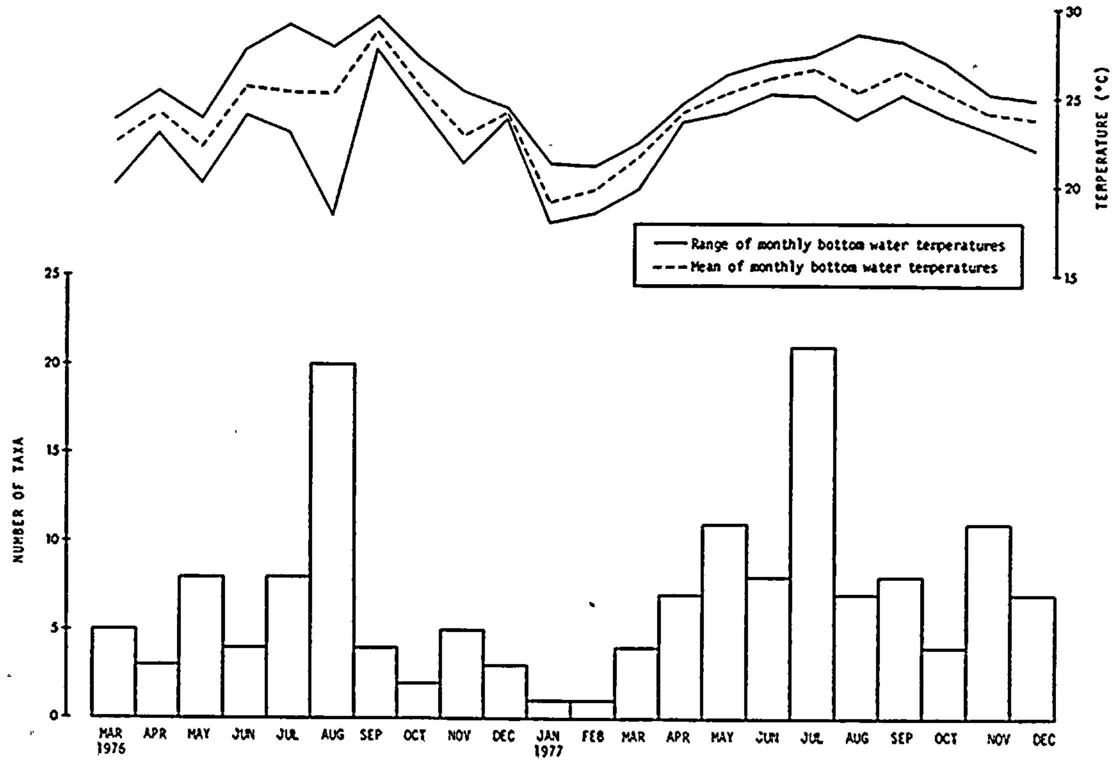


Figure C-20. Total number of macroinvertebrate taxa collected by monthly otter trawls with mean and range of bottom water temperatures at Station 3, St. Lucie Plant, March 1976 through December 1977.

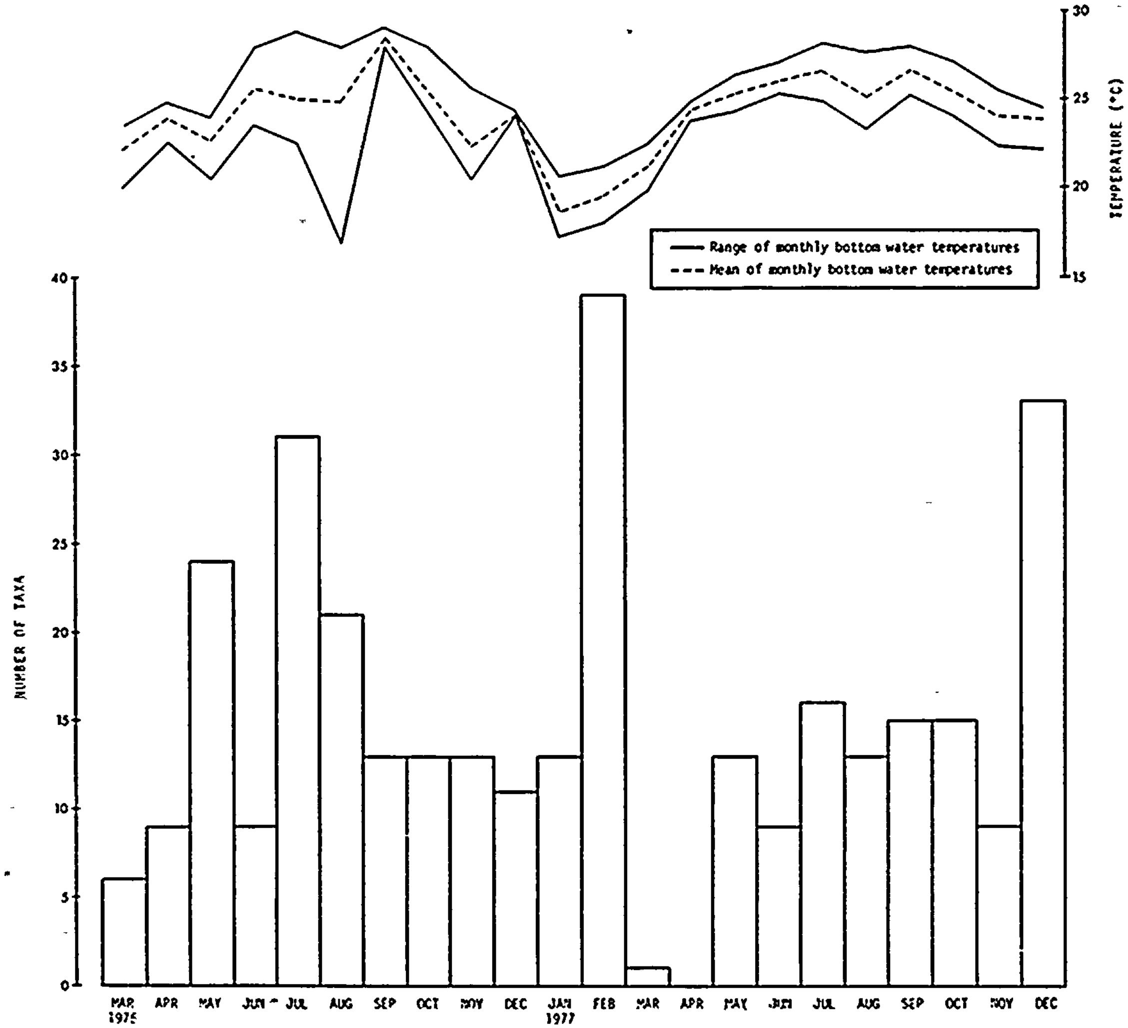


Figure C-21. Total number of macroinvertebrate taxa collected by monthly otter trawls with mean and range of bottom water temperatures at Station 4, St. Lucie Plant, March 1976 through December 1977.

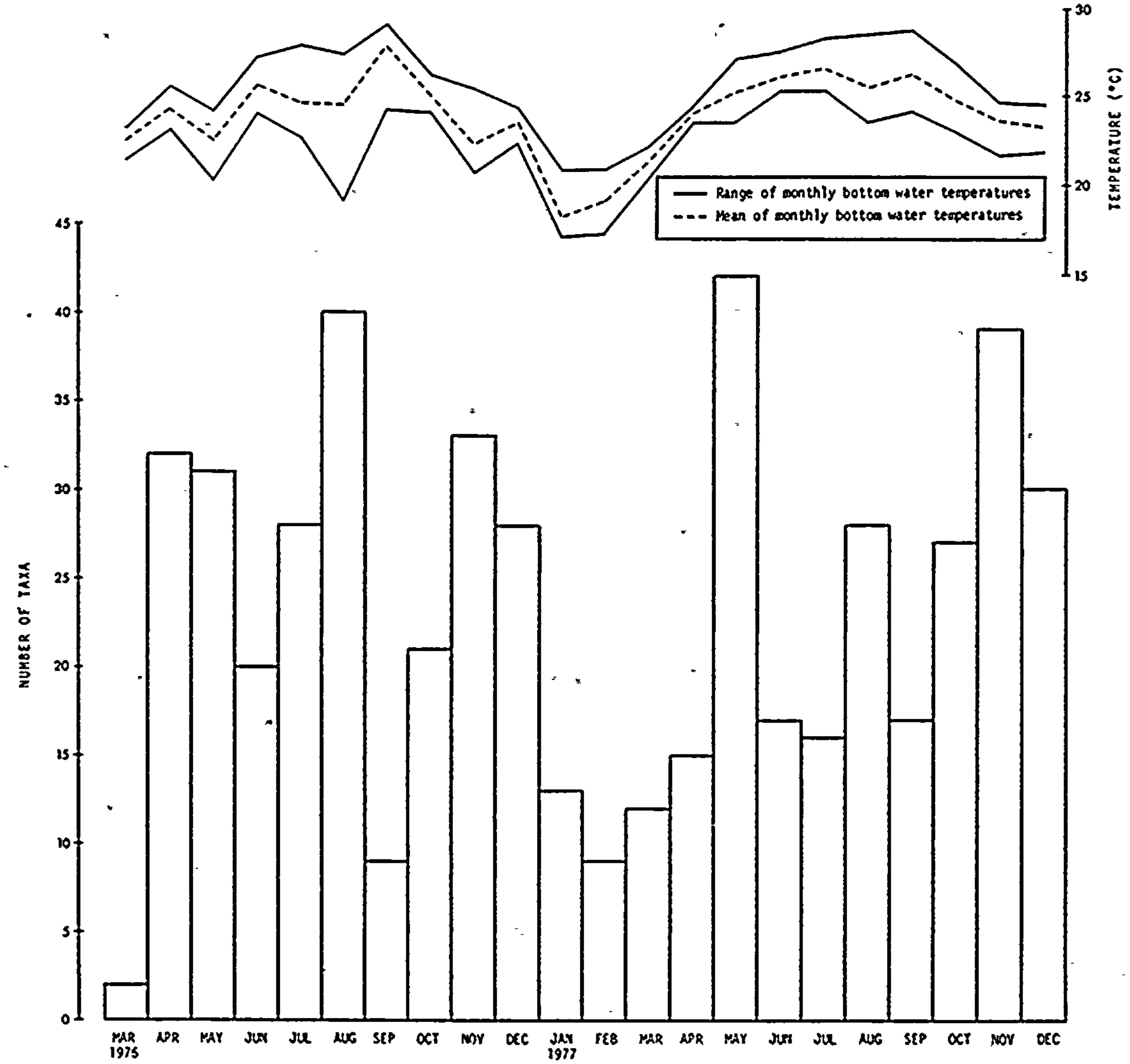


Figure C-22. Total number of macroinvertebrate taxa collected by monthly otter trawls with mean and range of bottom water temperatures at Station 5, St. Lucie Plant, March 1976 through December 1977.

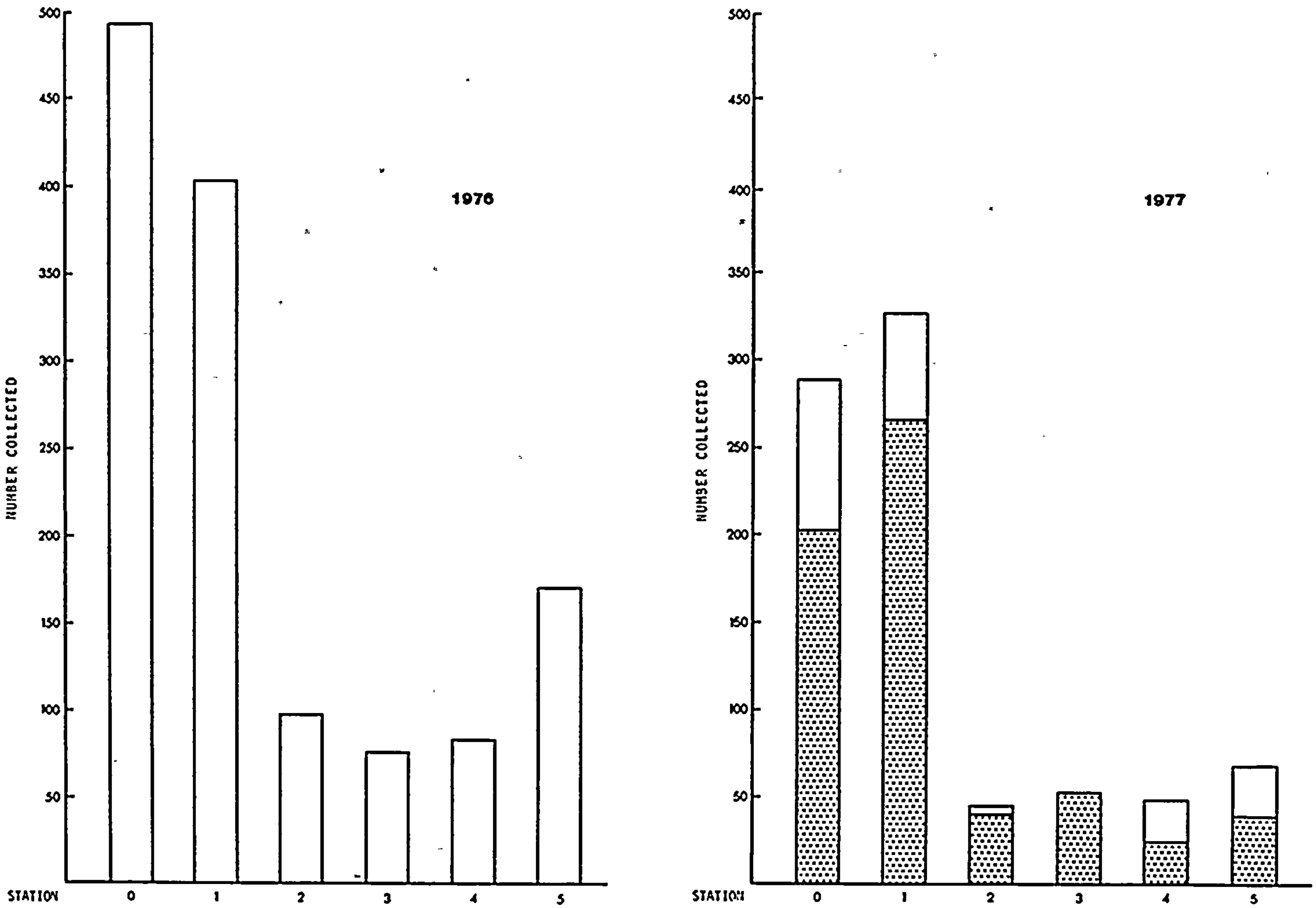


Figure C-23. Abundance of *Trachypenaeus constrictus* in trawl collections all months combined (March-December for 1976 and January-December for 1977), St. Lucie Plant, 1976 and 1977. Shaded areas represent number collected between March and December 1977.

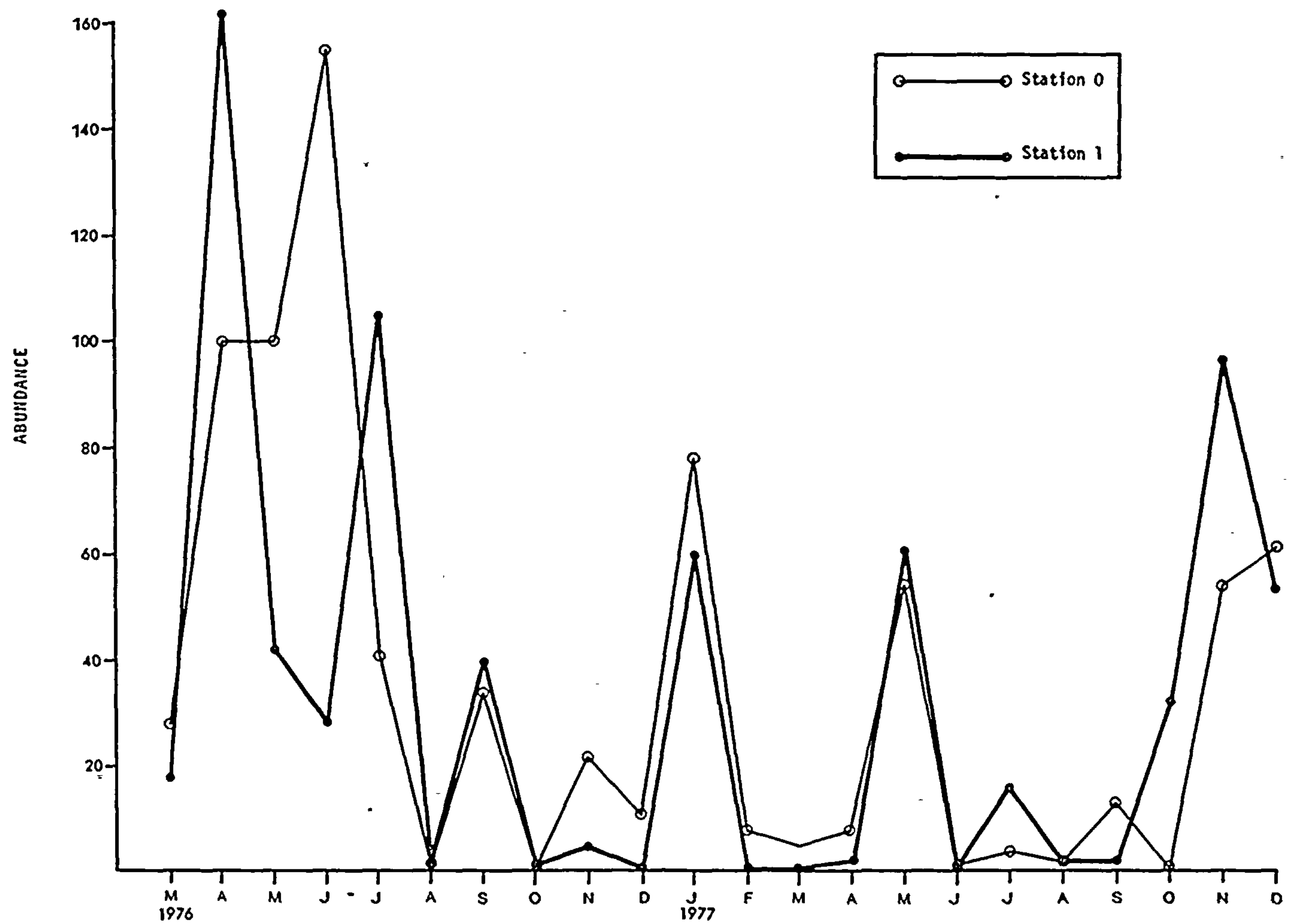


Figure C-24. Seasonal abundance of *Trachypenaeus constrictus* in trawl collections at Stations 0 and 1, St. Lucie Plant, 1976-1977.

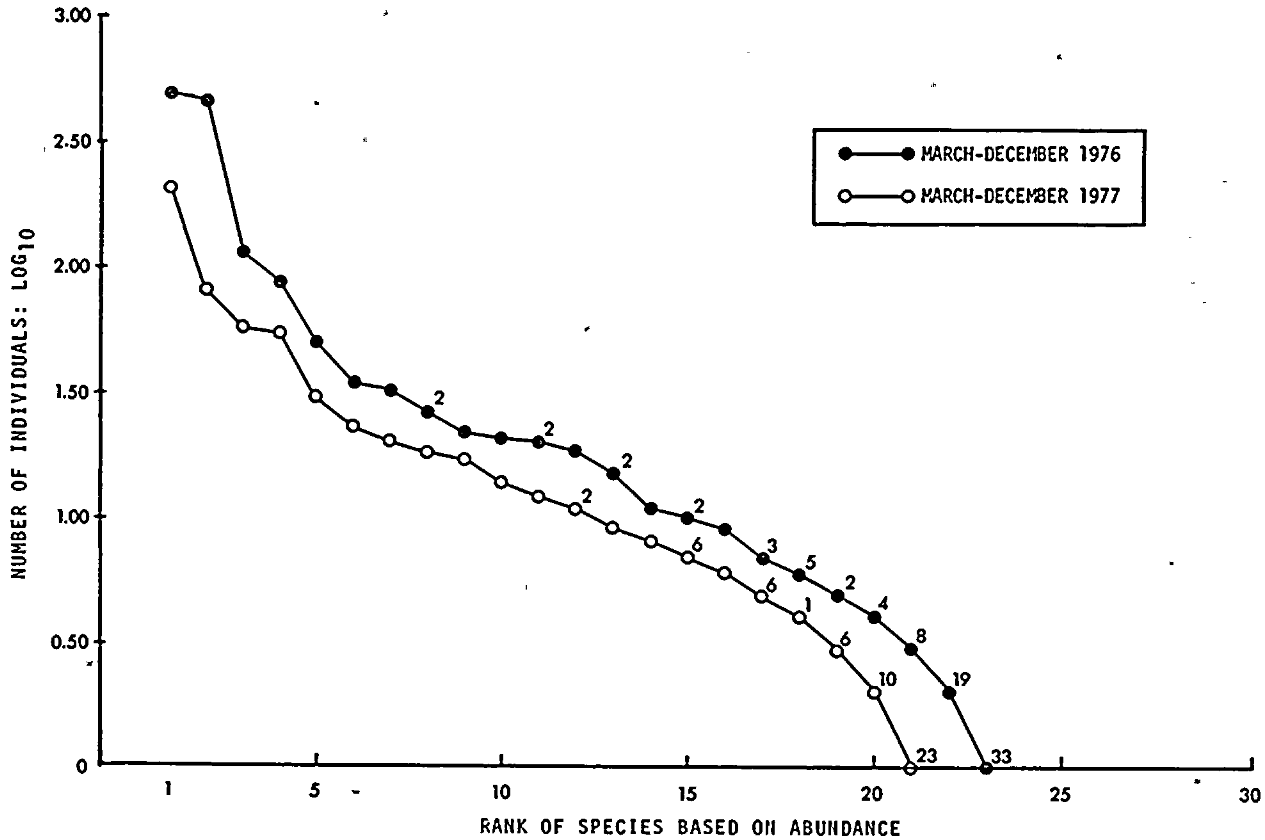


Figure C-25. Dominance-diversity curves for trawl collections at Station 0, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

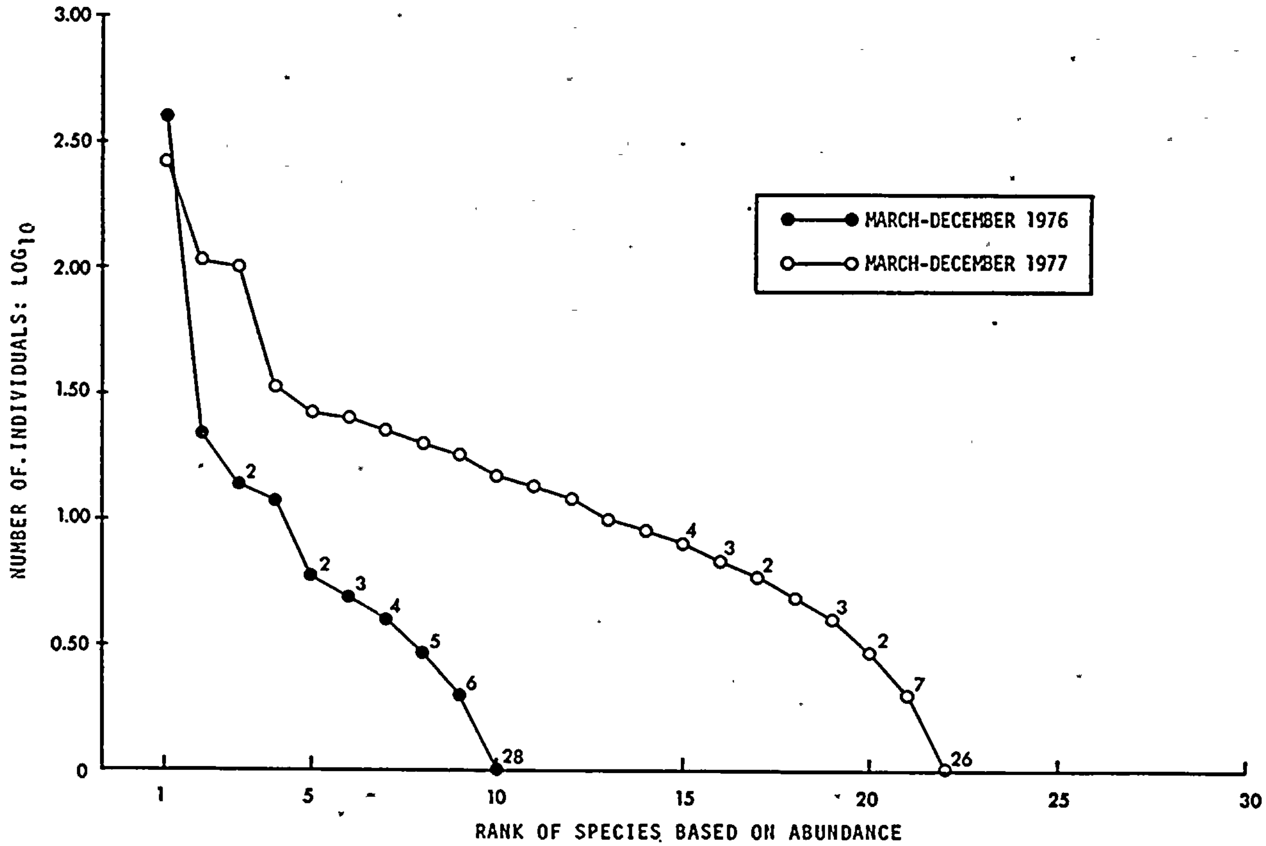


Figure C-26. Dominance-diversity curves for trawl collections at Station 1, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

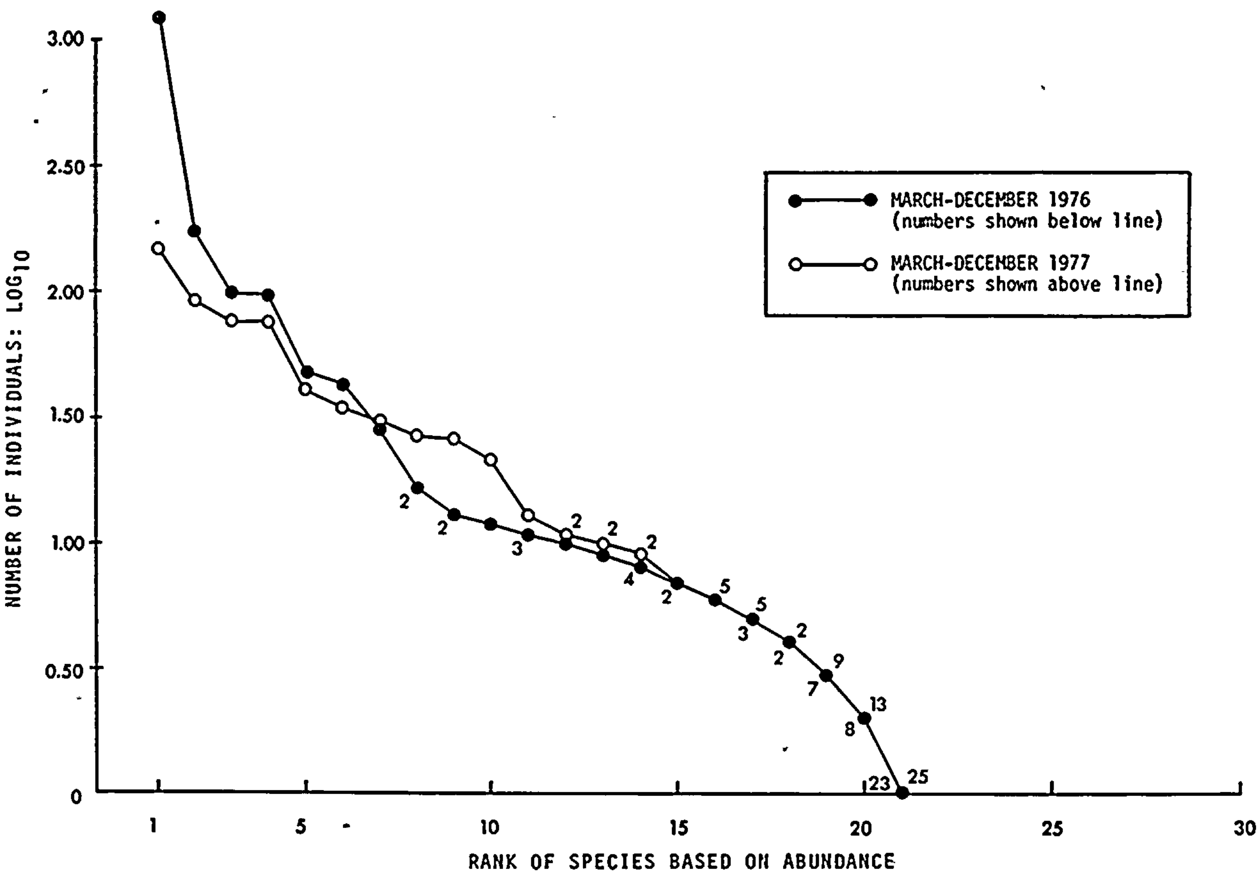


Figure C-27. Dominance-diversity curves for trawl collections at Station 2, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

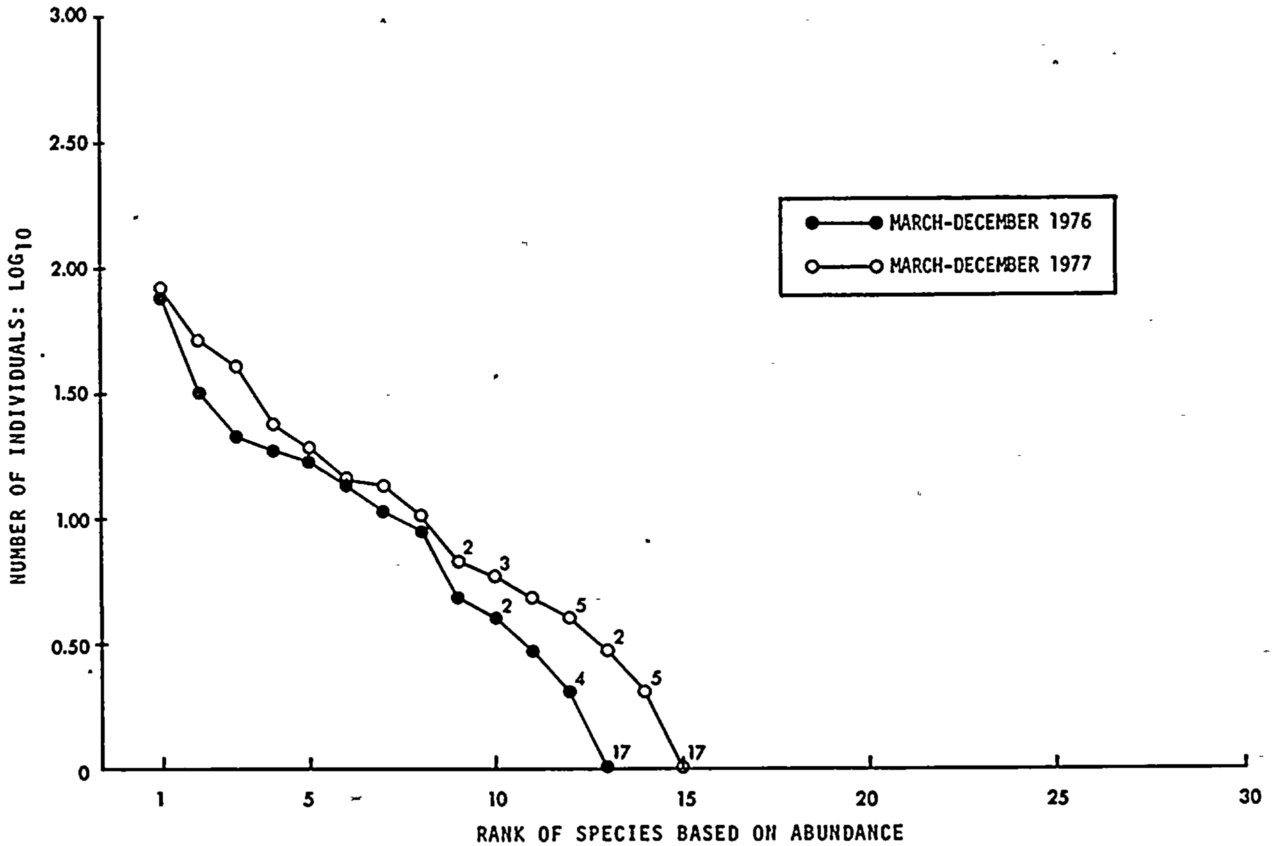


Figure C-28. Dominance-diversity curves for trawl collections at Station 3, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

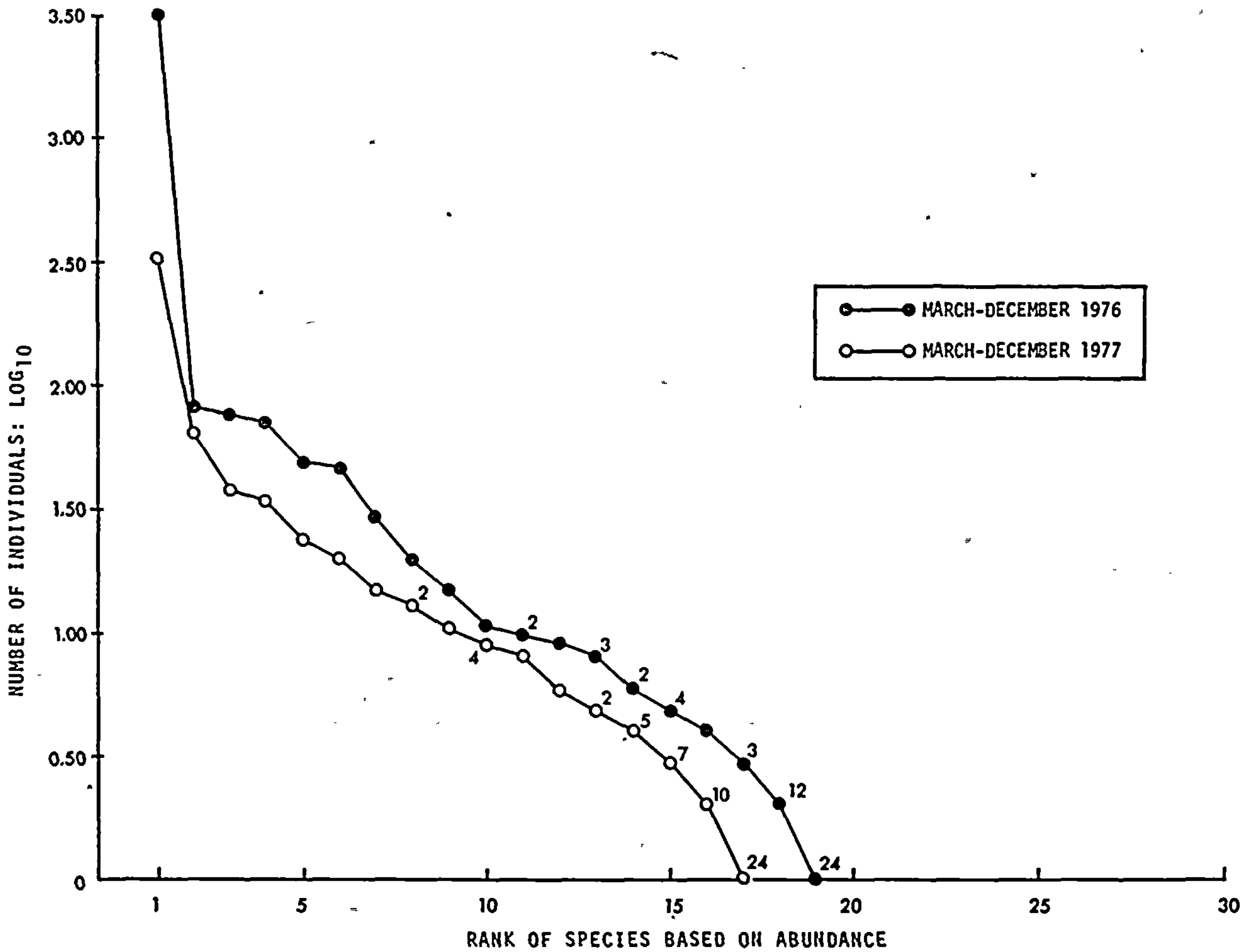


Figure C-29. Dominance-diversity curves for trawl collections at Station 4, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

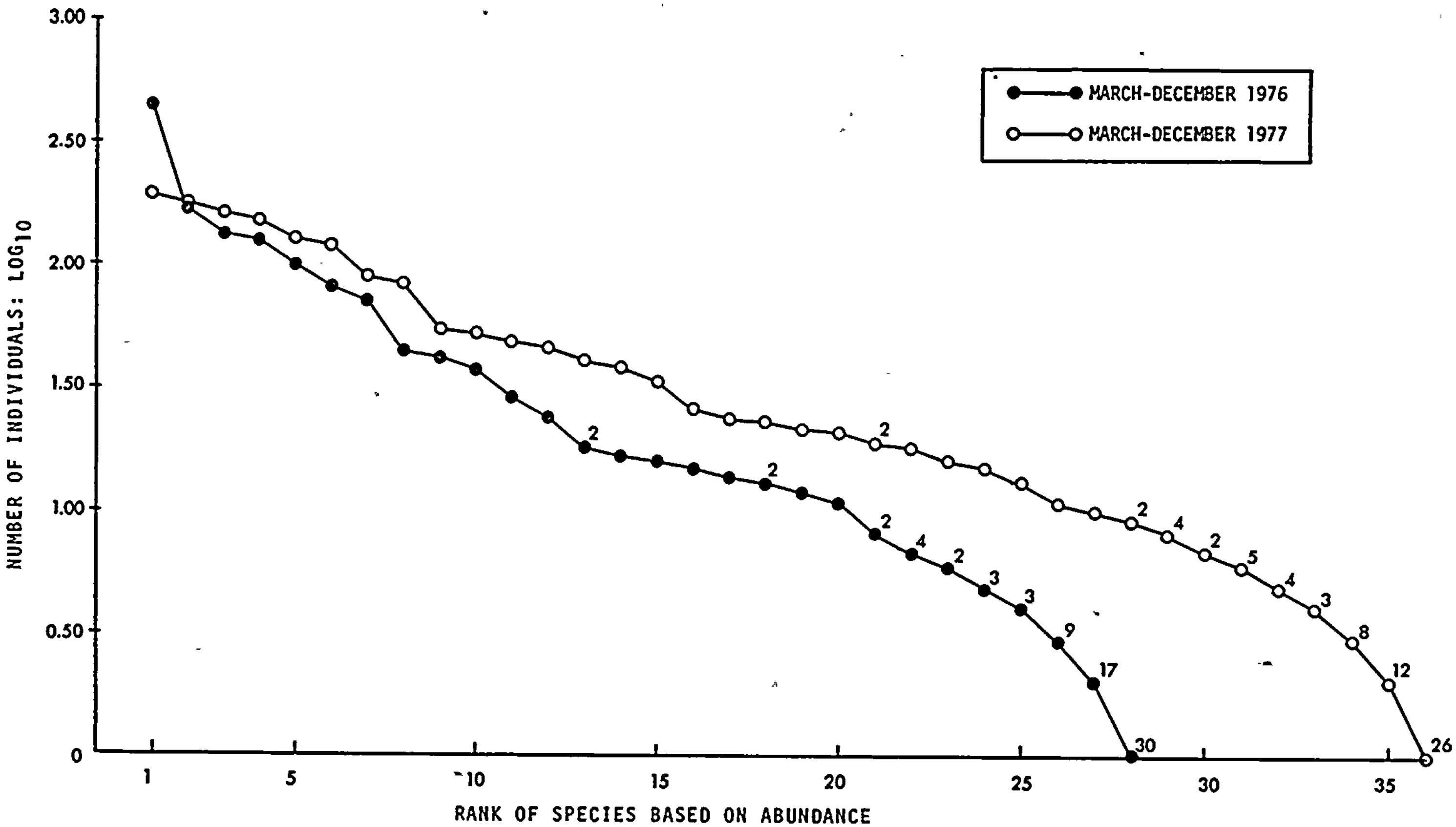


Figure C-30. Dominance-diversity curves for trawl collections at Station 5, St. Lucie Plant, 1976-1977. When a given rank is shared by two or more taxa, the number of taxa sharing the rank is indicated.

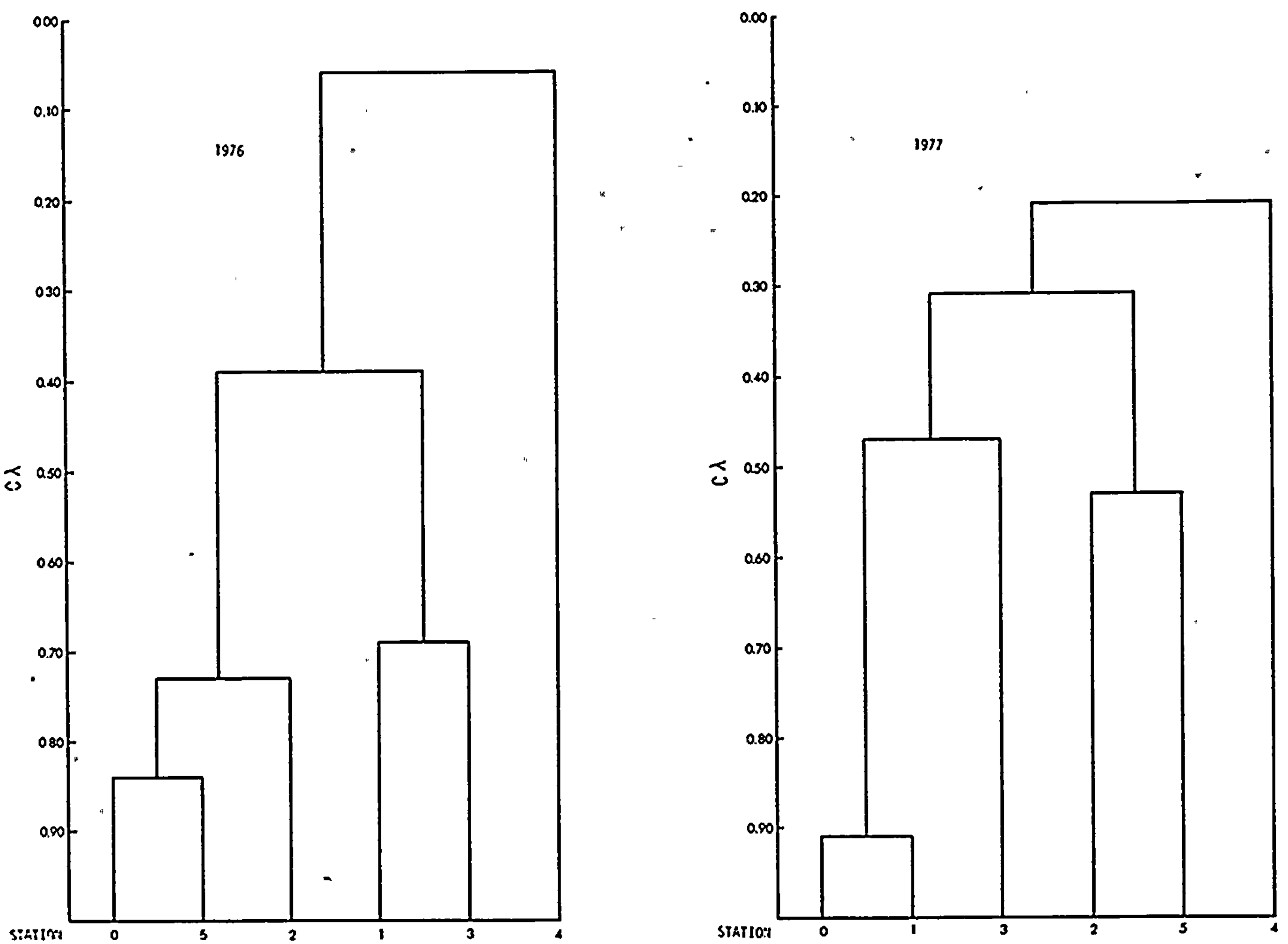


Figure C-31. Dendrogram of similarities (Cλ) between stations for 1976 and 1977 trawl collections. Group-average sorting was used to produce clusters.

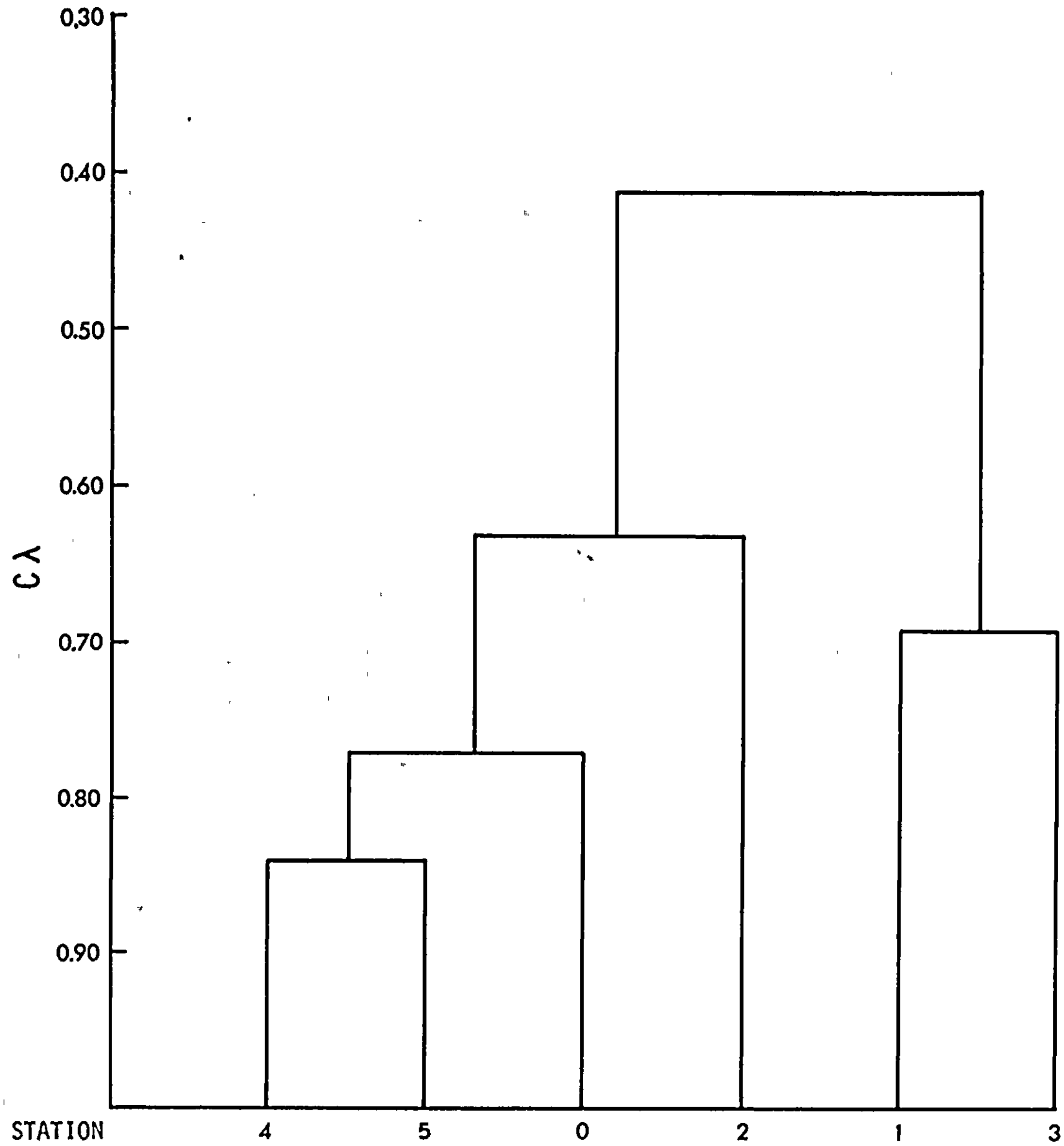


Figure C-32. Dendrogram of similarities (Cλ) between stations for 1976 trawl collections (excluding *Mellita quinquiesperforata*), St. Lucie Plant. Group average sorting was used to produce the observed clusters.

TABLE C-1

SUMMARY OF MACROINVERTEBRATE STUDY METHODS
ST. LUCIE PLANT
1976-1977

Study year	Shipek sample and trawl stations and locations	Shipek sample replicates	Trawl samples	Benthic grab sample preservation
1976	0 - offshore trough 1 - beach terrace 2 - offshore trough 3 - Pierce Shoal 4 - offshore trough 5 - offshore trough	4/Station	One 15-minute tow/station/ month	10% buffered seawater-formalin plus Rose Bengal stain
1977	0 - beach terrace 1 - beach terrace 2 - offshore trough 3 - Pierce Shoal 4 - offshore trough 5 - offshore trough	4/Station; plus 7 at Station 1, and 4 at Station 5 during March 1977	One 15-minute tow/station/ month	Methanol crystals added to sample prior to preservation, then as above.

TABLE C-2

BENTHIC GRAB AND TRAWL STATION COORDINATES
ST. LUCIE PLANT
1976-1977

Station	Depth (m)	Latitude-Longitude
1	7.6	27°21.2' N 80°14.1' W
2	11.3	27°21.4' N 80°13.3' W
3	7.6	27°21.7' N 80°12.4' W
4	11.3	27°20.6' N 80°12.8' W
5	11.3	27°22.9' N 80°14.0' W
0[a]	8.2	27°19.1' N 80°13.2' W

[a] Station 0 was moved about 100 m inshore onto the beach terrace in 1977. This location was more representative of sediments found near the plant discharge's structure.

0

TABLE C-3

BENTHIC GRAB MACROINVERTEBRATE AND STATISTICAL DATA BY STATION AND QUARTER
OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

Parameter	Qtr.	Station and year: 0		1		2		3		4		5		Mean		Mean (excluding Sta. 0)	
		1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
No. of taxa	1	96	56	8	51	94	152	14	33	91	91	125	152	71.3	89.2	66.4	95.8
	2	125	38	18	34	127	143	33	38	111	118	92	155	84.3	87.7	76.2	97.6
	3	147	40	34	35	132	141	45	50	117	118	107	158	97.0	90.2	87.0	100.2
	4	104	21	38	20	101	111	37	27	94	92	110	144	80.7	69.2	76.0	78.8
	Total	260	109	75	99	249	259	84	84	219	203	236	303				
	Mean	118.0	38.7	24.5	34.7	113.5	136.7	32.3	37.0	103.3	104.7	108.5	152.2				
Density (individuals/m²)	1	12042	4483	225	1933	10500	23917	817	858	8817	3817	8275	19425	6779	9072	5743	9990
	2	19292	3100	300	725	18308	14100	1892	2217	9350	9433	14825	17033	10661	7768	8935	8702
	3	14658	950	642	833	24150	14525	3458	6300	22892	12383	11983	17592	12964	8764	12625	10327
	4	10267	575	1058	425	11600	9017	1392	1008	7908	6733	12900	15800	7519	5593	6972	6597
		56259	9108	2225	3916	64558	61559	7559	10383	48967	32366	47983	69850				
		14065	2277	556	979	16140	15390	1890	2596	12242	8091	11996	17463				
Mean number of individuals per sample	1	482±146	179±110	9± 3	77±42	420±163	957±106	33±15	34±12	353±157	153± 17	331± 66	777±440				
	2	772±299	124± 71	12± 8	29± 6	732±432	564± 77	76±53	89±14	374±102	118± 42	593±175	681±188				
	3	586±246	38± 8	26±15	33± 8	966±267	581±218	138±69	252±42	916±181	495±100	479± 59	704±201				
	4	411±112	23± 7	42±11	17± 6	464± 69	361± 49	56± 8	40±13	316±110	269± 45	516±105	632±365				
	Total[a]	6751	1093	267	470	7747	7387	907	1246	5876	3884	5758	8382				

TABLE C-3
(continued)
BENTHIC GRAB MACROINVERTEBRATE AND STATISTICAL DATA BY STATION AND QUARTER
OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

		Station and year												Mean		Mean (excluding Sta. 0)	
		0		1		2		3		4		5					
Parameter	Qtr.	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Biomass (g/m^2)	1	97.303	5.100	2.585	1.610	25.363	16.465	2.083	1.233	3.453	0.795	7.460	17.695	23.041	7.150	8.189	7.560
	2	11.985	0.718	3.815	5.795	8.643	9.178	2.240	16.548	10.558	7.800	5.953	13.335	7.199	8.896	6.242	10.531
	3	2.880	7.060	0.995	13.400	9.273	14.100	1.975	4.105	2.643	19.000	6.498	16.220	4.044	12.314	4.277	13.365
	4	10.910	2.620	1.865	1.120	6.080	7.460	1.765	5.320	3.605	1.090	3.200	227.475	4.586	40.847	3.321	48.493
	Total	123.078	15.498	9.260	21.925	49.359	47.203	8.063	27.206	20.349	28.685	23.110	247.725				
	Mean	30.769	3.875	2.315	5.482	12.340	11.801	2.016	6.802	5.087	7.171	5.777	68.681				
Diversity ($\bar{d}$)	1	4.160	3.502	1.553	4.808	4.218	5.523	3.025	4.345	4.161	5.464	5.111	5.397	3.705	4.840	3.608	5.107
	2	4.400	3.013	3.636	4.480	4.522	5.291	3.184	3.360	4.690	5.108	4.244	5.622	4.113	4.479	4.055	4.772
	3	5.389	4.479	4.423	4.208	4.748	5.228	2.694	2.602	4.842	5.146	5.058	5.510	4.526	4.529	4.353	4.539
	4	5.336	3.650	4.388	3.648	4.511	4.665	4.316	3.585	5.036	4.132	4.284	5.428	4.645	4.185	4.507	4.292
	$\bar{d}$/year	5.561	4.471	5.127	5.612	4.973	5.836	3.838	3.636	5.279	5.505	5.287	6.205				
	Mean	4.821	3.661	3.500	4.286	4.500	5.177	3.305	3.473	4.683	4.963	4.674	5.489				
Equitability (e)	1	0.273	0.291	0.464	0.817	0.291	0.454	0.819	0.907	0.288	0.728	0.413	0.415	0.425	0.602	0.454	0.664
	2	0.249	0.299	0.997	0.970	0.267	0.410	0.391	0.386	0.347	0.437	0.303	0.477	0.426	0.497	0.461	0.536
	3	0.421	0.824	0.931	0.798	0.302	0.398	0.199	0.167	0.365	0.448	0.465	0.433	0.447	0.511	0.452	0.449
	4	0.582	0.864	0.813	0.355	0.334	0.339	0.793	0.641	0.521	0.279	0.261	0.448	0.551	0.488	0.544	0.412
	e/year	0.273	0.301	0.696	0.742	0.188	0.332	0.247	0.214	0.264	0.336	0.248	0.365				
	Mean	0.385	0.569	0.801	0.735	0.299	0.400	0.551	0.525	0.380	0.473	0.361	0.443				

[a]Total number of individuals collected at Station for year.

TABLE C-4

SPEARMAN RANK CORRELATION COEFFICIENTS (r_s)
FOR VARIOUS COMBINATIONS OF NUMBER OF TAXA,
DENSITY AND WATER TEMPERATURE AT FIVE OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

Station	Taxa vs. density	Taxa vs. temperature	Density vs. temperature	Density vs. biomass
1	0.994**	0.000	-0.023	-0.072
2	0.357	0.214	0.238	0.262
3	0.922**	0.838**	0.500	0.095
4	0.819*	0.916**	0.928**	0.386
5	0.714*	-0.048	-0.167	0.714*
All stations combined	0.667*	0.452	0.357	-0.238

* Significant correlation (p=0.05); tabulated r_s=0.643 for n=8.
** Highly significant correlation (p=0.01); tabulated r_s=0.833 for n=8.

TABLE C-5

MANN-WHITNEY U-TEST COMPARISONS OF GRAB REPLICATE DATA
BETWEEN 1976 AND 1977
ST. LUCIE PLANT

Parameter	Station 0	1	2	3	4	5
Grab efficiency	*decrease	*decrease	NS	NS	NS	*decrease
Number of taxa	*decrease	NS	*increase	NS	NS	*increase
Number of individuals	*decrease	NS	NS	NS	NS	*increase

* Significant at p = 0.05. NS = not significant.

TABLE C-6

TOP-RANKED[a] DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES
FROM GRAB SAMPLES AT SIX OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

	Station and year											
	0		1		2		3		4		5	
Taxon	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
NEMERTINA	10	1	1	1	4	2		4	8	3	5	3
ANNELLIDA												
Apoprionospio dayi				8								
Armandia agilis		5										
Axiothella mucosa												7
Brania wellfleetensis								5				
Exogone dispar	2											4
Filogranula sp.	1				1	4	10		1	2	1	1
Goniada littorea		8										
Goniadides carolinae	3			7	6	5			6	4	2	
Hemipodus roseus			8									
Loimia medusa	7											
Macrochaeta sp.						8				10		
Marionina sp.									9	5		
Mediomastus californiensis		2		10	10	9						2
Oligochaeta					7				7		4	
Parapionosyllis longicirrata								10				
Peloscolex sp.C									10			
Polycirrus eximius						10						
Polygordius sp.	9											
Prionospio cristata	6		3		8							
Protodorvillea kefersteini			9							7		

[a] Ranked according to McCloskey (1970) biological index values.

TABLE C-6
(continued)
TOP-RANKED[a] DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES
FROM GRAB SAMPLES AT SIX OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

	Station and year											
	0		1		2		3		4		5	
Taxon	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
ANNELLIDA (continued)												
Protodrilus sp.								7				
Sabellaria vulgaris											8	
Sphaerosyllis sp. A										8		5
Sphaerosyllis sp.					3						6	
Spio pettiboneae		10										
Spirorbis sp.							9		3			
Syllis spongicola												9
Tharyx sp.											9	
Tubificid sp. E										9		
Vermiliopsis sp.	4				5							
MOLLUSCA												
Caecum strigosum	8											
Crasinella duplinana							1	1				
Crasinella lunulata												8
Crepidula fornicata					9	7					7	
Dentalium calamus							5	3				
Glycemeris spectralis							2	2				
Ischnochiton hartmeyeri						6						
Ischnochiton papillosus						3				6		
Olivella floralia				3								
Tellinairis sp.			4	2								

[a] Ranked according to McCloskey (1970) biological index values.

TABLE C-6
(continued)
TOP-RANKED[a] DOMINANT TAXA OF BENTHIC MACROINVERTEBRATES
FROM GRAB SAMPLES AT SIX OFFSHORE STATIONS
ST. LUCIE PLANT
1976-1977

Taxa	Station and year											
	0		1		2		3		4		5	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
CRUSTACEA												
Balanus venustus									5			
Cyclaspis pustula		9		6								
Cyclaspis varians		3		5								
Eurydice littoralis			7				8	8				
Microcerberus sp.A											10	
Oxyurostylis smithi		4										
Protohaustorius sp.A							7	6				
Pseudoplatyishnopus sp.A		6	5									
Synchelidium americana		7		9								
Trichophoxus sp.A							4					
SIPUNCULIDA	5		2	4	2	1			2	1	3	6
ECHINODERMATA												
Amphiodia pulchella												10
Clypeasteroidea							6	9				
Ophiuroidea									4			
CEPHALOCHORDATA												
Branchiostoma caribaeum			6				3					

[a] Ranked according to McCloskey (1970) biological index values.

TABLE C-7

MANN-WHITNEY U-TEST COMPARISONS
BETWEEN 1971-1973[a] AND 1976-1977
GRAB DATA
ST. LUCIE PLANT

Parameter	Station 1	2	3	4	5
Lancelet density (no./m^2)	NS	NS	NS	NS	NS
Arthropod density (no./m^2)	*increase	NS	NS	NS	*increase
Arthropod diversity ($\bar{d}$)	NS	*increase	NS	NS	NS

[a] Futch and Dwinell, 1977; Camp et al., 1977.
* Significant at p=0.05. NS = not significant.

TABLE C-8

COMMERCIALLY IMPORTANT SPECIES OF MACROINVERTEBRATES
CAPTURED BY TRAWL COLLECTIONS
ST. LUCIE PLANT
1976 AND 1977

Species	Year	Number captured	Station
Penaeus duorarum duorarum	1976	43	0, 4 & 5
	1977	57	all stations
Sicyonia brevirostris	1976	21	0, 2, 3 & 5
	1977	35	0, 2, 3, 4 & 5
Penaeus aztecus aztecus	1976	None	
	1977	12	0, 1 & 5
Penaeus brasiliensis	1976	3	0 & 5
	1977	2	0 & 2
Penaeus sp. (juvenile)	1976	11	0 & 1
	1977	15	0 & 1
Callinectes sapidus	1976	2	0 & 1
	1977	2	1
Menippe mercenaria	1976	1	0
	1977	None	

TABLE C-9

DOMINANT TRAWL SPECIES RANKED BY McCLOSKEY'S INDEX[a]
FREQUENCY AND ABUNDANCE
ST. LUCIE PLANT
1976-1977

Station	Species	1976 Rank (BIV)	1976 BIV	1976 Rank (Freq.)	1976 Freq.	1976 Rank (Abun.)	1976 Abun.	1977 Rank (BIV)	1977 BIV	1977 Rank (Freq.)	1977 Freq.	1977 Rank (Abun.)	1977 Abun.
0	*Trachypenaeus constrictus*	1	36.0	2	9	1	493	1	30.0	1	9	1	202
	Crepidula fornicata	2	27.0	2	9	2	464						
	Mellita quinquiesperforata	3	14.5	4	7	3	112	2	14.5	2	6	3	57
	Anomia simplex	3	14.5	3	8	4	87						
	Portunus spinimanus	4	11.0	1	10	5	50						
	Trachypenaeus sp.							3	11.0	5	3	2	80
	Turbo castança							4	8.7	2	6	5	30
	Loligo plei							5	7.0	5	3	4	54
1	*Trachypenaeus constrictus*	1	39.0	1	9	1	403	1	36.5	1	9	1	266
	Sicyonia dorsalis	2	13.7	2	6	2	22						
	Leptochela serratorbita	3	8.1	3	5	3	14	4	10.5	3	5	5	27
	Mellita quinquiesperforata	4	6.0	3	5	3	14						
	Squilla neglecta	5	5.2	5	3	5	6						
	Periclimenes longicaudatus							2	13.4	2	6	3	101
	Loligo plei							3	12.5	4	4	8	20
	Trachypenaeus sp.							5	8.0	6	2	2	110
2	*Crepidula fornicata*	1	40.0	2	8	1	1188	3	14.5	6	3	3	78
	Trachypenaeus constrictus	2	25.5	2	8	3	98	2	17.0	1	8	5	40
	Anomia simplex	3	19.5	4	6	2	171						
	Portunus spinimanus	4	17.0	1	9	4	92	5	10.5	1	8	9	27
	Processa hemphilli	5	7.2	7	3	13	9						
	Periclimenes longicaudatus							1	20.6	2	7	1	147
	Loligo plei							4	11.0	3	6	2	92

TABLE C-9
(continued)
DOMINANT TRAWL SPECIES RANKED BY McCLOSKEY'S INDEX[a]
FREQUENCY AND ABUNDANCE
ST. LUCIE PLANT
1976-1977

Station	Species	1976 Rank (BIV)	1976 BIV	1976 Rank (Freq.)	1976 Freq.	1976 Rank (Abun.)	1976 Abun.	1977 Rank (BIV)	1977 BIV	1977 Rank (Freq.)	1977 Freq.	1977 Rank (Abun.)	1977 Abun.
3	*Trachypenaeus constrictus*	1	39.5	1	9	1	76	1	28.3	1	8	2	52
	Trachypeneopsis mobilispinis	2	16.5	2	6	2	32	2	27.5	1	8	1	83
	Portunus anceps	3	12.5	4	4	3	22						
	Leptochela serratorbita	4	9.0	5	2	8	9	4	9.7	3	3	8	12
	Encope michelini	5	8.5	4	4	10	4						
	Periclimenes longicaudatus							3	11.0	2	4	7	14
	Processa sp.A							5	7.5	2	4	3	40
4	*Mellita quinquiesperforata*	1	39.0	1	9	1	3205	1	20.0	1	6	1	329
	Trachypenaeus constrictus	2	22.0	2	8	2	83	5	9.0	2	5	5	24
	Chaetopleura apiculata	3	17.5	1	9	5	50						
	Portunus spinimanus	4	12.0	3	6	6	47						
	Anomia simplex	5	9.5	5	4	3	76						
	Periclimenes longicaudatus							2	16.5	1	6	2	64
	Turbo castanea							3	13.7	1	6	4	34
	Loligo plei							4	10.2	4	3	3	38
5	*Crepidula fornicata*	1	36.0	2	9	1	449						
	Trachypenaeus constrictus	2	27.0	1	10	2	171						
	Turbo castanea	3	18.0	2	9	3	133	2	18.0	1	10	6	122
	Anomia simplex	4	14.0	4	7	4	126						
	Portunus spinimanus	5	12.0	2	9	6	82						
	Lytechinus variegatus							1	23.0	1	10	5	128
	Chaetopleura apiculata							3	16.0	4	7	7	90
	Arbacia punctulata							4	13.0	2	9	8	86
	Chione grus							5	9.0	6	5	9	56

[a] Biological index value (BIV).

D. PHYTOPLANKTON

INTRODUCTION

The purpose of the phytoplankton study at the St. Lucie Plant was to monitor changes in phytoplankton density, relative abundance, pigment levels and productivity, and to examine the relationships between these factors and power plant operation. Therefore, changes in the phytoplankton component of the ecosystem at the St. Lucie Plant were interpreted with regard to the physicochemical regime which existed at the time samples were collected, as well as to the potential influence of power plant operation.

Phytoplankton consists of passively drifting or weakly swimming algae. Benthic algae are frequently included temporarily in the phytoplankton. Due to limited motility, these microscopic plants are largely at the mercy of waves and currents in aquatic environments.

Excluding those organisms adapted to either very low or very high temperatures, most ogranisms live in the 0 to 45°C (32 to 113°F) temperature range (Raymond, 1963). Major groups of algae vary in temperature tolerance ranges and temperature ranges for optimum growth and reproduction (Patrick, 1969). Drost-Hansen (1969) proposed that certain temperature ranges may exert a profound and sometimes dominating effect on biological activity due to physical changes in the structure of water. Ukeles (1961) reported maximum

temperatures at which normal growth occurred in representative marine algae: Chrysophytes (yellow-brown algae), 24 to 27°C (75 to 81°F); diatoms, 24 to 30°C (75 to 86°F); and green algae, 27 to 35°C (81 to 95°F). No growth was observed in any group at temperatures greater than 39°C (102°F), and return to marginal growth was greatly inhibited.

Because temperature optima and tolerance ranges vary, temperature is an important determinant in the seasonal succession of algal groups and species under natural conditions. Carpenter (1973) noted successional changes (increased dinoflagellates) in brackish-water phytoplankton after incubation in a pool which averaged 5.5°C (9.9°F) higher temperature than a control pool. Briand (1975) found that power plant entrainment reduced species diversity and disrupted phytoplankton community structure due to selective mortality of certain algal groups and enhancement of more tolerant species. Thermal additions to waters from power plants may alter natural seasonal patterns by causing an early onset of succession or even permanent alteration of species composition (Patrick, 1974). Since phytoplankters are primary producers, their abundance and community composition either directly or indirectly influence the quantity and quality of all larger organisms that ultimately depend upon them for food.

Phytoplankton standing crop is determined by the dynamic interaction of physicochemical parameters and by grazing pressure from

primary consumers. Physicochemical factors which may influence the spatial and temporal distribution of phytoplankton are water temperature, light, nutrient availability, salinity, and currents (Whitford, 1960). Because any of these factors may limit phytoplankton productivity or affect community composition and abundance, their relationship to standing crop must be considered when evaluating the impact of power plant operation.

The response of phytoplankton communities to thermal loading is due not only to increased temperature, but to the synergistic effects of various environmental factors associated with heated water. Investigators of this concept include Fisher and Wurster (1973), Grayum (1971), Griffiths (1973), Roberts (1977), and Thomas and Dodson (1974). In general, these authors found that factors such as polychlorinated biphenyls, ionizing radiation, high light intensity, low nutrient levels, and chlorine, in combination with increased temperature, affected phytoplankton more adversely than increased temperature alone. Even when water temperatures are not elevated to the point of causing thermal death, synergistic effects may have a profound effect on phytoplankton productivity, species composition, physiology, etc., leading directly or indirectly to impact at higher trophic levels.

Pertinent past studies concerning the effects of power plant cooling water on phytoplankton populations have been done by Briand

(1975), Eppley et al. (1976), Fox and Moyer (1973), Ricklef (1972), and McKeller (1977). Results of these studies were varied, indicating that power plant effects must be assessed on an individual basis.

The San Onofre Nuclear Generating Station in southern California was chosen by Ricklef (1972) and Eppley et al. (1976) for investigations of effects on plankton. Based on the density and diversity of plankton at affected and control stations, Ricklef found no detrimental plant-related effect on plankton. However, Eppley et al. recorded a 70 to 80% reduction in phytoplankton productivity at the outfall of this plant and concluded that power plant effects on entrained phytoplankton were due primarily to chlorine rather than heat.

Briand (1975) studied the effects of power plant cooling systems on marine phytoplankton at two southern California coastal power plants. Influent water temperatures ranged from 14°C (57°F) in January to 23°C (73°F) in August, and temperature rise in the condensers averaged 9.3°C (16.7°F). This investigator found that average phytoplankton mortality was 41.7% after plant passage. Entrainment reduced species diversity and disrupted phytoplankton community structure due to selective mortality of certain algal groups and enhancement of more tolerant species. Diatoms were killed in greater numbers (45.7%) than dinoflagellates (32.8%).

Fox and Moyer (1973) found that effects of increased water temperature on marine organisms at the Crystal River Power Plant, Florida, were most profound immediately after heat exposure. These investigators found that change in photosynthetic capacity was due to temperature increase and was dependent on the temperature of intake water. A decrease in productivity was observed when intake temperatures were 27°C (81°F) or greater, and as long as temperatures remained above 32°C (90°F), productivity values continued to drop. Increases in productivity were recorded when intake water temperature was 24°C (75°F) and discharge water temperatures did not exceed 32°C (90°F). The time of day samples were collected affected values more than plant effects. In a model simulation of a proposed nuclear unit at the Crystal River site, a maximum summer plume temperature of 98.6°F resulted in a projected 20% decrease in producer biomass (McKeller, 1977). Selection of phytoplankton over benthic producers was indicated. However, McKeller suggested that water exchange in the environment acts as a stabilizing energy which moderates large fluctuations in planktonic populations and tends to stabilize the entire system.

MATERIALS AND METHODS

Phytoplankton Analysis

Phytoplankton samples were collected monthly from surface and bottom levels of the water column at six offshore stations and in the intake canal. Only the surface level was sampled in the discharge

canal for samples taken after November 1976 (Figure D-1). Replicate one-liter whole-water samples were collected at each station with a pump (Figure D-2) designed to minimize damage to the phytoplankters. Each one-liter water sample was preserved in the field with 5% buffered formalin and returned to the laboratory. The preserved samples were allowed to settle for a minimum period of 10 days before concentration. Whole-water samples were used in conjunction with the sedimentation technique for qualitative analyses and quantitative estimates of standing crop.

Microscopic analysis was performed by the Utermöhl (1958) technique with inverted compound microscopes equipped with calibrated ocular micrometers. Identifications and counts were made after the sample concentrates had settled a minimum of four hours in counting chambers. Phytoplankton species were enumerated at appropriate magnification by random field counts (EPA, 1973; APHA, 1971; Littleford et al., 1940) in two identically prepared counting chambers per replicate sample. A minimum of one-half the entire counting chamber was examined to enumerate large and relatively scarce phytoplankters. Statistical analyses (hierarchical design analysis of variance) were used to determine the examined volume of sample concentrate necessary to ensure 90% accuracy in counts at the 95% confidence interval.

All phytoplankters, except some greens and blue-greens, were counted individually. Filamentous green and blue-green algae were measured in 100μ standard lengths with each length representing one counting unit. Colonial forms exclusive of diatoms were counted as each colony representing one counting unit. An average number of individuals per colony was specified where possible. Cells per liter were calculated as N by:

$$N = \frac{\frac{V_s}{V_c} C}{V_i}$$

where: C = count

V_s= volume of sample concentrate (ml)

V_c= determined by multiplying the aliquot volume (ml) by the proportion of the counting chamber which was examined

V_i= initial sample volume (l)

A minimum of two individuals verified both qualitative and quantitative analyses for each group of monthly samples. Analysis of variance was used to determine significant differences between these individuals. If discrepancies were greater than 10% or if significant differences existed between operators at the 95% confidence level, counts were repeated. Qualitative verification of new species was performed on each sample as new species were encountered. All samples were retained in the Applied Biology laboratory as permanent vouchers.

Samples for water chemistry were collected and physical measurements and weather observations were made concurrently with phytoplankton collections at each station. These data were examined as potential factors influencing phytoplankton populations.

Pigment Analysis

Replicate water samples for pigment determinations were collected monthly concurrently with phytoplankton samples. Samples were pumped from specified surface and bottom depths at each station and transported to the laboratory as quickly as possible to minimize chlorophyll degradation.

Samples were processed according to the method of Strickland and Parsons (1972) and recommendations of Unesco (1966). Samples were filtered on the day of collection through Whatman GFC filters. The filters were folded in half with the filtered particulates on the inside, immediately frozen under darkened conditions, and shipped in light-proof containers to the Atlanta laboratory for extraction and analysis.

Frozen filters from replicate samples were extracted by grinding in a 90% aqueous solution of spectrophotometric-grade acetone. The volume of the extract was measured and extinction values were read with 1-cm cuvettes in a spectrophotometer at a slit width of 1.0 nanometer.

Chlorophyll-*a*, -*b*, and -*c* concentrations were determined from readings at 665, 645, and 630 nm, respectively. Carotenoid concentration was determined from extinction at 480 nm. The amount of non-active chlorophyll-*a*, in terms of the quantity of phaeopigments present, was estimated from extinction at 665 nm one minute after acidification with 50% HCl. All extinctions were corrected by subtracting the turbidity reading at 750 nm. Excessive turbidity readings were reduced by additional centrifugation. Results were obtained from the equations of Strickland and Parsons (1972), and chlorophyll and phaeopigment values were expressed as mg/m^3. Carotenoid values were expressed as m-SPU (millispecified pigment unit)/m^3.

RESULTS AND DISCUSSION

Nine divisions/classes of phytoplankton were observed in 1977 collections from the St. Lucie Plant area. These groups were 1) Bacillariophyta (diatoms), 2) Pyrrhophyta (dinoflagellates), 3) Chlorophyta (green algae), 4) Cyanophyta (blue-green algae), 5) Euglenophyta (euglenoids), 6) Cryptophyta, 7) Chrysophyceae (yellow-brown algae and silicoflagellates), 8) Haptophyceae (including coccolithophores), and 9) Prasinophyceae, plus one additional major group, consisting of unidentified phytoflagellates. Illustration of phytoplankton abundance and percentage composition for November and December 1976, not shown in the 1976 St. Lucie Annual Report (ABI, 1977), appears in the appendix of this report (Tables M-1 and M-2; Figures M-1 through M-3).

Phytoplankton Density

Total phytoplankton densities ranged from a low of 86 x 10^3 cells/liter on the bottom at Station 2 in December to 9723 x 10^3 cells/liter on the bottom at Station 1 in November (Tables M-3 through M-14). Average phytoplankton density was greatest in the intake canal and at Station 1, intermediate at Station 0, and lowest in the discharge canal and at Stations 2, 3, 4 and 5. As in the 1976 collections, bottom populations were generally larger than surface populations. Phytoplankton density was greatest in November with maximum densities observed at most stations during this month (Figures D-3 through D-14). Minimum phytoplankton abundance was generally observed in July and August. Phytoplankton populations were lower during the period February through September in 1977 than during a similar period in 1976, and average total phytoplankton density for March through December of each year was lower at all stations during 1977 (Figure D-15). Annual differences in density could not be attributed to plant operational effect.

Whereas phytoplankton density at most stations in 1976 exhibited a bimodal pattern, with high populations in spring and fall, only the canal stations and Station 0 exhibited this pattern in 1977. At offshore Stations 1, 2, 3, 4 and 5, only weak spring pulses or none at all were observed, resulting in a unimodal pattern at these stations. Although the bimodal phytoplankton cycle with peaks in spring and fall is typical of East Coast neritic waters, natural

variation in this pattern is common. Turner and Hopkins (1974), in a study of the Tampa Bay System, found a unimodal seasonal pattern in one year and varied patterns in a second year. Phytoplankton density in the Indian River between Vero Beach and Fort Pierce showed various seasonal fluctuations (Youngbluth et al., 1976). Thus, annual differences in the phytoplankton seasonal cycle between 1976 and 1977 at the St. Lucie Plant were typical of natural variations in seasonal phytoplankton density; alterations attributable to power plant operation were not indicated.

Phytoplankton Community Composition

Diatoms and phytoflagellates were the most abundant phytoplankton groups. Unidentified phytoflagellates were the dominant phytoplankton group in January and February but became secondarily important as diatoms became dominant in March and April, comprising 12 to 18% of the total (Figures D-16 and D-17; Tables M-3 through M-6). Diatoms were also dominant during March and April 1976, but their relative abundance was much higher, 80 to 99% at most stations. During the remainder of 1977, phytoflagellates were dominant from May - August and in October, while diatoms were dominant in September, November and December (Figures D-18 through D-21; Tables M-7 through M-14). Phytoflagellate dominance from May - August was also observed in 1976, excluding June when diatoms were dominant. In general, phytoflagellate relative abundance was higher offshore at the St. Lucie

Plant in 1977 than in 1976, and this trend may represent a plant effect on phytoplankton species composition.

The most important species, in terms of abundance, throughout the sampling interval were diatoms. Again, as in 1976, *Skeletonema costatum* was the most abundant diatom. Diatoms, particularly *Skeletonema costatum*, are the dominant phytoplankters in East Coast neritic waters (Carpenter, 1971; Marshall, 1976; Mulford and Norcross, 1971; Patten et al., 1963; Smayda, 1957; and Turner and Hopkins, 1974). Phytoflagellates sometimes achieve secondary importance (Youngbluth et al., 1976; Smayda, 1957) and, as Smayda noted, may exhibit negative association with diatoms.

Descriptions of synonymous species names and unidentified species appear in Tables M-15 and M-16. As in 1976, several trends in the abundance of particular species were noted (Tables M-17 through M-28). Species observed to fall into one of the following three categories are summarized in Table D-1: 1) those observed only offshore, 2) those more frequently observed offshore, and 3) those observed only in the intake/discharge canals. *Ceratium fusus*, *Cymbella* spp., and *Pleurosigma elongatum* exhibited a general shift in abundance from offshore to the intake/discharge canals within the May-June period. However, only four species, *Rhizosolenia alata* f. *indica*, *R. imbricata*, *R. stolterfothii*, and *Peridinium hirobis* exhibited the same pattern in both 1976 and 1977 collections.

Upper lethal temperatures are known for four diatom species found at St. Lucie: *Chaetoceros laciniosus* [29°C (84°F)], *Ditylum brightwellii* [>30°C (>86.0°F)], *Nitzschia acicularis* [35°C (95°F)], and *Skeletonema costatum* [34-37°C (93.2-98.6°F)] (Crippen,1974; Saks et al., 1974; Hirayama and Hirano, 1970; and Drost-Hansen, 1969). The latter two species occurred frequently enough over the 2-year period to permit conclusions to be drawn. When the respective lethal temperatures of these two species were exceeded in the discharge canal, *N. acicularis* decreased in density between intake and discharge and increased between discharge and Station 1 surface, whereas *S. costatum* showed no pattern in either situation. Temperatures measured at offshore stations never exceeded the lethal range of either species and the densities of both species at Station 1 were generally comparable to those at the other offshore stations.

These results indicated a plant entrainment effect on *N. acicularis*, but no consistent pattern of offshore plant effect was observed for either species. As noted for total phytoplankton, the densities of both species were generally lower at all stations in 1977 than in 1976, but this was not indicative of plant effect.

Statistical Evaluation of Offshore Phytoplankton Data

Analysis of variance for surface offshore stations indicated significant differences in phytoplankton abundance between months but not between stations; the same result was observed in 1976 collections (Table D-2). In 1977 phytoplankton abundance was significantly greater in November than in all other months, and in 1976 abundance was significantly greater in October than in all months except March (Table M-29). For the period March through December of both years, 1977 offshore surface phytoplankton densities were significantly less than those in 1976 (Table D-3). Phytoplankton density for this period was significantly higher at Station 1 than at Stations 3 and 4 (Table M-30). Significant differences in phytoplankton abundance between months were indicated for bottom offshore stations in 1977 as well as in 1976 (Table D-2). As in surface collections, November 1977 and October 1976 showed significantly greater abundance than other months (Table M-31). In 1977, Station 1 bottom was significantly greater than Stations 2 and 3 bottom (Table M-32). Offshore bottom phytoplankton density for the period March through December of both years was significantly less in 1977 than in 1976 (Table D-3). Station 1 phytoplankton abundance for this period was significantly higher than that at Stations 2, 3 and 4. Station 3 abundance was significantly less than that at Stations 0 and 1 (Table M-30).

The foregoing data demonstrate an apparent stimulation of phytoplankton density at Station 1 due to plant operation. This stimulation may be caused by one or both of the following situations: 1) phytoplankton densities were higher in entrained canal water than at Station 1, and 2) phytoplankton reproduction was thermally stimulated in the vicinity of Station 1. However, overall decreases in phytoplankton density at offshore stations in 1977 compared to 1976 may reflect annual variation in phytoplankton density rather than plant effect.

During the period March 1976 through December 1977, offshore surface phytoplankton density showed no significant correlations with chemical or physical parameters; however, offshore bottom phytoplankton density was significantly correlated with phosphate and salinity (Tables D-4 and D-5). Curvilinear multiple regression for the same period indicated that temperature was the most important factor affecting offshore phytoplankton densities. However, temperature explained only 8.6% of the variation in phytoplankton density, whereas nitrite and ammonia explained 18.1% of the variation in phytoplankton density (Table D-6).

Entrainment and Temperature Relationships

Comparison of changes in average phytoplankton density between intake (Station 11) and discharge (Station 12) appears in Table D-7. Average populations in the intake canal ranged from 657 x 10^3 to

4857 x 10^3 cells/liter and in the discharge canal from 339 x 10^3 to 4431 x 10^3 cells/liter. The range in temperature change (ΔT) between intake and discharge was +1.0 to +23.6°F (Table D-7). Whereas in 1976 no relationship between phytoplankton abundance and ΔT was discernible, the sustained plant operational conditions characteristic of 1977 caused decreased phytoplankton density in the discharge canal in 10 of the 12 months studied.

Sustained plant operation may result in alteration of the relative abundance of phytoplankton groups in the discharge canal and at Station 1. Entrainment notably enhanced diatom relative abundance and reduced unidentified phytoflagellate relative abundance in the discharge canal in all months except March, April and November (Tables M-3 through M-14). Proportionately greater phytoflagellate entrainment mortality was largely responsible for this change in relative abundance. During eight months, high or enhanced diatom relative abundance in the discharge canal was associated with a diatom relative abundance that was higher at Station 1 than at Stations 2, 3, 4 and 5. Briand (1975) found that open ocean power plants in California could affect offshore phytoplankton species composition by enhancing certain groups and reducing others. The large volume of offshore water available for exchange in the St. Lucie area tends to stabilize and limit fluctuations in the phytoplankton population. The impact observed at the St. Lucie Power Plant in 1977 is likely limited to the immediate vicinity of the offshore discharge at Station 1.

Significant differences in canal phytoplankton density between months existed for both 1976 and 1977 collections (Table D-8). Phytoplankton densities were significantly higher in November than in all other months of 1977, indicating peak canal populations during this month (Table M-33). However, in 1976 October phytoplankton abundance was significantly higher than that in all other months except August, indicating that peak canal phytoplankton densities occurred earlier in 1976 than in 1977. These differences were attributable mainly to seasonal variation. There was no significant difference between intake and discharge stations in 1976, whereas in 1977 these stations exhibited a significant difference; this change is indicative of a significant plant-related decrease of phytoplankton abundance in the discharge canal. However, for the period March through December of both years, no significant overall difference was observed between stations (Table D-8). Phytoplankton density in the canals was significantly correlated with temperature, nitrate and nitrite during the period March 1976 through December 1977 (Table D-9). Curvilinear multiple regression for the same period indicated that nutrients, particularly phosphate, silica and ammonia, explained most of the variations in canal phytoplankton density (Table D-10).

Pigment Analysis and Primary Productivity

Active chlorophyll-*a* concentration is widely used as an index of phytoplankton standing crop since this pigment is common to all

photosynthetic algae. Chlorophyll-*a* was highly correlated with phytoplankton density at the St. Lucie Plant, further emphasizing the value of this pigment as an indicator of phytoplankton standing crop.

Chlorophyll-*a* values at offshore stations ranged from 0.18 mg/m^3 in July to 6.86 mg/m^3 in November at the surface, and from 0.29 mg/m^3 in June to 11.29 mg/m^3 in November at the bottom (Table M-34). Surface values were slightly lower than bottom values. This trend was observed in 1976 (ABI, 1977) and in the baseline data (Worth and Hollinger, 1977). Chlorophyll-*a* was significantly lower in 1977 than in 1976, although 1977 levels were comparable to baseline data. Chlorophyll-*a* maxima for both surface and bottom at all offshore stations were observed in November (Figure D-22). Maximum chlorophyll-*a* was generally observed in October of 1976 at all stations. These seasonal maxima in October and November of 1976 and 1977, respectively, were significantly greater than those in all other months, and analysis of variance for both years combined indicated significantly greater chlorophyll-*a* in September, October, and November than in other months (Tables D-11, M-35, and M-36). Higher chlorophyll-*a* in these late fall months was also observed during the baseline study. These peaks in chlorophyll-*a* corresponded to periods of higher nutrient levels (nitrate, nitrite, and silica). Stepwise multiple regression indicated that variations in temperature, nitrate, nitrite, and silica were most important in describing changes in active chlorophyll-*a*, accounting for 47% of the variation (Table D-6).

A significant negative correlation between chlorophyll-*a* and salinity was observed at offshore stations (Tables D-4 and D-5). This negative relationship may reflect the influx into the sampling area of low-salinity estuarine water high in chlorophyll-*a* at Stations 1, 2 and 5, as observed during the baseline study. Conversely, intrusion of oceanic water high in salinity and low in phytoplankton standing crop could also account for a negative relationship between chlorophyll-*a* and salinity.

Interstation comparisons between surface samples and between bottom samples indicated significantly higher surface chlorophyll-*a* at Station 1 than at Stations 3 and 4 and significantly higher bottom chlorophyll-*a* at Station 0 than at Station 3 (Tables D-11 and M-37). Significant interstation differences were not observed in 1976; however, when data from both 1976 and 1977 were combined, Station 1 was greater than Stations 3, 4 and 5 and Station 0 was greater than Station 3 at the surface. At the bottom Station 0 was greater than Stations 2, 3 and 4 and Station 1 was greater than Station 3 (Tables D-12 and M-38). Clearly, phytoplankton standing crop is not impoverished near the discharge. Chlorophyll-*a* at Station 1 is either similar to or greater than chlorophyll-*a* at other offshore stations. This may be the result of either 1) influx of estuarine water high in chlorophyll-*a*, 2) local thermal stimulation of productivity resulting in high phytoplankton standing crop, 3) enrichment of the area around the offshore discharge from high chlorophyll-*a* levels in the intake canal, or 4) any combination of these three factors.

Chlorophyll-*a* was generally higher in the intake canal than at offshore stations. Average chlorophyll-*a* was less in the discharge canal (Station 12) than in the intake canal (Station 11) during both 1976 and 1977 (Figure D-23), although these differences were not significant. Chlorophyll-*a* in the canals exhibited seasonal and annual trends similar to those observed offshore (Tables D-12 and M-39). However, the fall maxima in the canals in 1976 and 1977 were not as pronounced with respect to other months as they were offshore. The significant negative relationship with salinity observed offshore was evident in the canals (Table D-9). A weak negative correlation with temperature was observed; however, nutrients were most important in accounting for changes in chlorophyll-*a* (Table D-10). Although a reduction in average chlorophyll-*a* due to plant entrainment was evident, this reduction was not great enough to reduce the higher chlorophyll-*a* levels in the canals below those generally observed offshore. Thus, water high in chlorophyll-*a* is discharged at Station 1 and may contribute substantially to the high chlorophyll-*a* observed in the surface samples at this station.

Phaeopigments are degradation products of chlorophyll and are thus an important indicator of phytoplankton destruction or normal algal cell death. As observed in 1976, phaeopigment levels offshore were greater on the bottom than on the surface (Figure D-24). A comparison of surface stations for both years indicated significantly higher phaeopigment at Station 1 than at any other station (Tables D-13

and M-40). For the 1977 data, stations were not significantly different at the surface, and phaeopigment levels on the bottom were significantly greater at Station 0 than at Station 3 (Table M-41). Significant monthly differences in phaeopigment reflected the seasonal variations observed for chlorophyll-*a* (Tables M-42 and M-43). These findings indicated that high phaeopigment levels were most closely associated with high chlorophyll-*a* and were not indicative of a negative impact on phytoplankton standing crop in the offshore area.

Average phaeopigment was slightly higher in the discharge canal during both 1976 and 1977. This is indicative of chlorophyll breakdown in the discharge canal. However, significant differences between stations or between months were not observed.

Results of carotenoid and chlorophyll-*b* and -*c* analyses appear in Table M-44. Carotenoids are accessory photosynthetic pigments found in a large number of algal classes. Examination of the offshore variation in this widespread pigment yielded results which were essentially identical to those obtained from an examination of chlorophyll-*a* data (Tables D-4, D-5, D-6, D-14 and M-45 through M-48).

Chlorophyll-*c* is a principal photosynthetic pigment found in diatoms, chrysophytes, cryptophytes, prasinophytes, and haptophytes, while chlorophyll-*b* is a principal pigment in green algae and euglenoids. These two pigments were examined in an attempt to evaluate

possible selective impact on either of these two algal assemblages. Members of the chlorophyll-*c* group make up a significant percentage of the phytoplankton in the offshore area at the St. Lucie Plant and are therefore present during much or all of the year. Because of the widespread occurrence and abundance of the chlorophyll-*c* bearing group, patterns in interstation, seasonal, and annual variation, as well as relationships to physical and chemical parameters, generally reflected the findings observed for chlorophyll-*a* and carotenoid pigments: seasonal maxima in late fall, greater pigment levels in 1976, and higher bottom levels, with Station 1 greatest on the surface and Station 0 greatest on the bottom (Tables D-4, D-5, D-6, D-15 and M-49 through M-52).

Chlorophyll-*b* exhibited no significant interstation differences at the surface. At bottom stations for both years combined, Station 0 was significantly greater than Station 4 (Tables D-16 and M-53). Seasonally, chlorophyll-*b* was generally greater in August through November than in March through July (Tables M-54 and M-55).

Gross primary productivity was calculated from active chlorophyll-*a* and light data using the total curve of Ryther and Yentsch (1956) for photosynthetic rate. An assimilation rate of 3.7 g carbon/hr/g chlorophyll was used. Solar insolation data for the site were not available for November and December 1977, so insolation values used in calculations were based on the average daily solar radiation for November and December 1976.

Productivity ranged from 0.10 to 0.70 g C/m^2/day (Table M-56). Results for November and December 1976 productivity calculations appear in Table M-57. As observed for pigments, productivity was less in 1977 than in 1976 (Figure D-25). Average productivity was lowest at Stations 1 and 3 and highest at Station 5. However, average productivity had a range of only 0.23 to 0.37 g C/m^2/day, and no significant differences between stations were evident. Productivity was significantly higher in September than in May (Tables D-17 and M-58). Minimum productivity was also observed during May in 1976. As in 1976, this low productivity corresponded to the period of lowest chlorophyll-*a* and lower phytoplankton density. Maximum productivity was observed in September, but it should be noted that productivity for November, a period of maximum chlorophyll-*a* and phytoplankton density, could not be calculated because of zero light transmittance at bottom stations.

SUMMARY

Phytoplankton abundance and chlorophyll-*a* (an index of phytoplankton standing crop) exhibited a unimodal seasonal pattern at offshore stations in 1977. Both were significantly higher in November than in any other month. Seasonal maxima in 1976 were observed in October at offshore stations. Phytoplankton abundance and chlorophyll-*a* were greater on the bottom than at the surface during both years. Patterns in seasonal abundance and depth distribution of phytoplankton density and chlorophyll-*a* were similar to those

observed in 1976 and did not indicate significant power plant influence. Both phytoplankton and chlorophyll-*a* abundance were less in 1977 than in 1976; however, these differences between years were attributable to normal seasonal variations.

The most important components of the phytoplankton in 1977 were diatoms and unidentified phytoflagellates. Diatoms were also most important in 1976, and the diatom *Skeletonema costatum* was the most abundant phytoplankter during both years. However, during nine months in 1977, diatom relative abundance was enhanced and phytoflagellate relative abundance was reduced in the discharge canal and at the offshore station closest to the discharge (Station 1) as a result of phytoflagellate entrainment mortality.

Significant reductions in total phytoplankton density, decreased chlorophyll-*a*, and increased phaeopigment in the discharge canal were indicative of phytoplankton destruction. However, phytoplankton density and chlorophyll-*a* were generally higher in the intake canal than offshore.

Standing crop at Station 1 was not significantly reduced and was possibly enhanced due to thermal stimulation. Phytoplankton abundance was greater at Station 1 (closest to the offshore discharge) than at the other offshore stations. Density differences at Station 1 may be

attributable to plant effect. Interstation differences in relative abundance between intake and discharge and between Station 1 and the other offshore stations (2-5) were attributable to plant effect. Chlorophyll-*a* and other pigments in general at Station 1 (surface) and at the control Station 0 (bottom) were either similar to or significantly greater than those at other offshore stations.

Gross primary productivity was lowest at Station 1 and the station farthest from shore (Station 3). Lower productivity at Station 1 was also observed in 1976. Minimum productivity in both years corresponded to the period of lowest chlorophyll-*a* and lower phytoplankton density.

Plant effects on standing crop and relative abundance were limited to the discharge canal and Station 1. These effects were ameliorated offshore by the mixing of large volumes of offshore water.

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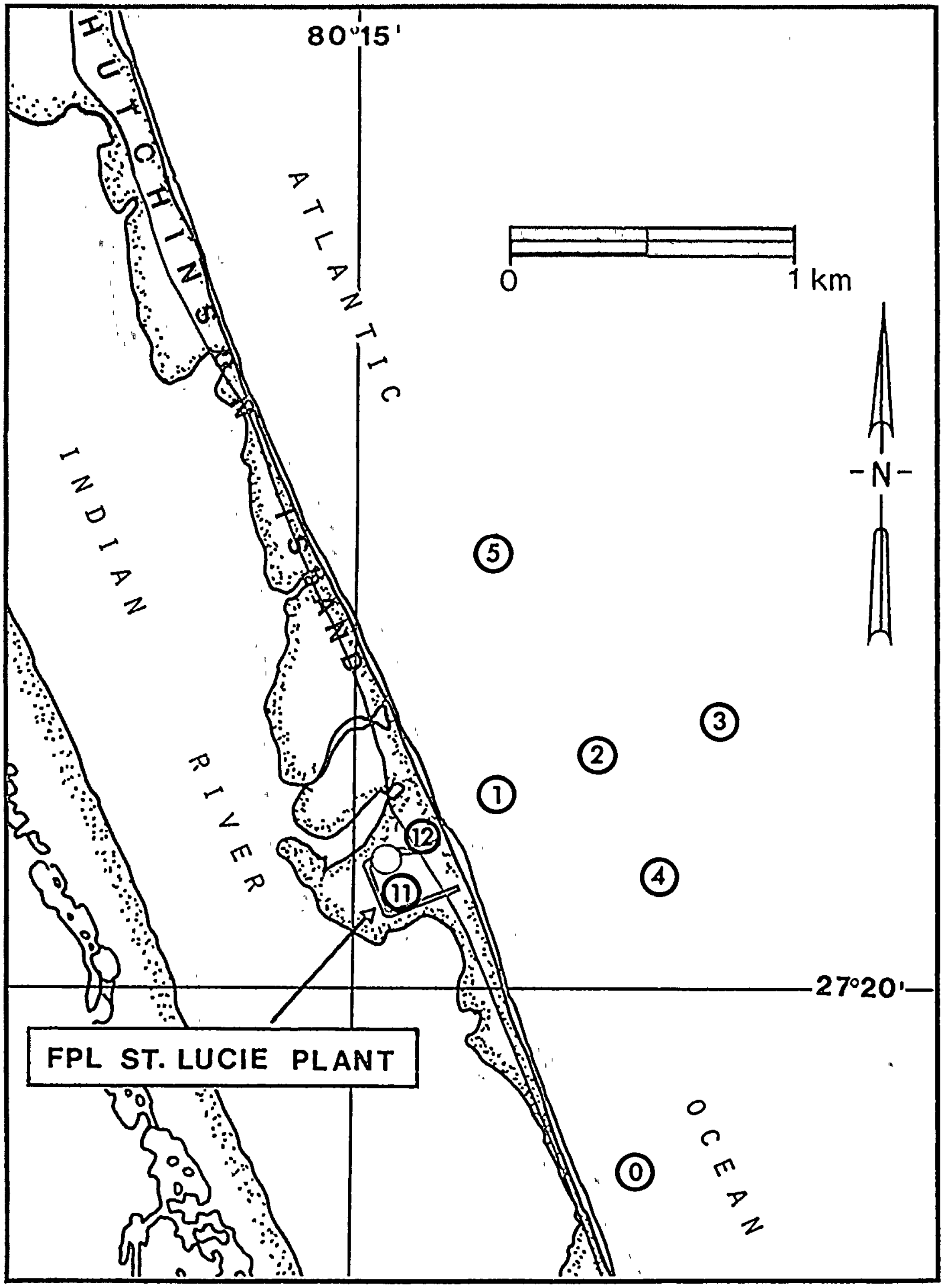


Figure D-1. Locations of phytoplankton sampling stations, 1977.

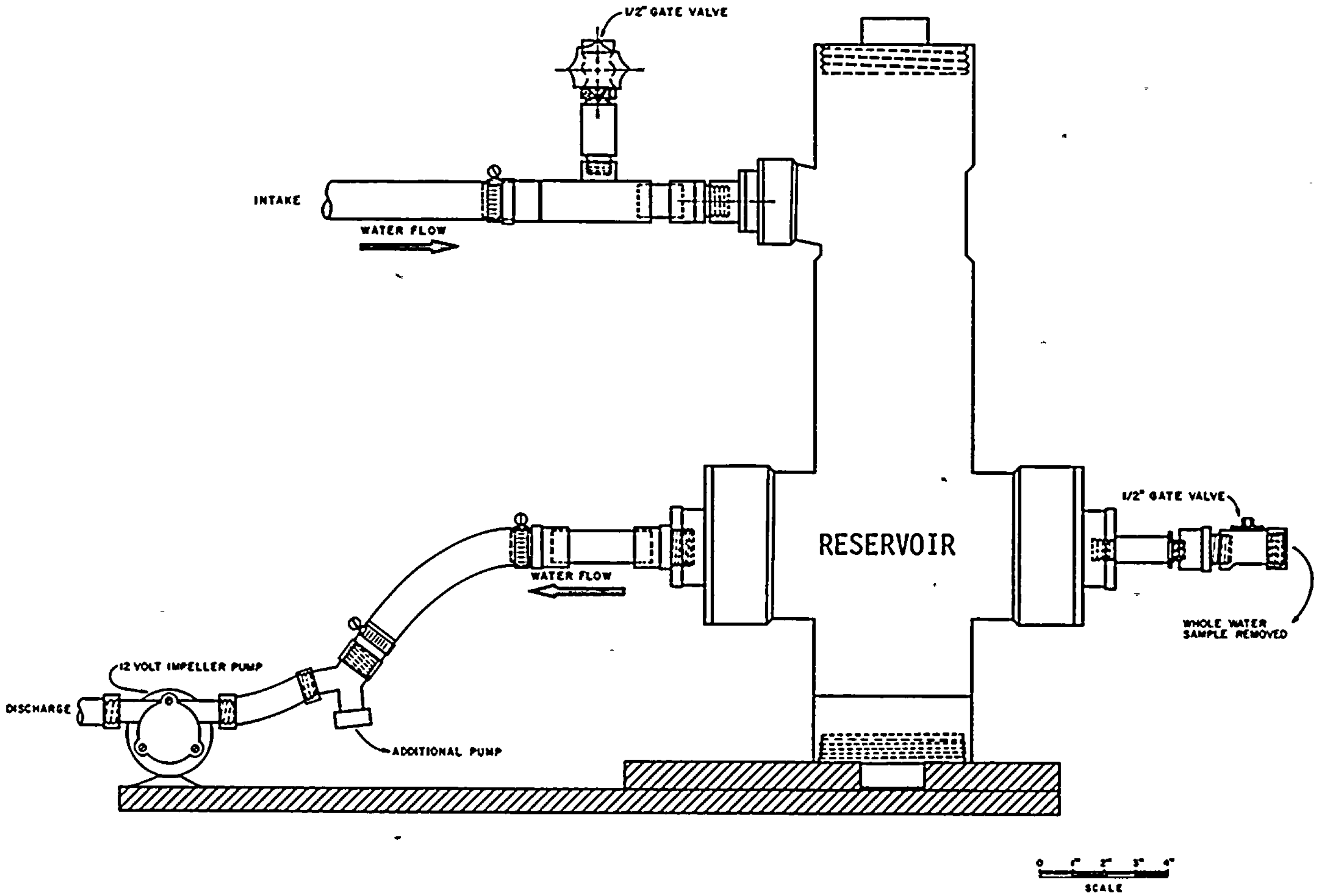


Figure D-2. Pump design for whole water sample collections at the St. Lucie Plant.

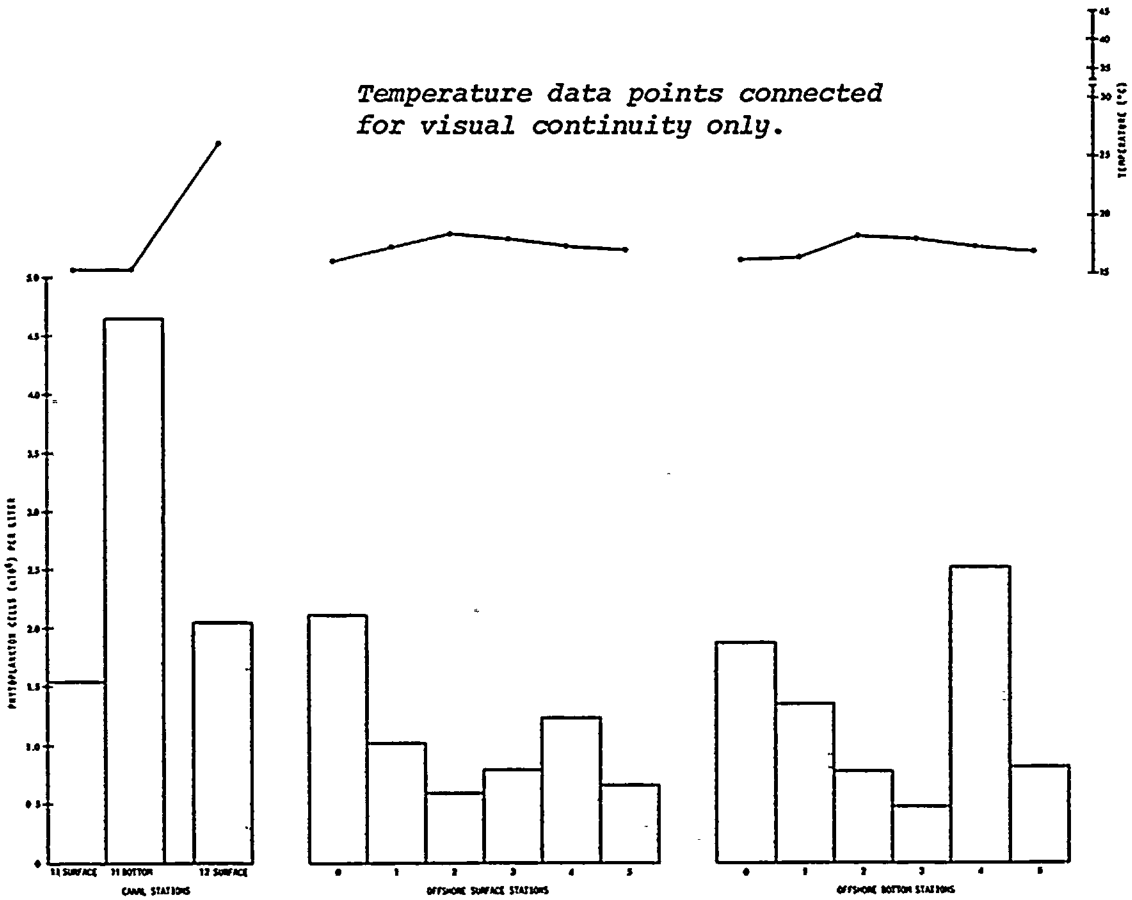


Figure D-3. Phytoplankton density and water temperature, St. Lucie Plant, 25 January 1977.

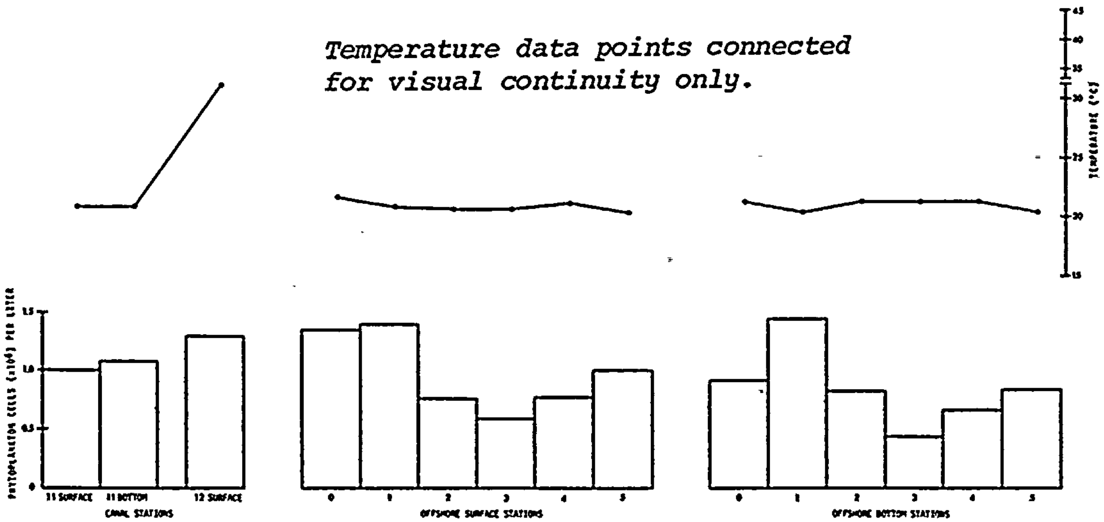


Figure D-4. Phytoplankton density and water temperature, St. Lucie Plant, 15 February 1977.

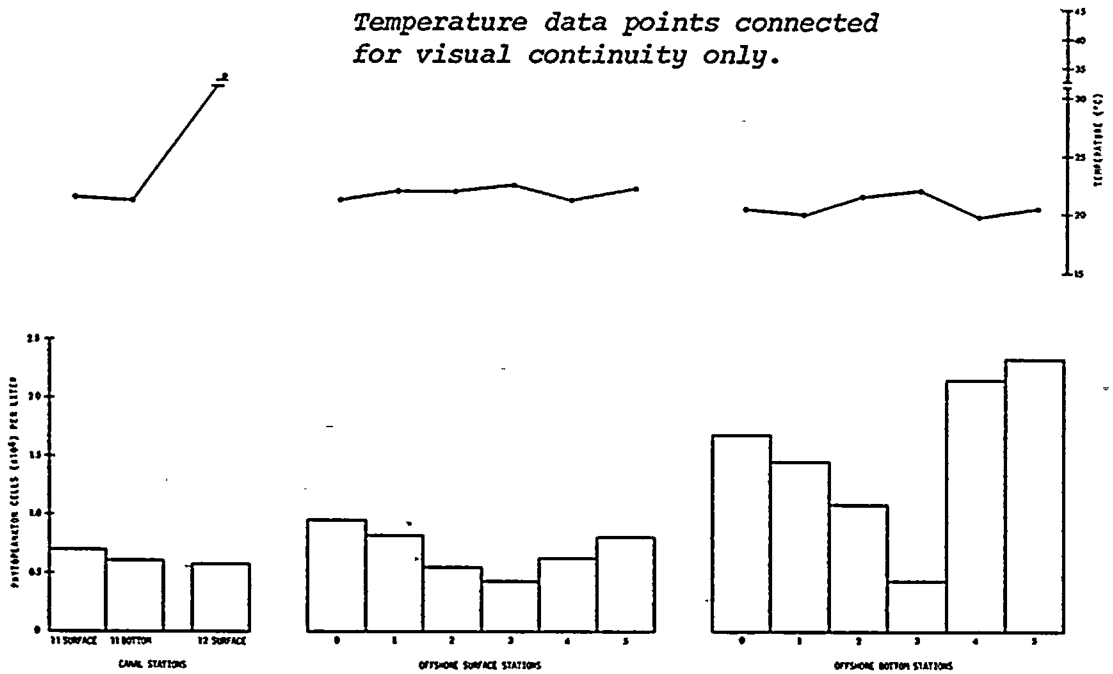


Figure D-5. Phytoplankton density and water temperature,
St. Lucie Plant, 11 March 1977.

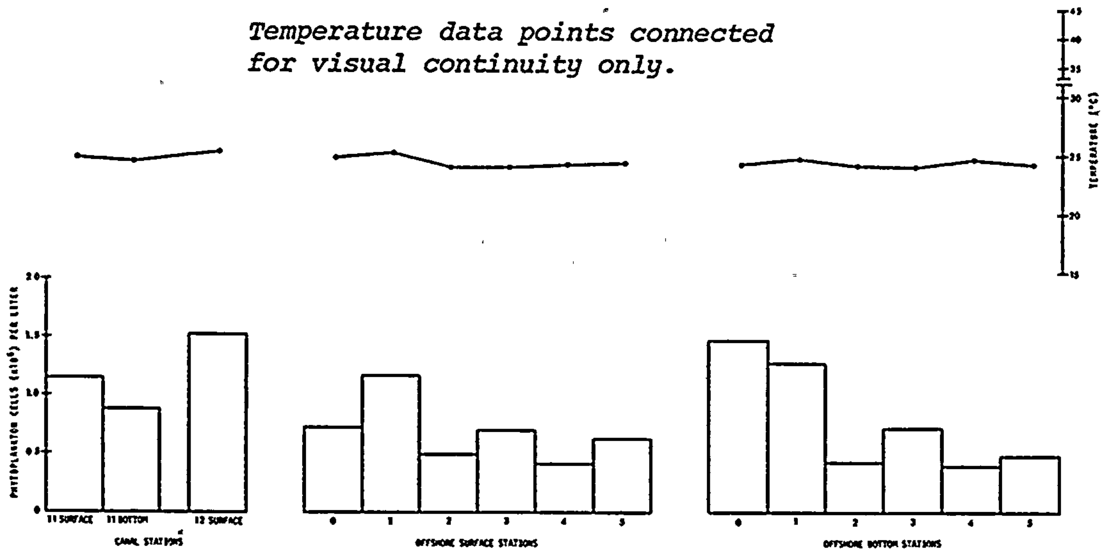


Figure D-6. Phytoplankton density and water temperature, St. Lucie Plant, 19 April 1977.

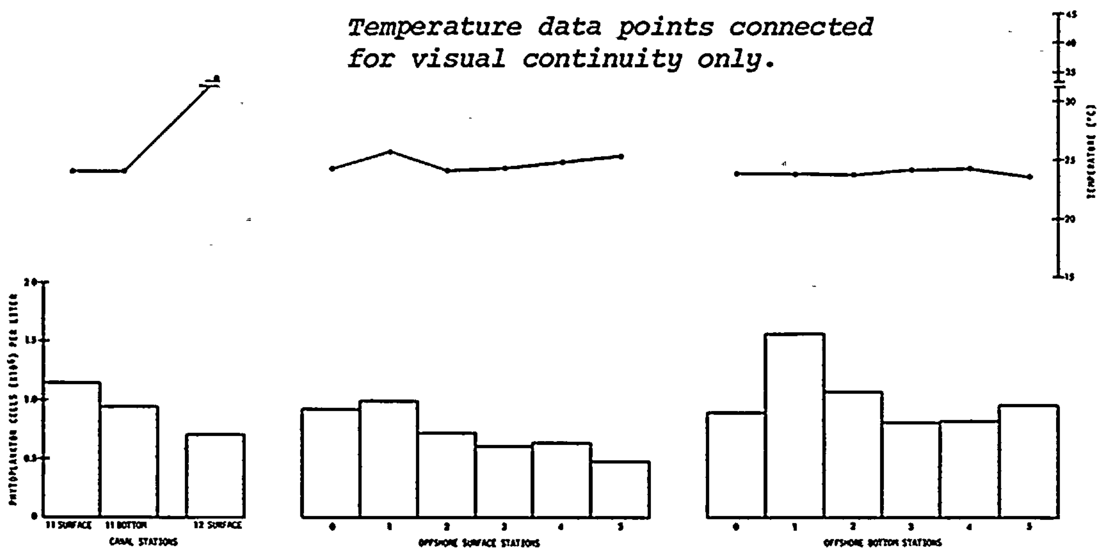


Figure D-7. Phytoplankton density and water temperature, St. Lucie Plant, 10 May 1977.

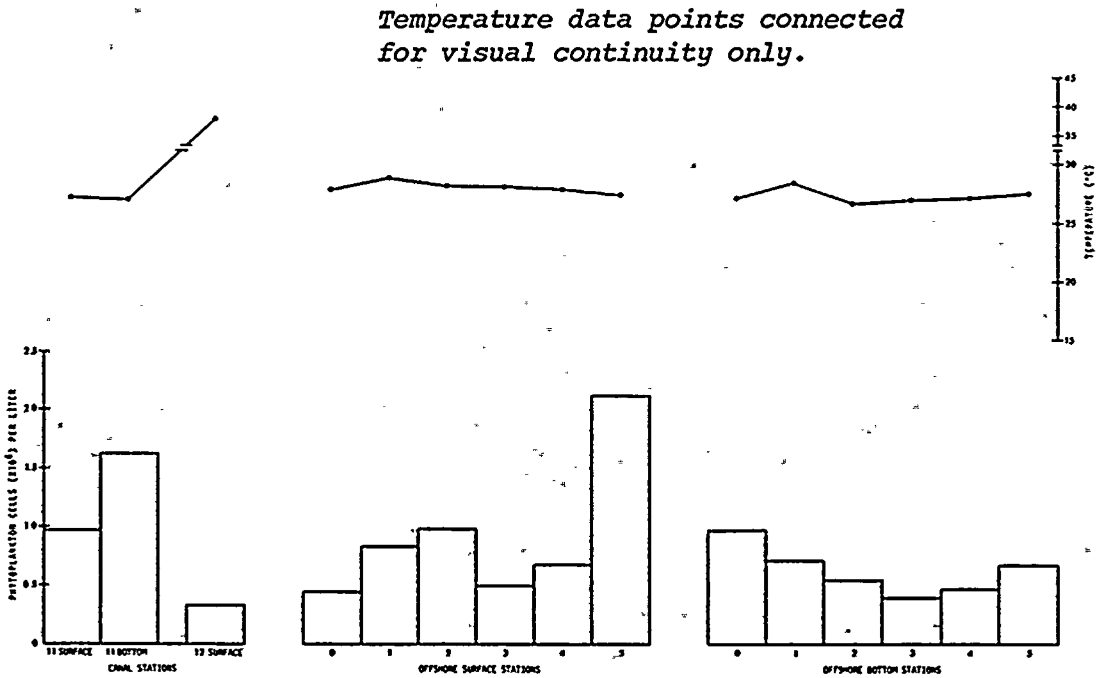


Figure D-8. Phytoplankton density and water temperature, St. Lucie Plant, 14 June 1977.

Temperature data points connected for visual continuity only.

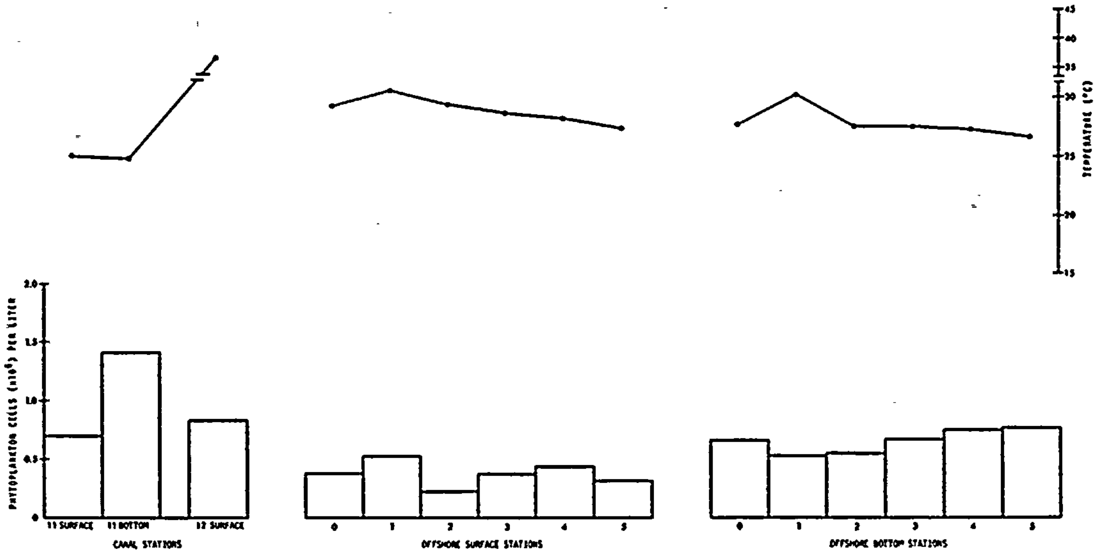


Figure D-9. Phytoplankton density and water temperature, St. Lucie Plant, 12 July 1977.

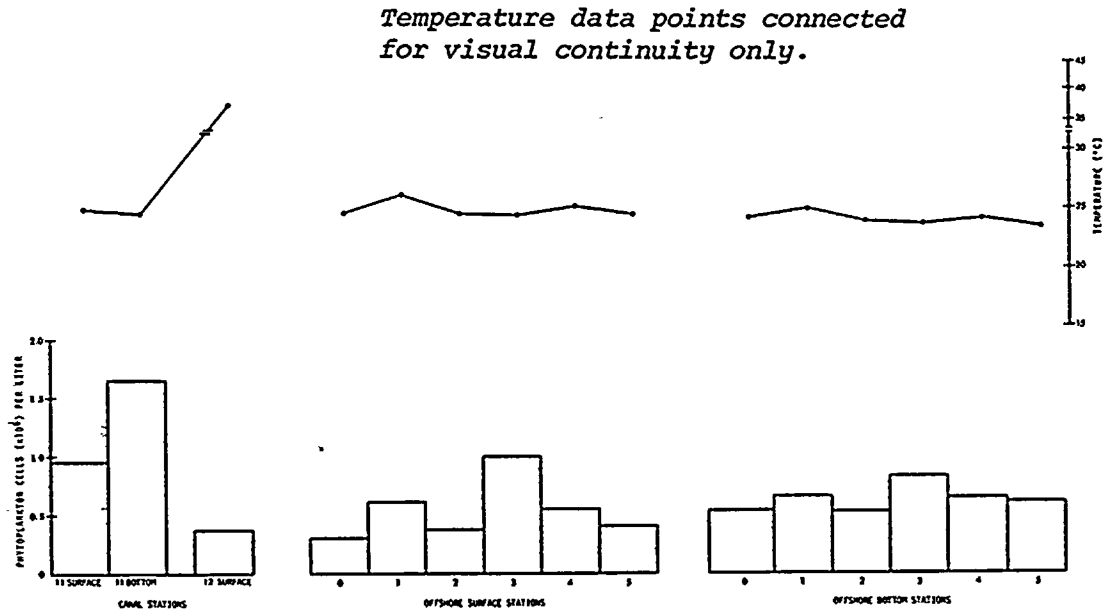


Figure D-10. Phytoplankton density and water temperature, St. Lucie Plant, 23 August 1977.

Temperature data points connected for visual continuity only.

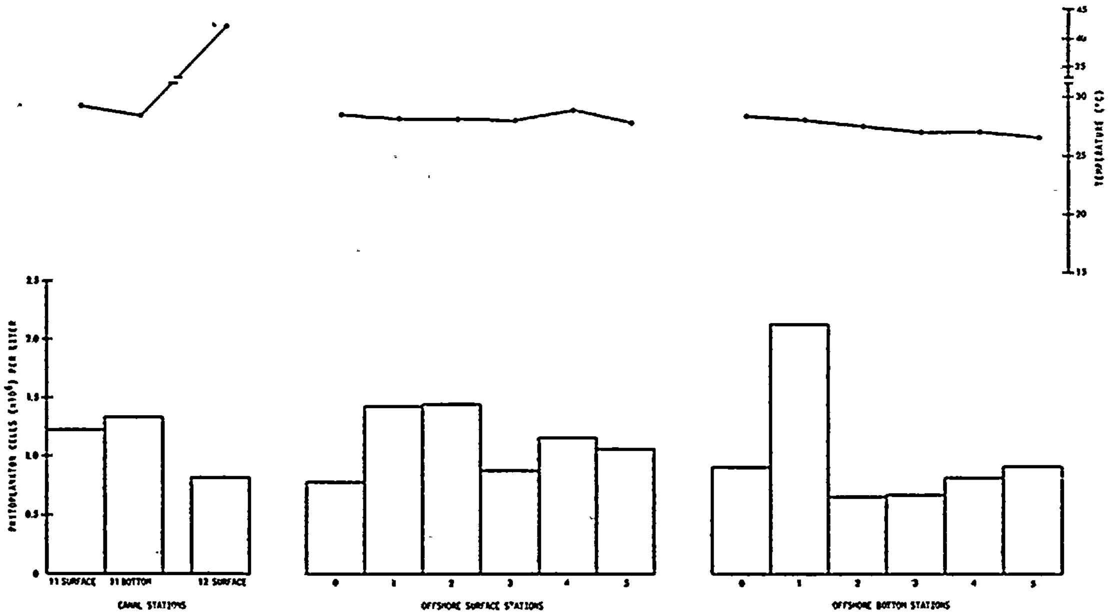


Figure D-11. Phytoplankton density and water temperature, St. Lucie Plant, 13 September 1977.

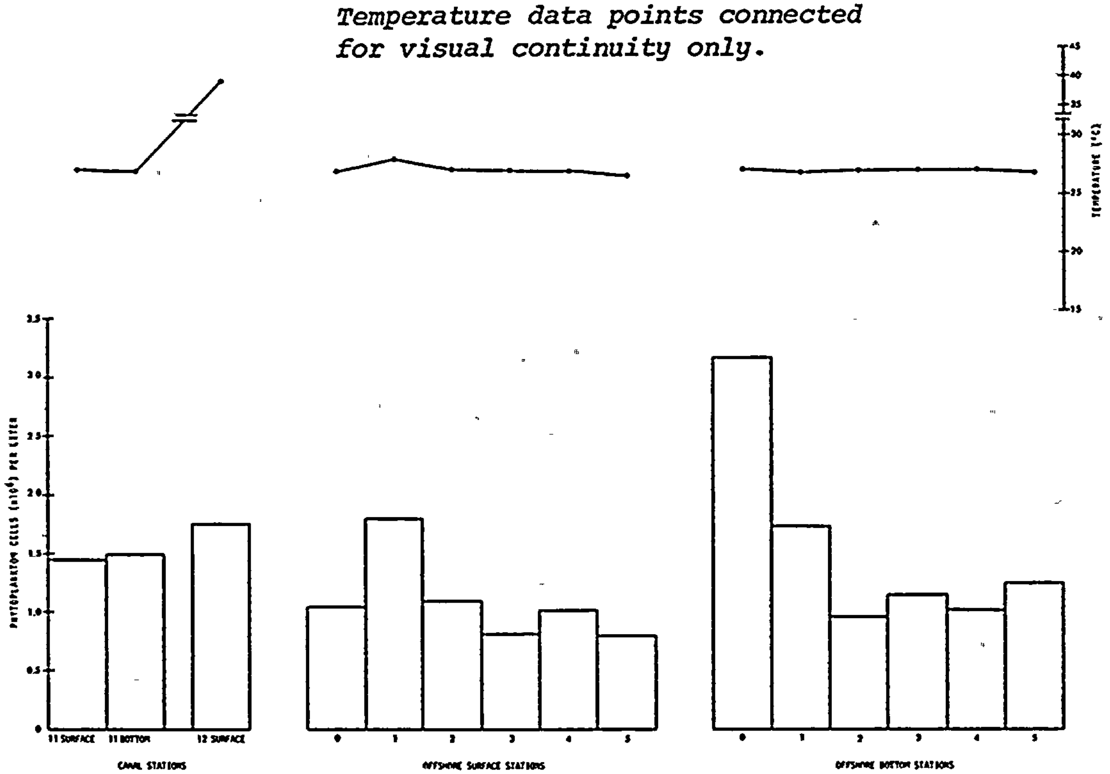


Figure D-12. Phytoplankton density and water temperature,
St. Lucie Plant, 11 October 1977.

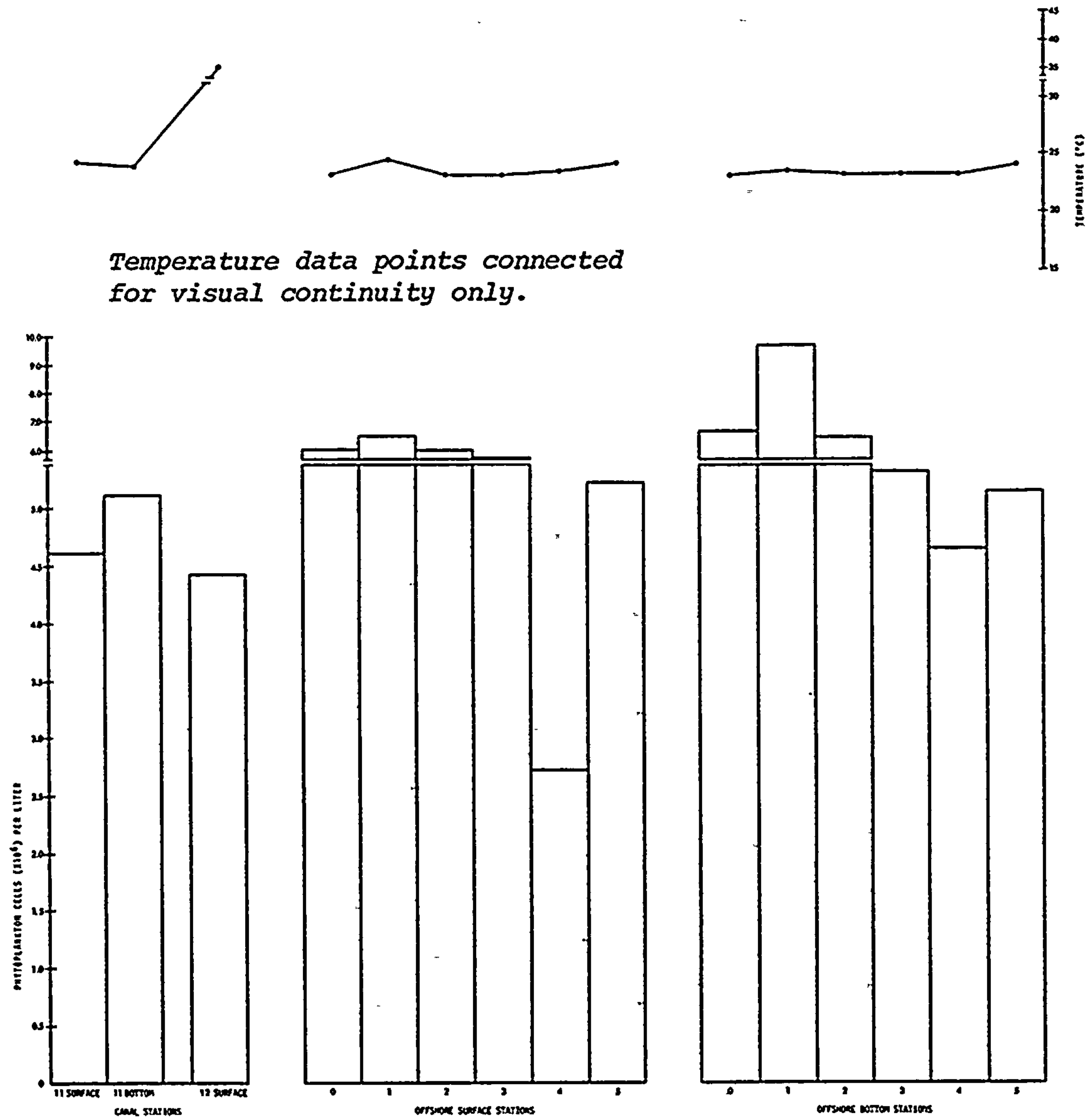


Figure D-13. Phytoplankton density and water temperature, St. Lucie Plant, 2 November 1977.

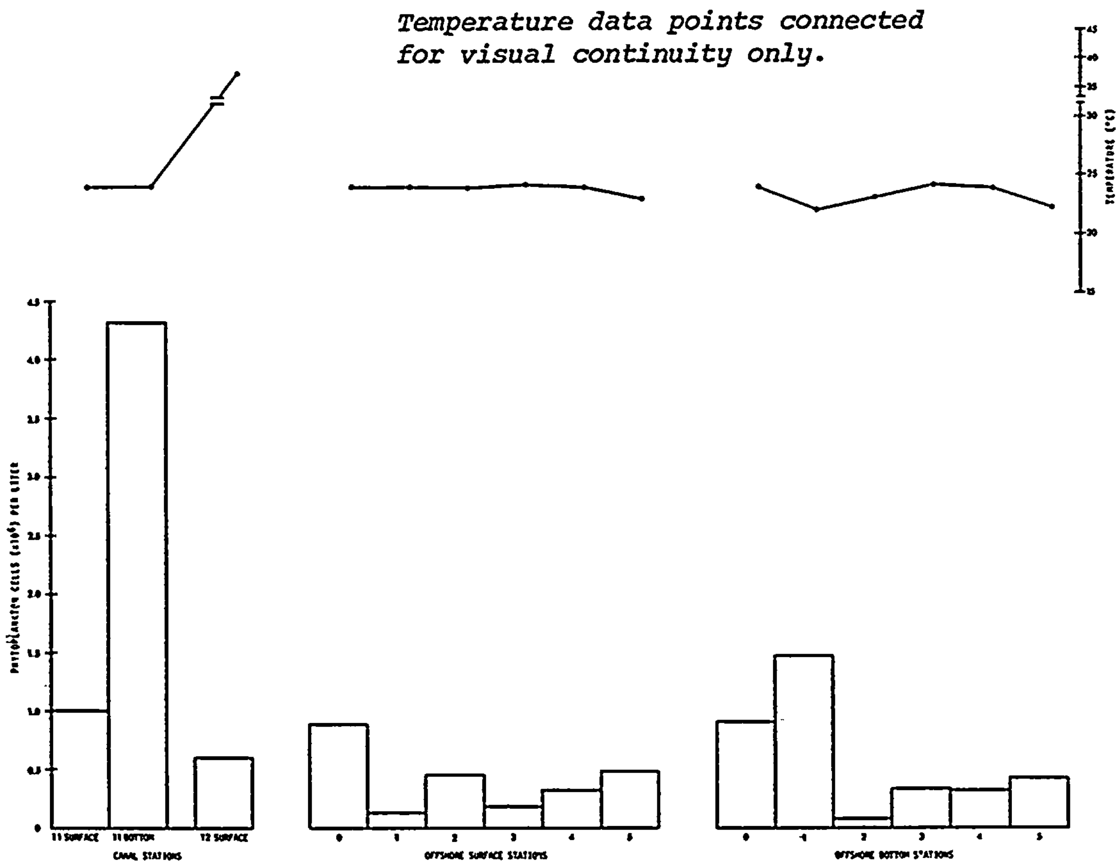


Figure D-14. Phytoplankton density and water temperature, St. Lucie Plant, 1 December 1977.

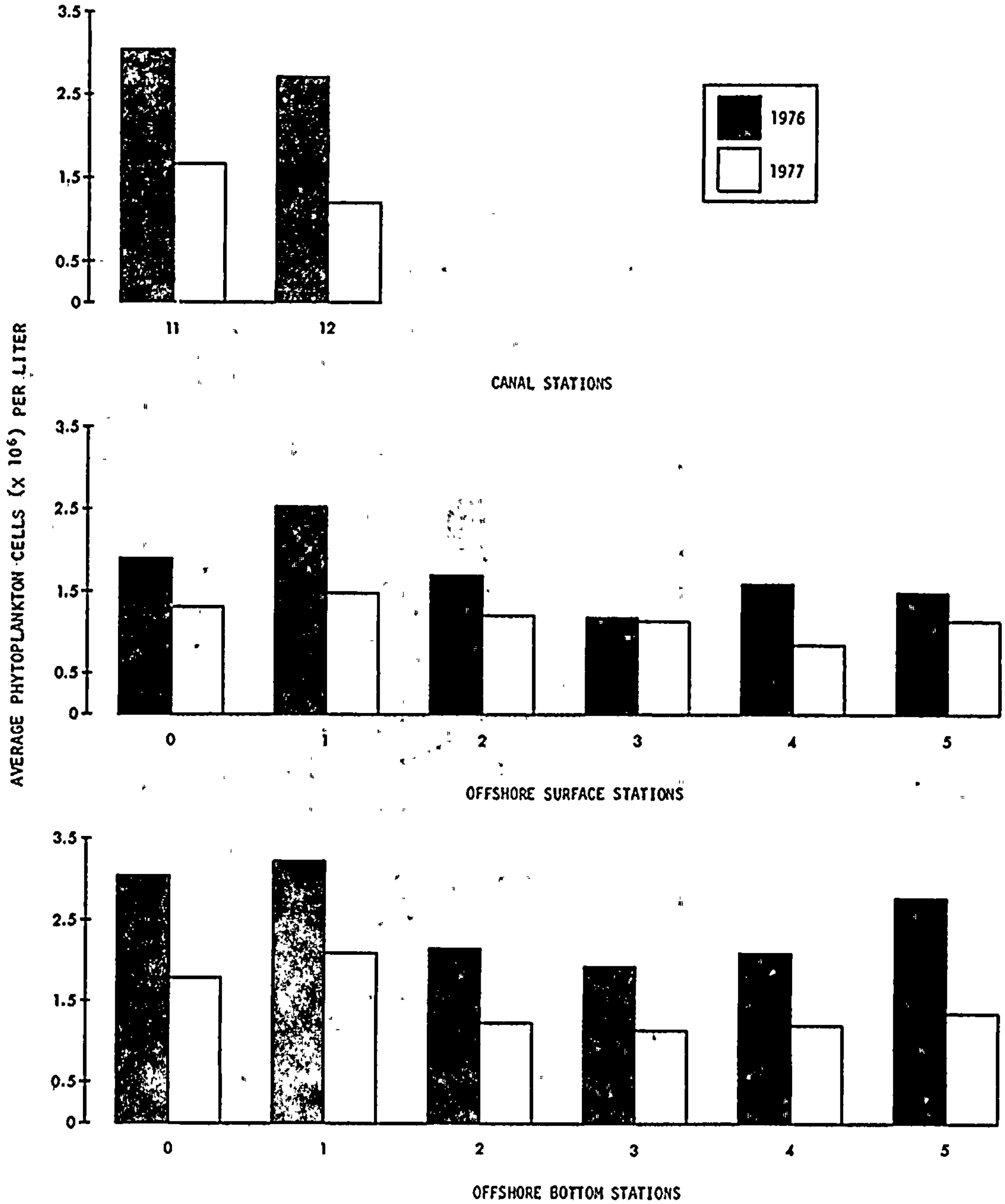
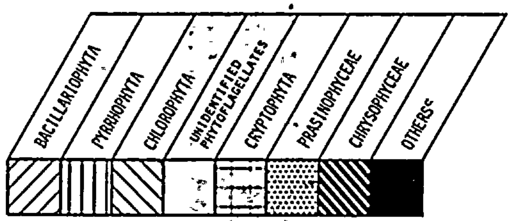


Figure D-15. Comparison of average total phytoplankton density, St. Lucie Plant, March-December 1976 and 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

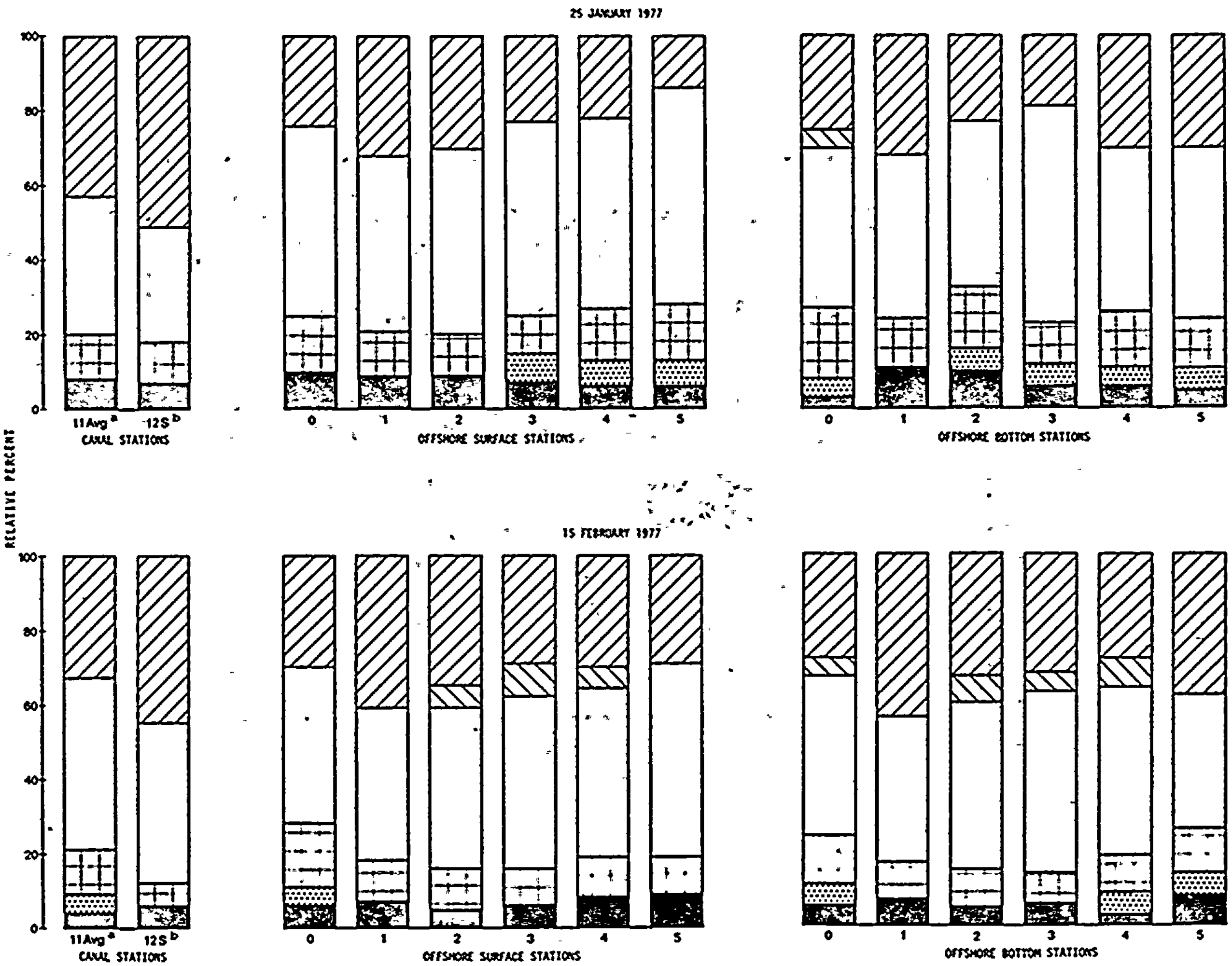
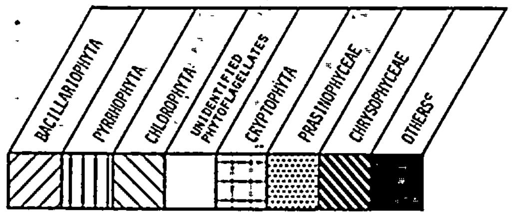


Figure D-16. Phytoplankton percentage composition at the St. Lucie Plant, 25 January and 15 February 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

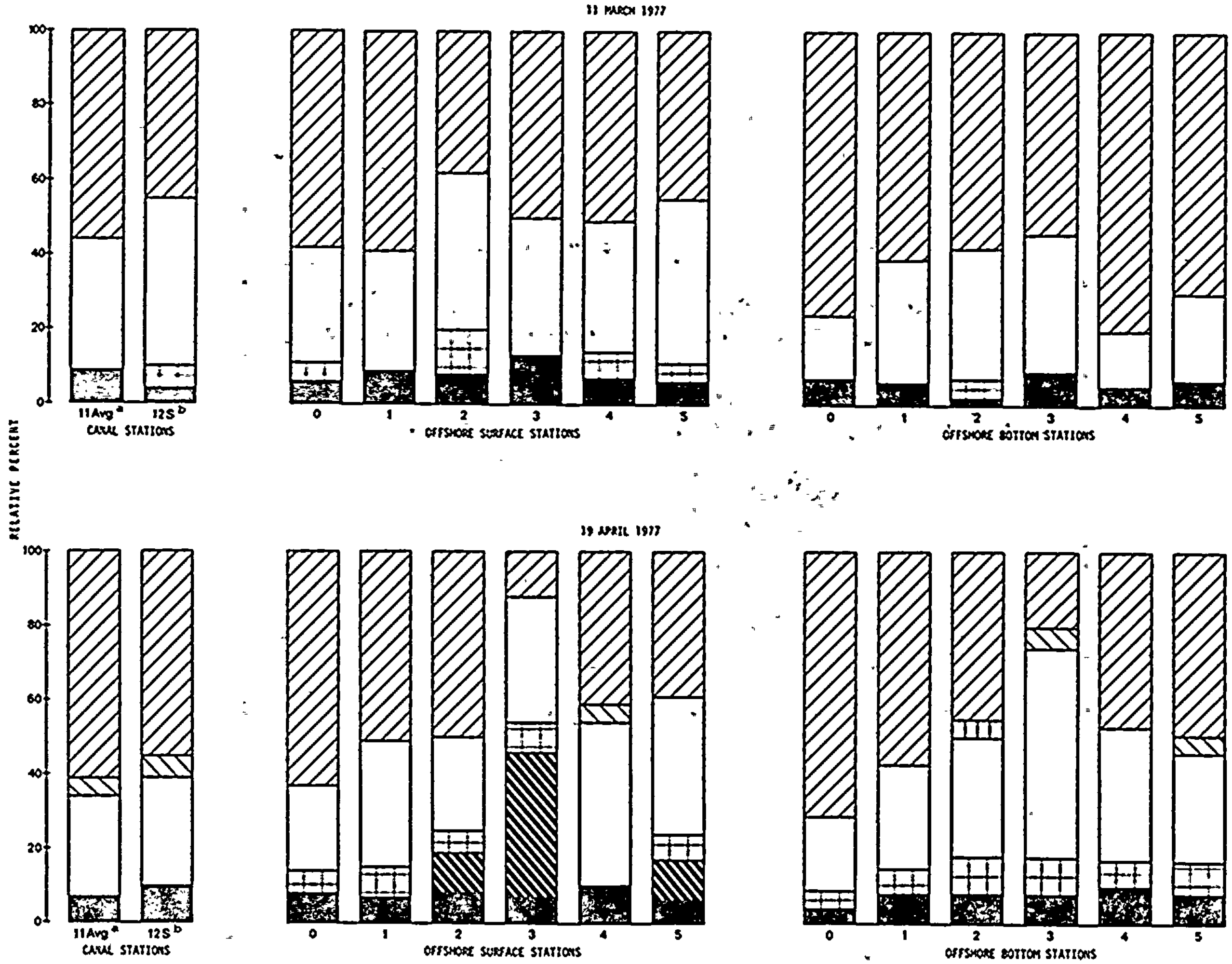
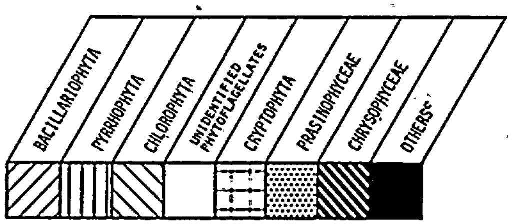


Figure D-17. Phytoplankton percentage composition at the St. Lucie Plant, 11 March 1977 and 19 April 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

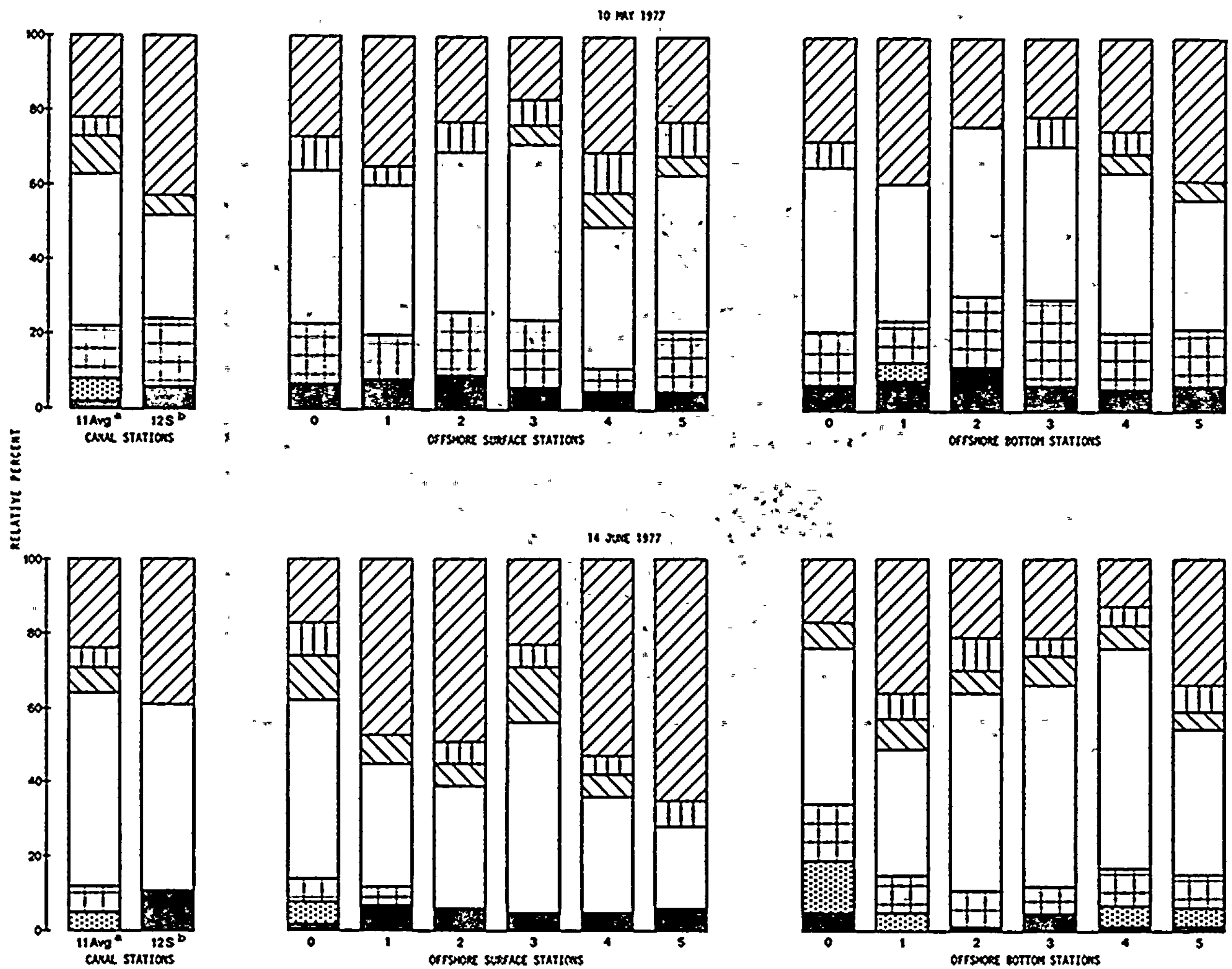
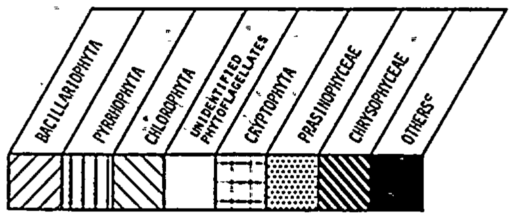


Figure D-18. Phytoplankton percentage composition at the St. Lucie Plant, 10 May 1977 and 14 June 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

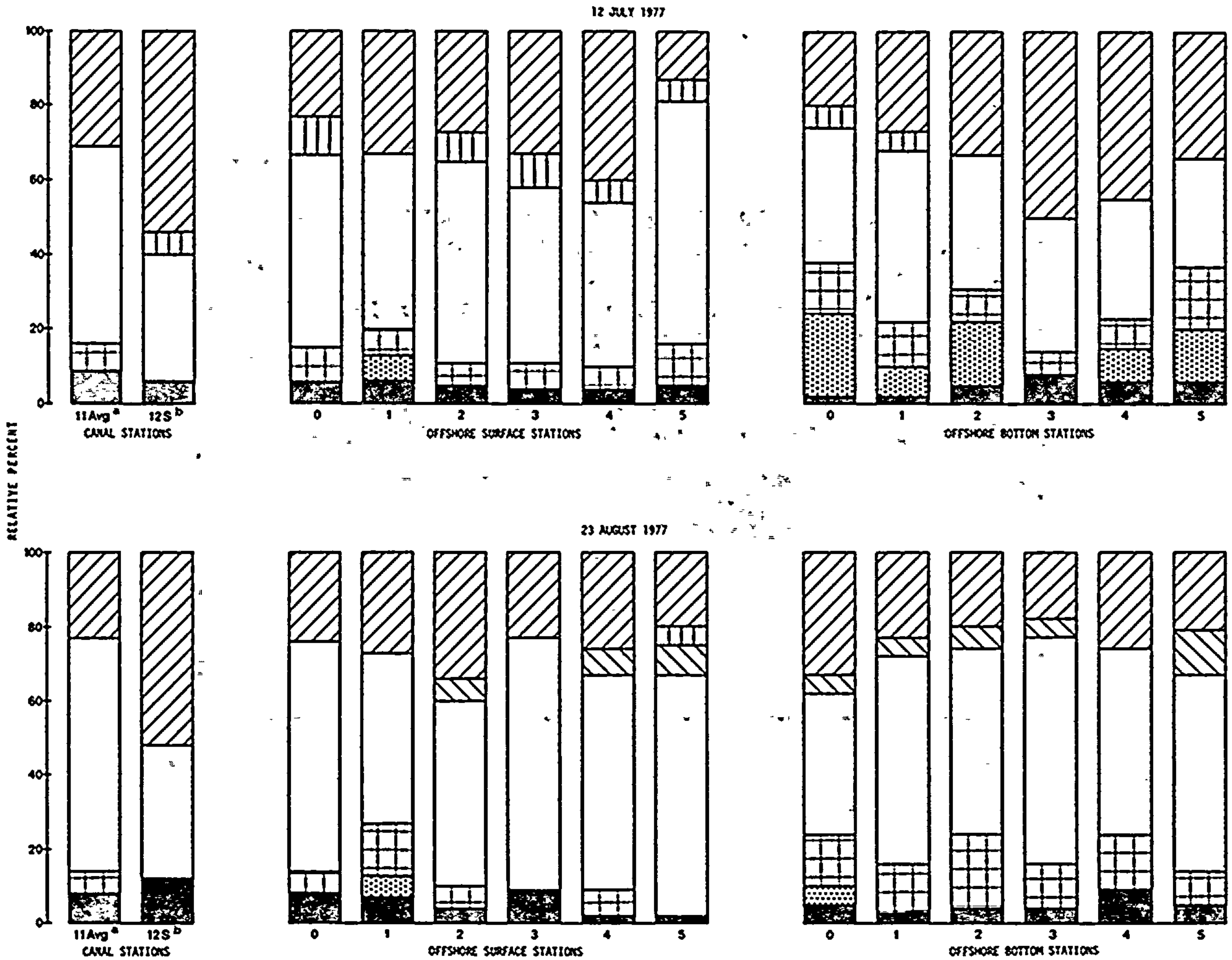
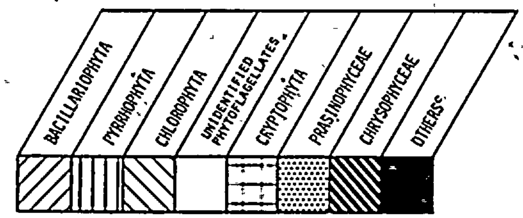


Figure D-19. Phytoplankton percentage composition at the St. Lucie Plant, 12 July 1977 and 23 August 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

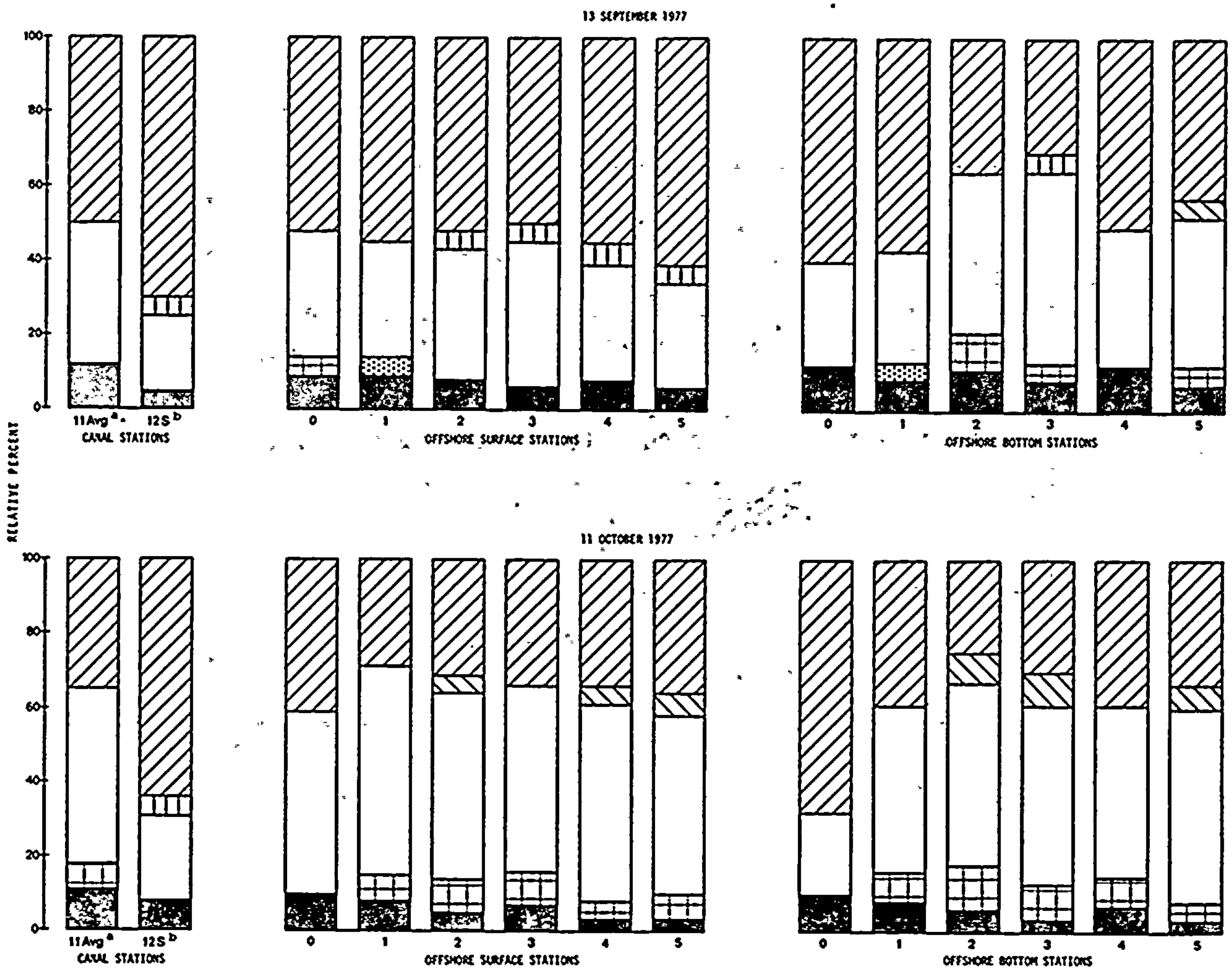
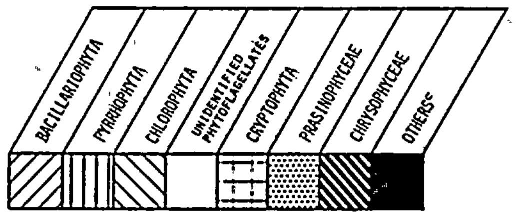


Figure D-20. Phytoplankton percentage composition at the St. Lucie Plant, 13 September 1977 and 11 October 1977.



[a] Percentage composition based on average density of surface and bottom samples.

[b] Percentage composition based on single-depth samples collected in immediate discharge.

[c] Any group representing <5% of the total density was included in the OTHERS category.

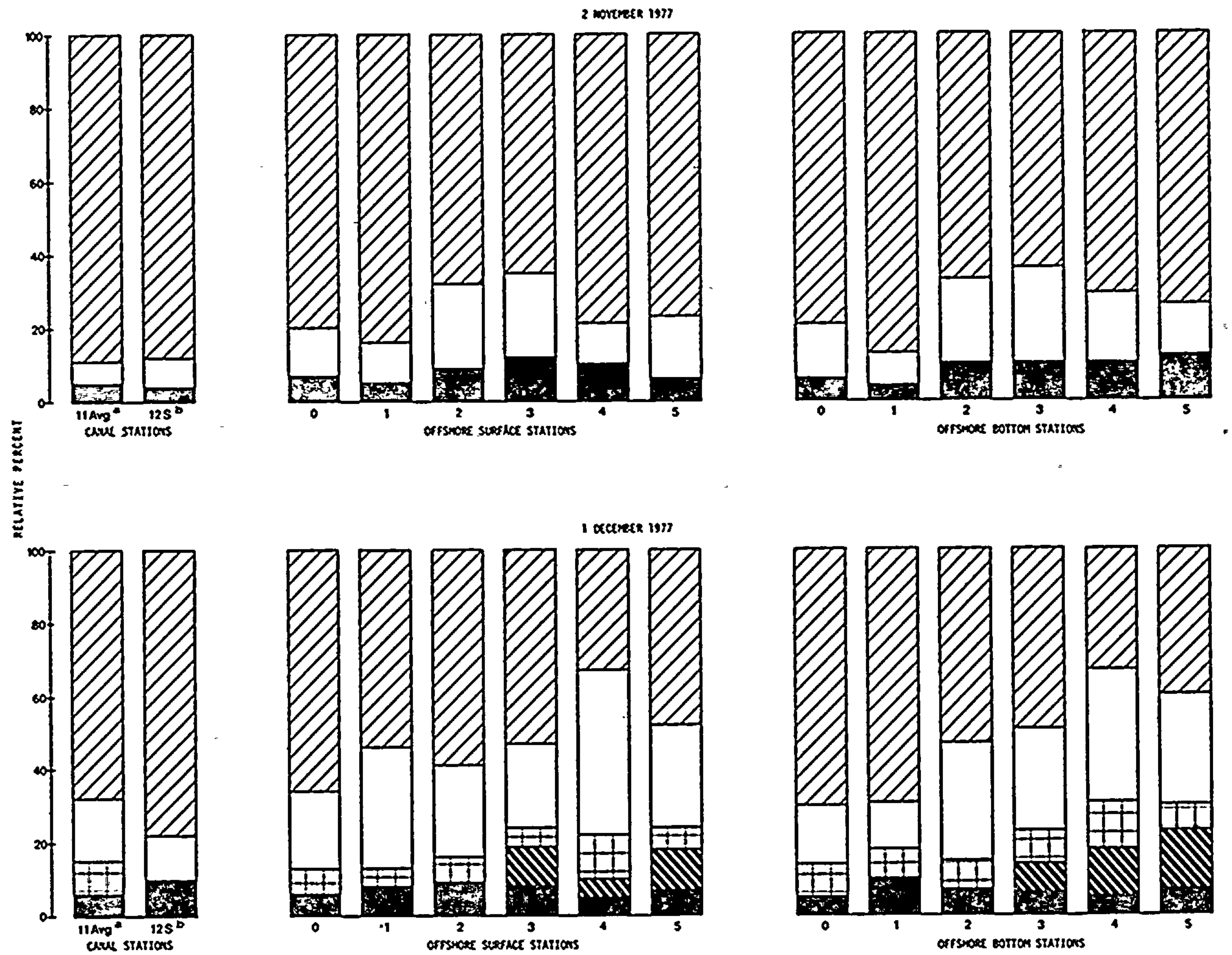


Figure D-21. Phytoplankton percentage composition at the St. Lucie Plant, 2 November 1977 and 1 December 1977.

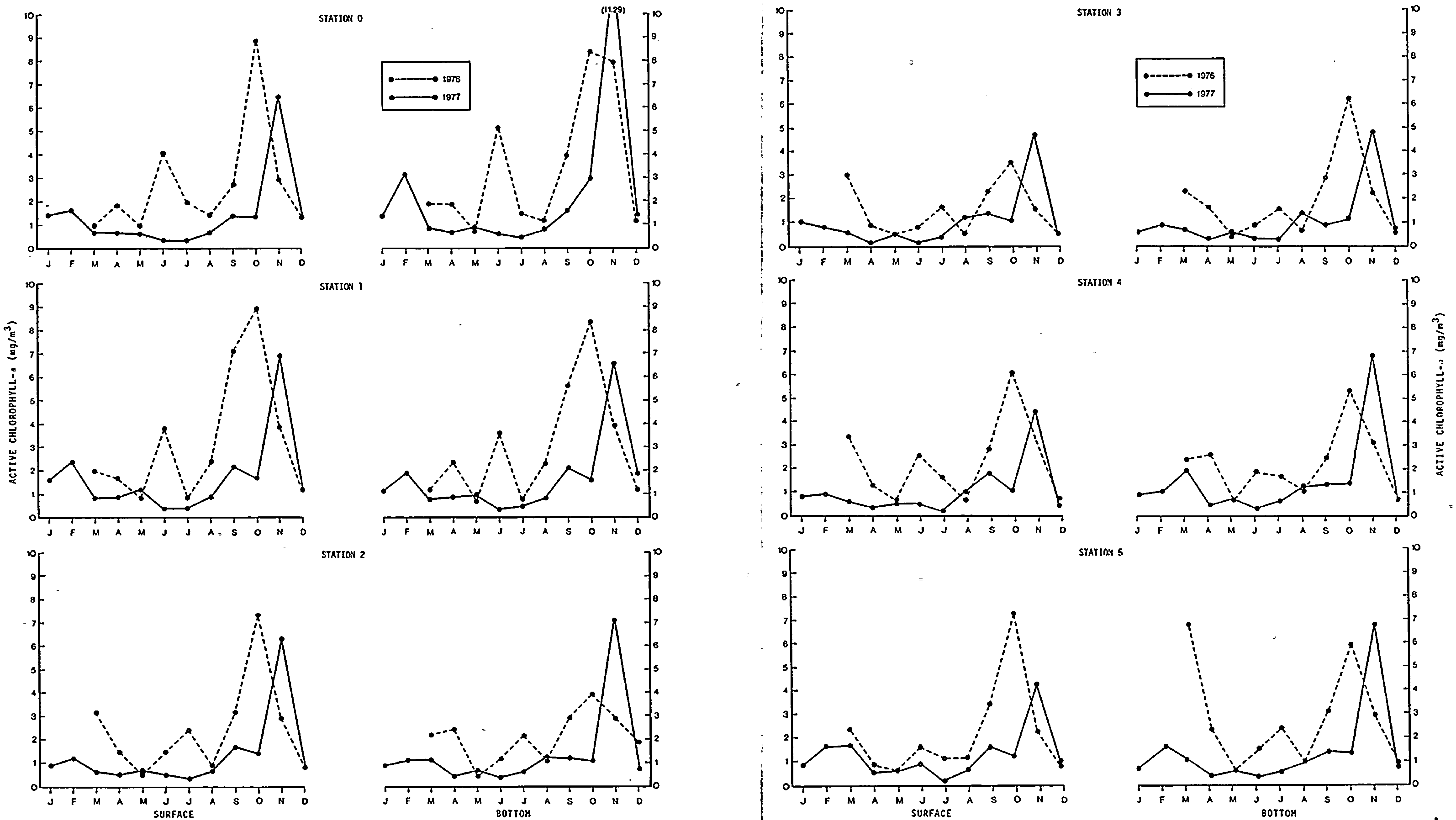


Figure D-22. Active chlorophyll-*a* concentration for offshore stations at the St. Lucie Plant, March 1976-December 1977.

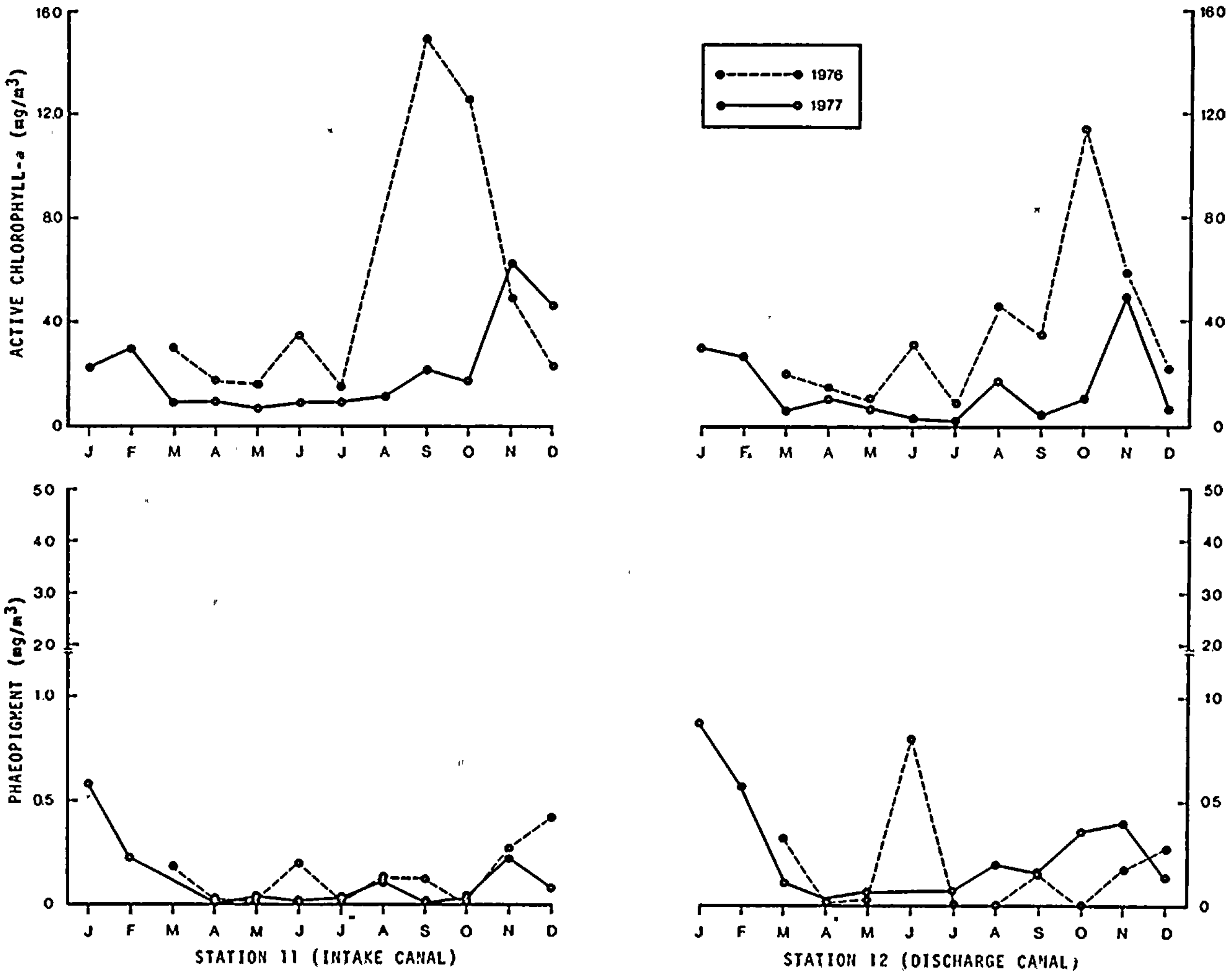


Figure D-23. Active chlorophyll-*a* and phaeopigment concentrations for intake and discharge stations at the St. Lucie Plant, March 1976-December 1977.

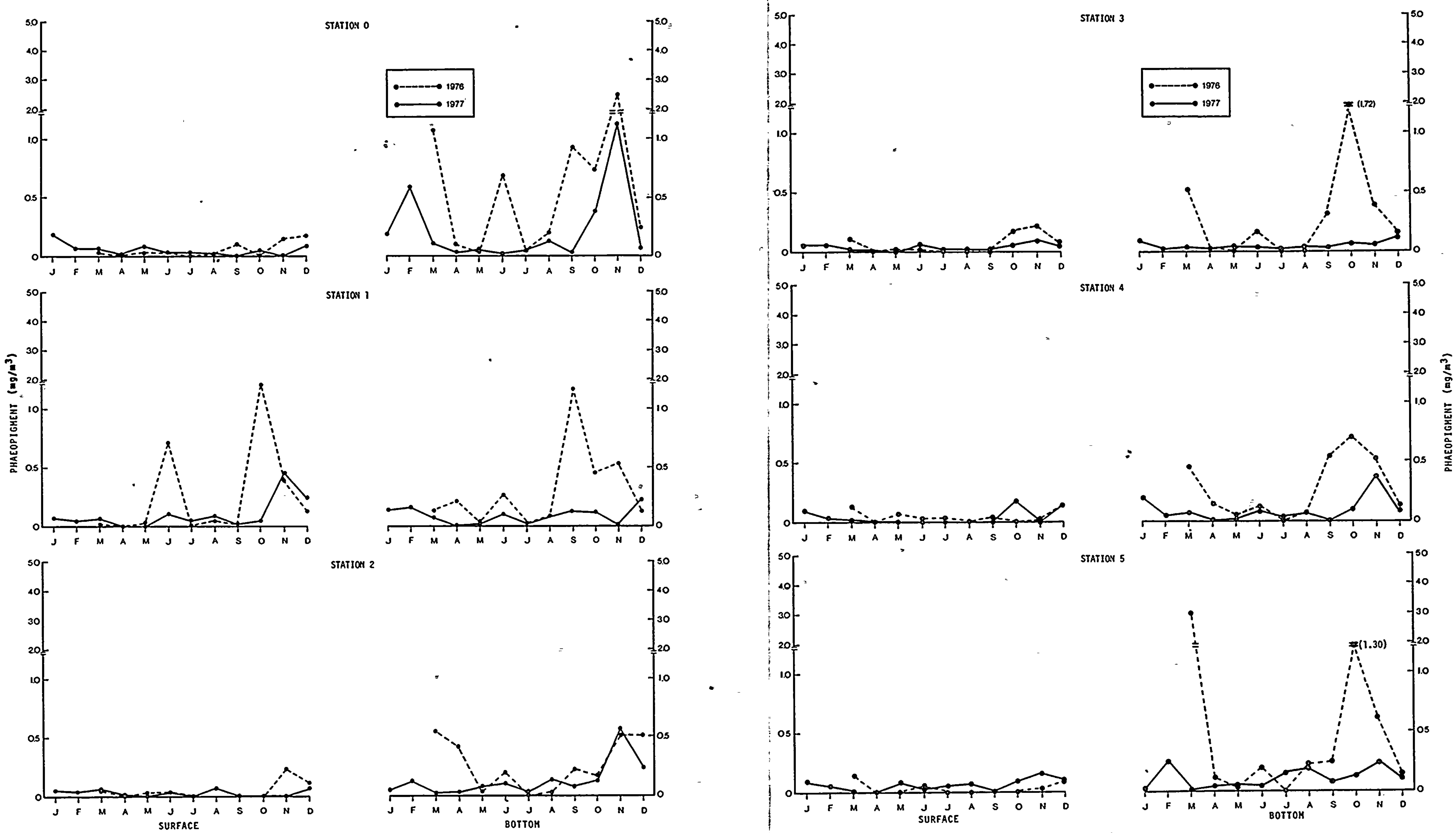


Figure D-24. Phaeopigment concentration for offshore stations at the St. Lucie Plant, March 1976-December 1977.

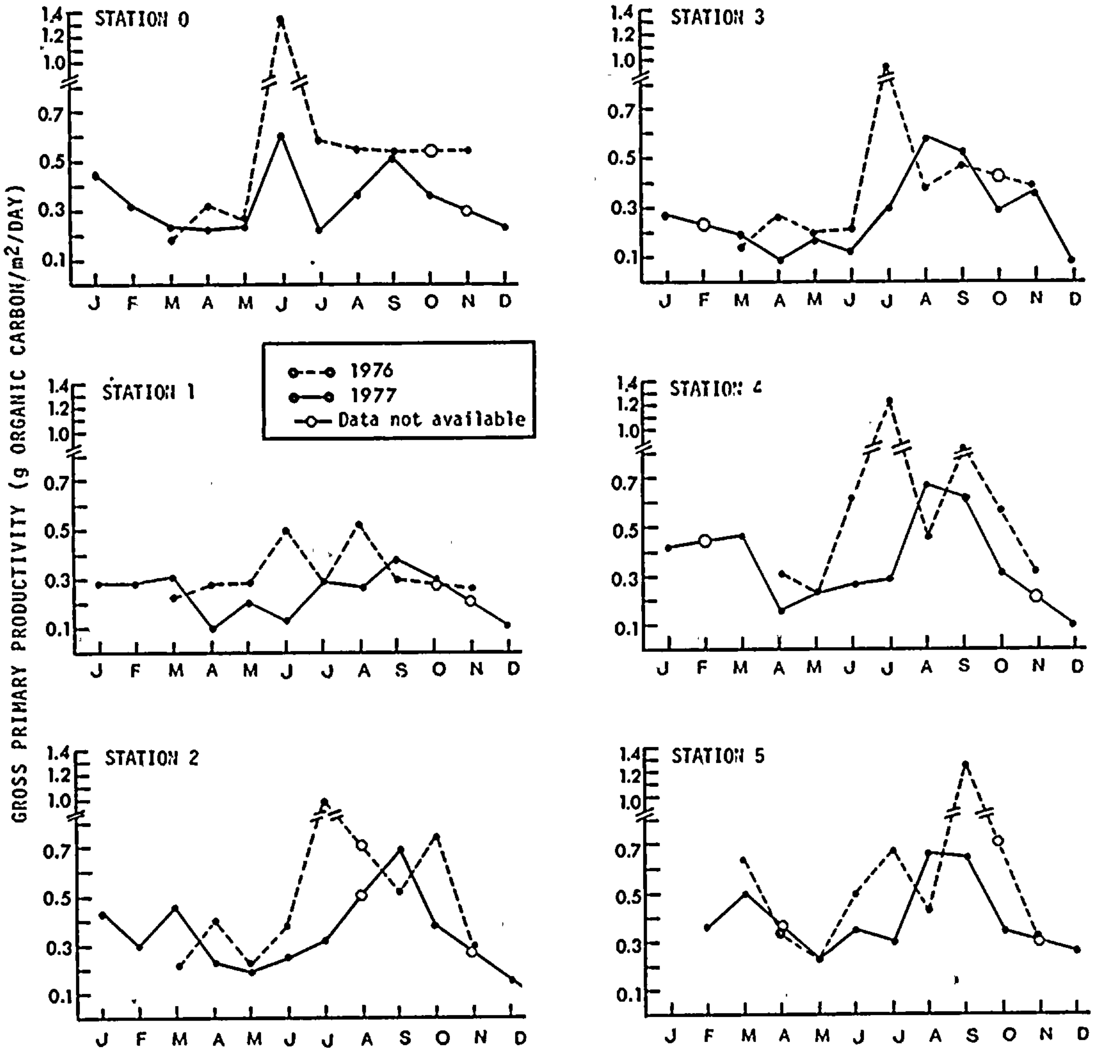


Figure D-25. Gross primary productivity at the St. Lucie Plant, March-December 1976 and January-December 1977.

TABLE D-1

PHYTOPLANKTON SPECIES OCCURRENCE
ST. LUCIE PLANT
1977

OBSERVED ONLY AT OFFSHORE STATIONS

Amphidinium sp. 1
Ceratium buceros f. *molle*
Ceratium pulchellum
Ceratium trichoceros
Ceratium tripos
Chaetoceros laciniosus
Chaetoceros laevis
Chaetoceros lorenzianus
Chaetoceros vistulae
Chlorophyte spp.
Chrysophyte sp. 3
Dactyliolsolen mediterraneus
Diploneis didyma v. *didyma*
Grammatophora marina
Gymnodinium galesianum
Hemiaulus hauckii
Hemiaulus sinensis
Isthmia enervis
Nitzschia filiformis
Prorocentrum redfieldi
Prorocentrum spp.
Rhizosolenia robusta
Scoliopleura sp.
Synedra undulata
Trachelomonas spp.

OBSERVED MORE FREQUENTLY AT OFFSHORE STATIONS

Amphidinium sp. 2
Apedinella radians
Bacteriastrum delicatulum
Ceratium fusus v. *seta*
Ceratium teres
Ceratium sp. 3
Chaetoceros eibenii
Chaetoceros spp.
Chlorophyte sp. 2
Chrysophyte sp. 2
Climacodium frauenfeldianum
Cymatosira belgica
Dictyocha spp.
Eucampia cornuta
Exuviaella baltica
Exuviaella spp.
Gyrodinium sp. 1
Hemidiscus cuneiformis v. *ventricosa*
Lithodesmium undulatum
Peridimium depressum
Peridinium hirobis
Prorocentrum minimum
Pyrophacus horologium
Rhizosolenia alata f. *indica*
Rhizosolenia calcar avis
Rhizosolenia cylindrus
Rhizosolenia imbricata
Rhizosolenia stolterfothii
Synedra sp. 1

OBSERVED ONLY IN THE INTAKE/DISCHARGE CANALS

Amphora sp. 3
Gyrosigma balticum v. *balticum*

TABLE D-2

ANALYSIS OF VARIANCE FOR PHYTOPLANKTON DENSITY
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
JANUARY - DECEMBER 1977

SURFACE

Source	Degrees of freedom	Sum of squares	Mean squares	F
Months	11	1210657×10^8	110059×10^8	4.43*
Stations	5	22931×10^8	4586×10^8	1.84
Error	55	136474×10^8	2481×10^8	
Total	71	1370062×10^8		

BOTTOM

Source	Degrees of freedom	Sum of squares	Mean squares	F
Months	11	1662227×10^8	151111×10^8	36.55*
Stations	5	83671×10^8	16734×10^8	4.04*
Error	55	227374×10^8	4134×10^8	
Total	71	1973273×10^8		

*Significant at $\alpha = .05$.

TABLE D-3

ANALYSIS OF VARIANCE FOR PHYTOPLANKTON DENSITY
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977[a]

SURFACE

Source	Degrees of freedom	Sum of squares	Mean squares	F
Years (Y)	1	86601 x 10^8	86601 x 10^8	15.44*
Months (M)	9	1109651 x 10^8	123294 x 10^8	21.98*
Stations (S)	5	89825 x 10^8	17965 x 10^8	3.20*
Y x M	9	649606 x 10^8	72178 x 10^8	12.87*
Y x S	5	30775 x 10^8	6155 x 10^8	1.10
M x S	45	286282 x 10^8	6361 x 10^8	1.13
Error	45	252335 x 10^8	5607 x 10^8	
Total	119	2505077 x 10^8		

BOTTOM

Source	Degrees of freedom	Sum of squares	Mean squares	F
Years (Y)	1	351786 x 10^8	351786 x 10^8	41.21*
Months (M)	9	2210211 x 10^8	245579 x 10^8	28.77*
Stations (S)	5	222205 x 10^8	44441 x 10^8	5.21*
Y x M	9	1088551 x 10^8	120950 x 10^8	14.17*
Y x S	5	15981 x 10^8	3196 x 10^8	37.45*
M x S	45	636495 x 10^8	14144 x 10^8	1.65
Error	45	384072 x 10^8	8534 x 10^8	
Total	119	4909300 x 10^8		

*Significant at $\alpha = .05$.

[a]January and February 1977 not included in analysis.

TABLE D-4

PEARSON CORRELATION COEFFICIENTS (r) FOR PHYTOPLANKTON DENSITY AND PIGMENTS VS. PHYSICAL AND CHEMICAL PARAMETERS, OFFSHORE SURFACE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

Parameter	Phytoplankton Density	Chlorophyll-*a*	Phaeopigment	Chlorophyll-*b*	Chlorophyll-*c*	Carotenoids
Temperature	-.0653	.0315	-.0735	.0060	.0312	.0427
Temperature^2	-.0714	.0294	-.0716	.0131	.0286	.0394
(n=132)[a]						
Salinity	-.1397	-.1935*	.0290	.1187	-.1524*	-.2225*
Salinity^2	-.1403	-.1954*	.0283	.1153	-.1547*	-.2246*
(n=132)						
Dissolved Oxygen	.1073	.1277	-.0243	.0115	.1466*	.0857
Dissolved Oxygen^2	.1007	.1271	-.0248	.0064	.1464*	.0841
(n=132)						
Nitrate	.0113	.1265	-.0989	.0772	.1450	.1406
Nitrate^2	.0137	.1334	-.1073	.0854	.1532	.1516
(n=56)						
Nitrite	-.0400	-.0873	-.0599	.3017*	-.0288	-.0347
Nitrite^2	-.0525	-.0864	-.0798	.2781*	-.0296	-.0282
(n=132)						
Ammonia	-.1075	-.1403	-.1331	.0715	-.1287	-.0958
Ammonia^2	-.0605	-.0905	-.1164	.0785	-.0696	-.0483
(n=132)						
Phosphate	-.1201	-.1240	-.0335	.0582	-.1136	-.1142
Phosphate^2	-.0982	-.0961	-.0252	.0701	-.0844	-.0864
(n=102)						
Silica	.0312	.0752	.0677	.4186*	.1061	.1122
Silica^2	-.0596	-.0120	.0350	.3754*	.0186	.0208
(n=66)						

*Significant at $\alpha = .05$.

[a]Number of observations.

TABLE D-5

PEARSON CORRELATION COEFFICIENTS (r) FOR PHYTOPLANKTON DENSITY AND PIGMENTS VS. PHYSICAL AND CHEMICAL PARAMETERS, OFFSHORE BOTTOM STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

Parameter	Phytoplankton Density	Chlorophyll-*a*	Phaeopigment	Chlorophyll-*b*	Chlorophyll-*c*	Carotenoids
Temperature	.0050	.0287	-.0443	-.0526	-.0099	.0118
Temperature² (n=132)[a]	.0038	.0255	-.0429	-.0500	-.0118	.0074
Salinity	-.2883*	-.2203*	-.3178*	-.2477*	-.2844*	-.3293*
Salinity² (n=132)	-.2882*	-.2214*	-.3158*	-.2491	-.2852*	-.3294*
Dissolved Oxygen	.0653	.0476	-.0947	.0026	.0388	.0050
Dissolved Oxygen² (n=132)	.0598	.0408	-.0998	-.0071	.0307	-.0041
Nitrate	.1527	.2148	.2208	.2371*	.2285*	.2013
Nitrate² (n=54)	-.0149	.0276	.0666	.0975	.0334	.0143
Nitrite	-.0181	-.0199	-.0140	.1240	.0152	-.0027
Nitrite² (n=132)	-.0464	-.0590	-.0353	.1192	-.0183	-.0276
Ammonia	.0130	.0589	-.0042	.0883	.0667	.0813
Ammonia² (n=132)	.0397	.0441	.0229	.0256	.0330	.0312
Phosphate	.3817*	.3149*	.3871*	.4023*	.3533*	.3436*
Phosphate² (n=102)	.4208*	.3611*	.4266*	.4180*	.3940*	.3908*
Silica	.0508	.1683	.2040	.6080*	.2271*	.1966
Silica² (n=66)	-.0131	.0921	.1486	.5833*	.1547	.1191

*Significant at α = .05.

[a]Number of observations.

TABLE D-6

MULTIPLE REGRESSION FOR OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

Dependent variables	Independent variables[a]	R	R^2
Density	Temperature	0.294	0.086
	Nitrite	0.357	0.128
	$Nitrite^2$	0.494	0.244
	$Ammonia^2$	0.517	0.267
Active chlorophyll-*a*	Temperature	0.324	0.105
	Nitrite	0.412	0.170
	$Nitrite^2$	0.565	0.320
	Silica	0.588	0.346
	$Silica^2$	0.653	0.426
	$Temperature^2$	0.669	0.447
	Nitrate	0.678	0.460
	$Nitrate^2$	0.687	0.472
Phaeopigment	Ammonia	0.434	0.188
Chlorophyll-*b*	Silica	0.521	0.272
	Temperature	0.672	0.452
	$Silica^2$	0.706	0.499
	Ammonia	0.732	0.536
	$Ammonia^2$	0.755	0.571
	Salinity	0.780	0.609
Chlorophyll-*c*	Temperature	0.320	0.102
	Nitrite	0.424	0.180
	$Nitrite^2$	0.575	0.330
	Silica	0.612	0.375
	$Silica^2$	0.675	0.455
	$Temperature^2$	0.691	0.478
Carotenoid	Temperature	0.307	0.094
	Nitrite	0.402	0.162
	$Nitrite^2$	0.549	0.301
	Silica	0.578	0.335
	$Silica^2$	0.641	0.411
	$Temperature^2$	0.655	0.430

[a] When the F-value to enter the regression was not significant (α=.05) for any independent variable, the stepwise procedure was stopped.

TABLE D-7

COMPARISON OF INTAKE (STATION 11) AND DISCHARGE (STATION 12) PHYTOPLANKTON
ST. LUCIE PLANT
NOVEMBER 1976-DECEMBER 1977

Date	Temperature in F° (°C) Intake[a]	Discharge	ΔT(°C)	Intake (cells/liter)	Discharge (cells/liter)	Changes in cell count[b] (%)
10 Nov	68.0 (20.0)	68.7 (20.4)	0.7 (0.4)	3,986,220.6	4,213,116.6	+5.6
13 Dec	75.4 (24.1)	84.0 (28.9)	8.6 (4.8)	2,116,060.1	1,245,602.9	-41.1
25 Jan	59.9 (15.5)	79.0 (26.1)	19.1 (10.6)	3,101,102.8	2,062,714.5	-33.4
15 Feb	69.8 (21.0)	90.1 (32.3)	20.3 (11.5)	1,051,416.5	1,314,201.3	+24.9
11 Mar	70.5 (21.4)	93.9 (34.4)	23.4 (13.0)	657,321.7	565,984.7	-13.8
19 Apr	76.5 (24.7)	77.5 (25.3)	1.0 (0.6)	1,022,444.4	1,512,525.8	+47.9
10 May	75.2 (24.0)	94.8 (34.9)	19.6 (10.9)	1,049,757.9	702,894.2	-33.0
14 Jun	81.1 (27.3)	100.9 (38.3)	19.8 (11.0)	1,293,545.6	339,202.3	-73.7
12 Jul	76.8 (24.9)	97.7 (36.5)	20.9 (11.6)	1,062,604.3	840,691.3	-20.8

TABLE D-7
(continued)
COMPARISON OF INTAKE (STATION 11) AND DISCHARGE (STATION 12) PHYTOPLANKTON
ST. LUCIE PLANT
NOVEMBER 1976-DECEMBER 1977

Date	Temperature in F° (°C) Intake[a]	Temperature in F° (°C) Discharge	ΔT(°C)	Intake (cells/liter)	Discharge (cells/liter)	Changes in cell count[b] (%)
23 Aug	76.6 (24.8)	99.5 (37.5)	22.9 (12.7)	1,306,168.5	379,637.7	-70.9
13 Sep	84.0 (28.9)	107.6 (42.0)	23.6 (13.1)	1,286,507.2	831,172.0	-35.4
11 Oct	80.8 (27.1)	103.1 (39.5)	22.3 (12.4)	1,466,091.0	1,755,461.3	-19.7
2 Nov	75.6 (24.2)	95.9 (35.5)	20.3 (11.3)	4,856,821.5	4,431,361.3	-8.8
1 Dec	75.4 (24.1)	98.8 (37.1)	23.4 (13.0)	2,664,011.3	609,124.4	-77.1

[a]Average of surface and bottom readings.

[b]Change in cell count = $\frac{\text{Discharge count - Intake count}}{\text{Intake count}} \times 100$

TABLE D-8

ANALYSIS OF VARIANCE FOR PHYTOPLANKTON DENSITY
CANAL STATIONS (11, 12)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

JANUARY-DECEMBER 1977				
Source	Degrees of freedom	Sum of squares	Mean squares	F
Months	11	276268 x 10^8	25115 x 10^8	9.99*
Stations	1	12481 x 10^8	12481 x 10^8	4.96*
Error	11	27664 x 10^8	2515 x 10^8	
Total	23	316412 x 10^8		

MARCH 1976-DECEMBER 1977[a]				
Source	Degrees of freedom	Sum of squares	Mean squares	F
Years (Y)	1	207416 x 10^8	207416 x 10^8	56.88*
Months (M)	9	473042 x 10^8	52560 x 10^8	14.41*
Stations (S)	1	15942 x 10^8	15942 x 10^8	4.37
Y x M	9	254728 x 10^8	28303 x 10^8	7.76*
Y x S	1	497 x 10^8	497 x 10^8	.14
M x S	9	28050 x 10^8	3117 x 10^8	.85
Error	9	32819 x 10^8	3647 x 10^8	
Total	39	1012494 x 10^8		

*Significant at $\alpha = .05$.

[a]January and February 1977 not included in analysis.

TABLE D-9

PEARSON CORRELATION COEFFICIENTS (r) FOR PHYTOPLANKTON DENSITY AND PIGMENTS VS PHYSICAL AND CHEMICAL PARAMETERS, CANAL STATIONS (11, 12)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

Parameter	Phytoplankton Density	Chlorophyll-*a*	Phaeopigment	Chlorophyll-*b*	Chlorophyll-*c*	Carotenoids
Temperature	-.2635*	-.1293	.0545	.2439*	-.0832	-.1077
Temperature²	-.2587*	-.1456	.1018	.2425*	-.0988	-.1233
(n=75)[a]						
Salinity	-.1098	-.3601*	-.2404*	-.2651*	-.4231*	-.4816*
Salinity²	-.1124	-.3617*	-.2296*	-.2606*	-.4233*	-.4811
(n=74)						
Dissolved Oxygen	.1142	.1870	-.1654	-.3943*	.1091	.0872
Dissolved Oxygen²	.1150	.1759	-.1526	.3644*	.1068	.0840
(n=74)						
Nitrate	.4249*	.5322*	.0647	-.3476*	.5318*	.5344*
Nitrate²	.3884*	.5220*	.0382	-.3557*	.5147*	.5287*
(n=27)						
Nitrite	.3338*	.1538	.0478	.0742	.1909	.1729
Nitrite²	.3659*	.1914	.0266	.0648	.2300*	.2169*
(n=75)						
Ammonia	.0028	.4056*	-.1624	.0352	.3607*	.3805*
Ammonia²	.0224	.5962*	-.1178	-.0114	.5410*	.5627*
(n=75)						
Phosphate	-.0609	-.0968	.5241*	.2256*	-.0911	-.0597
Phosphate²	-.0538	-.0822	.5172*	.2053	-.0788	-.0444
(n=55)						
Silica	-.0649	.0130	.3392*	.6071*	.0334	.0417
Silica²	-.0902	-.0200	.2893	.5679*	-.0011	.0129
(n=33)						

*Significant at $\alpha = .05$.

[a]Number of observations.

TABLE D-10

MULTIPLE REGRESSION FOR CANAL STATIONS (11, 12)
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

Dependent variables	Independent variables[a]	R	R^2
Density	Phosphate	0.620	0.384
	Silica^2	0.820	0.673
	Ammonia^2	0.884	0.781
	Ammonia	0.911	0.831
	Silica	0.934	0.871
	Temperature^2	0.952	0.907
	Nitrite	0.966	0.933
Active chlorophyll-*a*	Nitrate	0.531	0.282
	Phosphate^2	0.704	0.496
	Silica^2	0.771	0.595
	Ammonia^2	0.822	0.675
	Ammonia	0.876	0.767
	Silica	0.898	0.807
	Temperature^2	0.917	0.842
Phaeopigment	Phosphate^2	0.572	0.327
	Temperature^2	0.689	0.475
	Temperature	0.757	0.573
Chlorophyll-*b*	Silica	0.563	0.317
Chlorophyll-*c*	Phosphate^2	0.538	0.289
	Nitrate^2	0.751	0.564
	Silica^2	0.819	0.671
Carotenoid	Ammonia^2	0.537	0.288
	Phosphate	0.694	0.482
	Silica^2	0.819	0.670
	Ammonia	0.887	0.786
	Silica	0.905	0.820
	Temperature^2	0.923	0.852

[a] When the F-value to enter the regression was not significant (α=.05) for any independent variable, the stepwise procedure was stopped.

TABLE D-11

ANALYSIS OF VARIANCE FOR CHLOROPHYLL-*a*
AT OFFSHORE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Months	11	128.4400	11.67636	72.78*
	Stations	5	2.9928	0.59856	3.73*
	Error	55	8.8227	0.16041	
	Total	71	140.2555		
Bottom	Months	11	257.4672	23.40610	49.25*
	Stations	5	8.5768	1.71536	3.61*
	Error	55	26.1387	0.47525	
	Total	71	292.1827		

March 1976-December 1977[a]					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Years (Y)	1	35.7188	35.71880	71.07*
	Months (M)	9	195.9557	21.77286	43.32*
	Stations (S)	5	13.4511	2.69022	5.35*
	Y x M	9	123.1643	13.68492	27.23*
	Y x S	5	4.0380	0.80760	1.60
	M x S	45	25.8410	0.57424	1.14
	Error	45	22.6169	0.50260	
	Total	119	420.7858		
Bottom	Years (Y)	1	28.2169	28.21686	49.44*
	Months (M)	9	279.5283	31.05870	54.42*
	Stations (S)	5	19.6516	3.93031	6.89*
	Y x M	9	131.9219	14.65798	25.68*
	Y x S	5	2.0989	0.41978	0.74
	M x S	45	65.3171	1.45149	2.54*
	Error	45	25.6812	0.57069	
	Total	119	552.4159		

* Significant at $\alpha = .05$.
[a] January and February 1977 not included in analysis.

TABLE D-12

ANALYSIS OF VARIANCE FOR CHLOROPHYLL-*a* AND PHAEOPIGMENT
AT INTAKE-DISCHARGE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977

Pigment	Source	Degrees of freedom	Sum of squares	Mean squares	F
Chlorophyll-*a*	Months	11	49.13490	4.46681	5.10*
	Stations	1	2.02711	2.02711	2.32
	Error	11	9.62680	0.87516	
	Total	23	60.78879		
Phaeopigment	Months	11	0.41352	0.03759	2.11
	Stations	1	0.03623	0.03623	2.04
	Error	11	0.19563	0.01778	
	Total	23	0.64537		

March 1976-December 1977[a]

Pigment	Source	Degrees of freedom	Sum of squares	Mean squares	F
Chlorophyll-*a*	Years (Y)	1	89.9846	89.98462	25.10*
	Months (M)	9	161.9741	17.99712	5.02*
	Stations (S)	1	17.2331	17.23305	4.81
	Y x M	9	126.1967	14.02185	3.91*
	Y x S	1	2.2021	2.20214	0.61
	M x S	9	33.8337	3.75930	1.05
	Error	9	32.2617	3.58463	
	Total	39	463.6860		
Phaeopigment	Years (Y)	1	0.01541	0.01541	0.95
	Months (M)	9	0.32244	0.03583	2.21
	Stations (S)	1	0.03813	0.03813	2.35
	Y x M	9	0.31003	0.03445	2.12
	Y x S	1	0.01024	0.01024	0.63
	M x S	9	0.11673	0.01297	0.80
	Error	9	0.14608	0.01623	
	Total	39	0.95906		

* Significant at $\alpha = .05$.
[a] January and February 1977 not included in analysis.

TABLE D-13

ANALYSIS OF VARIANCE FOR PHAEOPIGMENT
AT OFFSHORE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Months	11	0.08794	0.00799	2.26*
	Stations	5	0.03214	0.00643	1.81
	Error	55	0.19474	0.00354	
	Total	71	0.31482		
Bottom	Months	11	0.71894	0.06536	3.49*
	Stations	5	0.23028	0.04606	2.46*
	Error	55	1.02792	0.01869	
	Total	71	1.97715		

March 1976-December 1977[a]					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Years (Y)	1	0.02640	0.02640	1.53
	Months (M)	9	0.33580	0.03731	2.17*
	Stations (S)	5	0.30684	0.06137	3.57*
	Y x M	9	0.10387	0.01154	0.67
	Y x S	5	0.09376	0.01875	1.09
	M x S	45	0.72721	0.01616	0.94
	Error	45	0.77348	0.01719	
	Total	119	2.36735		
Bottom	Years (Y)	1	2.78312	2.78312	24.12*
	Months (M)	9	5.24665	0.58296	5.05*
	Stations (S)	5	1.12802	0.22560	1.96
	Y x M	9	3.21995	0.35777	3.10*
	Y x S	5	0.61625	0.12325	1.07
	M x S	45	7.26692	0.16149	1.40
	Error	45	5.19240	0.11539	
	Total	119	25.45328		

* Significant at $\alpha = .05$.
[a] January and February 1977 not included in analysis.

TABLE D-14

ANALYSIS OF VARIANCE FOR CAROTENOIDS
AT OFFSHORE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Months	11	107.4502	9.76820	62.47*
	Stations	5	3.3640	0.67279	4.30*
	Error	55	8.6006	0.15637	
	Total	71	119.4148		
Bottom	Months	11	250.3495	22.75903	39.12*
	Stations	5	11.7500	2.35000	4.04*
	Error	55	31.9971	0.5818	
	Total	71	294.0966		

March 1976-December 1977[a]					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Years (Y)	1	48.4371	48.43713	102.29*
	Months (M)	9	167.6711	18.63011	39.34*
	Stations (S)	5	15.9192	3.18383	6.72*
	Y x M	9	99.2792	11.03103	23.30*
	Y x S	5	4.8208	0.96416	2.03
	M x S	45	25.2213	0.56047	1.18
	Error	45	21.3079	0.47351	
	Total	119	382.6566		
Bottom	Years (Y)	1	71.5481	71.54811	55.07*
	Months (M)	9	295.7015	32.85571	25.28*
	Stations (S)	5	36.7774	7.35549	5.66*
	Y x M	9	137.9185	15.32428	11.79*
	Y x S	5	10.1189	2.02378	1.56
	M x S	45	101.1911	2.24869	1.73
	Error	45	58.4622	1.29916	
	Total	119	711.7177		

* Significant at $\alpha = .05$.
[a] January and February 1977 not included in analysis.

TABLE D-15

ANALYSIS OF VARIANCE FOR CHLOROPHYLL-*c*
AT OFFSHORE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Months	11	28.31495	2.57409	65.13*
	Stations	5	0.72674	0.14535	3.68*
	Error	55	2.17351	0.03952	
	Total	71	31.21518		
Bottom	Months	11	56.04689	5.09517	5.91*
	Stations	5	1.88330	0.37666	4.13*
	Error	55	5.01201	0.09113	
	Total	71	62.94218		

March 1976-December 1977[a]					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Years (Y)	1	8.23715	8.23715	81.86*
	Months (M)	9	50.66145	5.62905	55.94*
	Stations (S)	5	2.50758	0.50152	4.98*
	Y x M	9	27.44795	3.04977	30.31*
	Y x S	5	0.78164	0.15633	1.55
	M x S	45	4.71112	0.10469	1.04
	Error	45	4.52789	0.10062	
	Total	119	98.87476		
Bottom	Years (Y)	1	11.63117	11.63117	57.38*
	Months (M)	9	68.82291	7.64699	37.73*
	Stations (S)	5	5.88142	1.17628	5.80*
	Y x M	9	28.52853	3.16984	15.63*
	Y x S	5	1.86905	0.37381	1.84
	M x S	45	13.27420	0.29498	1.45
	Error	45	9.12053	0.20268	
	Total	119	139.12778		

* Significant at $\alpha = .05$.
[a] January and February 1977 not included in analysis.

TABLE D-16

ANALYSIS OF VARIANCE FOR CHLOROPHYLL-*b*
AT OFFSHORE STATIONS
ST. LUCIE PLANT
MARCH 1976-DECEMBER 1977

January-December 1977					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Months	11	0.16367	0.01488	10.62*
	Stations	5	0.00557	0.00111	0.79
	Error	55	0.07689	0.00140	
	Total	71	0.24612		
Bottom	Months	11	0.30980	0.02816	15.64*
	Stations	5	0.00486	0.00097	0.54
	Error	55	0.09922	0.00180	
	Total	71	0.41389		

March 1976-December 1977[a]					
Depth	Source	Degrees of freedom	Sum of squares	Mean squares	F
Surface	Years (Y)	1	0.00105	0.00105	0.39
	Months (M)	9	0.32159	0.03573	13.13*
	Stations (S)	5	0.00561	0.00112	0.41
	Y x M	9	0.05094	0.00566	2.08
	Y x S	5	0.00729	0.00146	0.54
	M x S	45	0.08811	0.00196	0.72
	Error	45	0.12241	0.00272	
	Total	119	0.59699		
Bottom	Years (Y)	1	0.15914	0.15914	13.85*
	Months (M)	9	0.51205	0:05689	4.95*
	Stations (S)	5	0.14467	0.02893	2.52*
	Y x M	9	0.22939	0.02549	2.22*
	Y x S	5	0.17920	0.03584	3.11*
	M x S	45	0.51157	0.01137	0.99
	Error	45	0.51705	0.01149	
	Total	119	2.25305		

* Significant at $\alpha = .05$.

[a] January and February 1977 not included in analysis.

TABLE D-17

ANALYSIS OF VARIANCE FOR GROSS PRIMARY PRODUCTIVITY AT OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
JANUARY-DECEMBER 1977[a]

Source	Degrees of freedom	Sum of squares	Mean squares	F
Stations	5	0.09331	0.01866	0.66
Months	6	0.44006	0.07334	2.61*
Error	30	0.84268	0.02809	
Total	41	1.37605		

* Significant at $\alpha = .05$.

[a] January, February, April, August and December were not included in analysis because data were not available at one or more stations.

E. ZOOPLANKTON

INTRODUCTION

The purpose of this study was to assess the effects of power plant operation on the density and composition of the zooplankton population. Variations in zooplankton density were analyzed and considered in relation to phytoplankton and the physical/chemical environment.

Zooplankton collectively refers to animals that are non-swimmers, poor swimmers, or free-floating organisms in a body of water. Zooplankters range in size from microscopic to macroscopic organisms variously distributed in the water column. Ecologically, zooplankton may be divided into two main groups: 1) holoplankters, which spend their entire life cycles in the water column, and 2) meroplankters, temporary members of the zooplankton that consist predominantly of larval forms associated with benthic adults.

The availability of soluble nutrients, which promote phytoplankton growth and reproduction, determines the abundance of phytoplankton as a basic food source for subsequent grazing by zooplankton (Bainbridge, 1953; Davis, 1955). Zooplankters, in turn, are an important food source for many other forms of marine animals.

MATERIALS AND METHODS

Zooplankton was collected monthly at six offshore stations, 0 through 5 (Figure E-1). All except Station 0 were potentially subjected to thermal addition by heated water discharge from the plant discharge structure. Stations located in the intake and discharge canals (11 and 12, respectively) were sampled to determine immediate entrainment effects. Collections were made with a half-meter, 202μ mesh plankton net. Towing speeds were 0.5 to 2 knots for intervals of 5 to 10 minutes. Duplicate samples were taken: one for qualitative and quantitative analysis and one for biomass determination. Offshore samples were collected from surface and bottom depths by towing horizontally; intake samples were collected by step-oblique tows; and discharge samples were collected with a set net, since water velocity was sufficient to keep the net suspended and the water column was well-mixed due to the turbulence. Offshore, the water column ranged in depth from 7.1 to 11.2 meters. Surface samples were collected at sufficient depth (1 to 2 meters) to ensure continued submergence of the plankton net. A flowmeter positioned in the mouth of the net indicated the amount of water filtered. Weather conditions, tidal stage, and moon phase were recorded. Wind velocity (knots), current direction and velocity (cm/sec), air and water temperature (°C), salinity (‰), dissolved oxygen (ppm), and turbidity were measured at each collection. Each sample was washed into a pre-labeled bottle and preserved with 5% buffered formalin, returned to the laboratory, and allowed to settle a minimum of four

days. Samples were concentrated by vacuum pump to a minimum working volume, and for qualitative and quantitative analysis, replicate one-ml aliquots were withdrawn with a Stempel pipette. Organisms were identified to the lowest practical taxon. Dissections and staining were used when necessary for identification.

Zooplankters per cubic meter were calculated by multiplying the count by appropriate dilution factors and dividing by the volume of water filtered in cubic meters. The volume of water filtered was calculated by:

$$V = \pi(r^2)l$$

where: V = volume of filtered water

r = radius of net at mouth

l = distance net is hauled.

Biomass of the zooplankton was determined by ash-free dry weight (EPA, 1973). Results of these determinations were expressed as milligrams of ash-free dry weight per unit volume of water.

Aliquots used as subsamples for identification and counts were retained along with the whole sample as vouchers. Vouchers were retained as part of a permanent collection which may be used in the future to verify counts and identifications. Zooplankton data were analyzed by analysis of variance, and zooplankton density was related to oceanographic parameters through correlation and regression.

RESULTS AND DISCUSSION

Zooplankton data for December 1976, which were not available for the 1976 annual report (ABI, 1977), are given in Appendix Tables N-1 through N-3.

Members of ten phyla observed during the January to December 1977 study period (Appendix Tables N-6 through N-27) were also observed during the 1976 study. They were Annelida (Polychaeta), Arthropoda (largely Crustacea), Bryozoa, Chaetognatha, Chordata, Coelenterata, Echinodermata, Mollusca, Nematoda, and Protozoa. Rotifera were not found in the 1977 study; representatives of the Phoronida were found in 1977. Copepods (Plate E-1), which are mostly holoplanktonic, were again the dominant component of the zooplankton and comprised 10 to 94% of the total population offshore. Other groups which were dominant at different times during the study included cirripedia (barnacle) nauplii, *Conchoecia elegans* (an ostracod), echinoderm larvae, eggs, *Evadne* sp. and *Penilia* sp. (cladocerans), foraminiferans (protozoa), molluscs (mostly gastropods), *Oikopleura* sp. (an appendicularian), polychaetes, *Sagitta enflata* and other chaetognaths.

As in the 1976 study, the zooplankton population was generally neritic (nearshore) rather than oceanic (offshore) in character. Oceanic zooplankters such as euphausids, salps including *Thalia democratica,* siphonophores, and the chaetognaths *Pterosagitta draco,*

Sagitta bipunctata, and *S. serratodentata atlantica* were found infrequently or in low concentrations. Neritic forms identified included the chaetognaths *S. friderici*, *S. helenae*, and *S. hispida*; the polychaete, *Tomopteris* sp.; and the sergestid shrimp, *Lucifer faxoni* (Plate E-2). The dominant calanoid copepod was *Paracalanus aculeatus*. Other calanoids that occurred consistently throughout the year and are typically neritic included *Acartia spinata*, *Labidocera aestiva*, *Temora turbinata*, and *Undinula vulgaris*. Dominant cyclopoids included *Corycaeus (Corycaeus) speciosus*, *C. (Onychocorycaeus) latus*, *Farranula gracilis*, and *Oncaea mediterranea*. *Euterpina* sp., the dominant harpacticoid copepod, occurred all year. All of the species mentioned above are holoplanktonic.

Meroplanktonic forms made a major contribution to the zooplankton population and included the larvae of decapods, echinoderms, gastropods, pelecypods, and polychaetes, along with actinotroch, actinula, cyphonautes and cypris larvae. Other meroplankton included barnacle nauplii, fish eggs, and stomatopod protozoeae.

Major physical, structural damage to individual zooplankters was noted in the microscopic analyses. Differences in the damaged and undamaged portions of the zooplankton populations are represented in Figures E-2 through E-13. Zooplankton density was minimal in December, when numbers per cubic meter ranged from 16.7 to 1797.5 (Appendix Table N-4, Figures E-13 and E-14). Maximum zooplankton

density occurred in March and ranged from 362.1 to 28,912.5 organisms per cubic meter (Figure E-4).

Biomass was minimal in January and ranged from 1.28 to 15.83 mg/m^3 (Appendix Table N-5. Maximum biomass was found in July and ranged from 4.28 to 223.47 mg/m^3. Minimum and maximum values represent seasonal pulses and may be expected to vary somewhat for density and biomass.

Canal Stations

The difference in temperature (ΔT) between the intake and discharge stations ranged from +0.1 to +13.1°C (Table E-1). The highest temperature of the 1977 study, 42.0°C, was recorded in the discharge canal in September.

Undamaged Zooplankton

There were no significant differences in densities of undamaged zooplankters between the intake and discharge stations for 1977 or for the two years combined (Tables E-2 and E-3, Figure E-15). In addition, there were no significant differences between years.

Damaged Zooplankton

Densities of damaged zooplankters (Table E-2) were significantly greater in the discharge than in the intake during 1977 (Table E-4, Figure E-15). This would indicate that zooplankters had suffered major structural damage as a result of passage through the plant.

There were no significant differences in the number of damaged zooplankters between intake and discharge in 1976, when the plant was not running or pumping minimally and with little or no thermal addition. Data for the canals for the two years combined (Table E-3) indicated that the number of damaged zooplankters in the canals was significantly greater in 1977 than in 1976 (Table E-4).

Biomass

Biomass showed no significant difference between the intake and discharge in 1976. However, biomass was significantly greater in the discharge in 1977 (Tables E-5 and E-6). Damaged zooplankters were not differentiated from undamaged in biomass determinations and could thus account for the higher values. Higher biomass values in the discharge may also be attributable to plant material, which was visually observed in some samples, and/or cirripedia (barnacle) nauplii populations, which frequently comprised 40 to 47% of the total zooplankton population in the discharge canal. There was no significant difference between years for biomass values (Table E-7, Figure E-16).

Offshore Stations

Physical parameters

Physical parameters monitored during collections included temperature, salinity, and dissolved oxygen (Appendix Tables 0-1 through 0-3). Minimum temperatures were recorded in January and ranged from 16.3 to 18.5°C. Maximum temperatures occurred in June and July; mean temperatures were 27.8°C and 28.4°C, respectively. Zooplankton abundance correlated significantly with temperature and dissolved oxygen (Table E-8). Stepwise multiple regression indicated that these parameters combined accounted for a maximum 12% variation in the zooplankton population (Table E-9).

Undamaged Zooplankton

Although there were no significant differences between stations (Table E-5), analysis of variance indicated significant seasonal variation in total zooplankton density between months in 1977 and between months in the two years combined (Table E-10). Significant positive correlations between temperature and zooplankton abundance at the offshore stations, surface and bottom (Table E-8), indicate that as temperature increases, so does zooplankton abundance. This positive relationship between the linear and curvilinear functions of temperature and zooplankton density probably reflects seasonal pulses of the zooplankton in warm months, since Tukey's test for difference between means (Tables E-11 through E-12) indicated that zooplankton abundance was significantly greater in March and July (Figures E-4,

E-8, and E-14) than in the other months. Total zooplankton densities in March 1977 ranged from 3323.2 to 28,912.5 zooplankters per cubic meter (Appendix Table N-8). Copepods comprised 70 to 93% of the total population. Densities in July 1977 ranged from 746.0 to 15,261.6 zooplankters per cubic meter (Appendix Table N-12). As in March, copepods made up the major portion of the population, 61 to 94%. Biomass was also significantly greater in the month of March than in the other months for the two years combined (Table E-13). Zooplankton density and biomass were significantly greater in 1977 than in 1976 (Tables E-6, E-7, E-10, and E-12).

Differences in zooplankton abundance from month to month and year to year are normal seasonal variations. A number of seasonal trends in the zooplankton noted in 1977 were, in general, also observed in 1976. Echinoderm larvae were abundant at offshore stations in the winter months. Sergestid protozoeae reached peak density in December. *Penilia* sp. was found in the warmer months, peaked in October, and began to decline in November and December. *Evadne* sp. also occurred during the summer months, but peaked after *Penilia* sp., in November.

Brachyuran zoeae reached their highest concentrations in June, July, and August, with some decline in the population in September, and reached their minimum density in October, November, and December. The meroplanktonic zoeae of two genera of commercially important

species were identified, *Callinectes* sp. (brachyuran) and *Sicyonia* sp. (penaeid); both reached maximum concentrations in August, although densities were low (Appendix Table N-25). The commercial fisheries for rock shrimp (*Sicyonia* spp.) and blue crab (*Callinectes sapidus*) in the St. Lucie Plant area are small and in St. Lucie County, Florida, represent 1.4% and <1%, respectively, of the total east coast landings (NOAA, 1977).

Damaged Zooplankton

As was the case with undamaged zooplankters, there was no significant difference in damaged zooplankters between stations, but seasonal variation in damaged zooplankton density was significant between months in 1976, 1977, and the two years combined (Table E-14). Tukey's test for difference between means (Tables E-15 and E-16) indicated that damaged zooplankton was significantly greater in August of 1976, mainly July in 1977, and July and August for the two years combined. Copepods represented the greatest percentage of damaged organisms in July 1977, ranging from 2 to 16% of the total zooplankton population.

Depth variation

Bottom zooplankton populations were greater than surface populations (Tables E-7, E-10, E-14, and E-17). Differences were significantly greater in 1976 for undamaged zooplankton densities and biomass and in 1977 for undamaged and damaged zooplankton densities.

For the two years combined, undamaged and damaged zooplankton and biomass were all significantly greater on the bottom. Since analysis of variance in 1977 did not indicate any significant density differences between stations, and also since bottom populations were greater than surface populations in 1976, differences between surface and bottom appear to be a natural phenomenon rather than a plant-related one. Many factors have been considered for this stratification in the zooplankton population. There was no trend between zooplankton density and inorganic nutrients or total organic carbon; nor was there any trend in correlations with phytoplankton density (number/liter) or chlorophyll-*a* values, an indicator of phytoplankton biomass. There was no apparent relationship with physical factors such as current (measured at the surface) and/or wind velocity, cloud cover, moon phase, or turbidity. Possible trophic interactions were also considered. The presence of either ctenophores and/or scyphomedusae such as *Aurelia aurita, Chiropsalmus quadromanus, Stomolophis meleagris,* and *Tamoya haplonema*, which are known to be capable of substantially reducing a zooplankton population by grazing, was noted by observation on the impingement screens. The occurrence of these planktivores did not noticeably affect the zooplankton density. Most of the copepods that occurred were filter feeders rather than carnivores and therefore would not have altered the zooplankton composition or density. Copepods did, however, show a tendency for greater densities on the bottom in June, July, and August when the water was calm.

During months when water conditions were choppy, the copepods tended to be more evenly distributed in the water column, although this was not consistently observed. If the natural tendency (without the influence of turbulent water) for the copepods is to congregate at the bottom, it is probably due to active light avoidance.

SUMMARY

The composition of the zooplankton population did not substantially change from 1976 to 1977. Essentially the same phyla were identified and copepods were the dominant component of the population. This would indicate, so far as broad groups are concerned, that plant operation is not qualitatively altering the zooplankton population.

Analysis of variance indicated significant differences in zooplankton densities and biomass between months offshore. Tukey's test indicated that March and July densities and March biomass values were significantly greater than these values for other months. Undamaged zooplankton densities and biomass were significantly greater in 1977 than in 1976. Seasonal fluctuations in zooplankton populations are normal occurrences and indicate no adverse effect due to plant operation offshore.

Analysis of variance and Tukey's test indicated that abundance of damaged zooplankters in the discharge canal was significantly higher in 1977 than in 1976. This is a positive indication of the detrimental effect of plant operation on zooplankton.

The zooplankton population was greater at the bottom than at the surface. Since this stratification was also noted in 1976, when there was little or no thermal addition offshore, it would appear to be a natural phenomenon.

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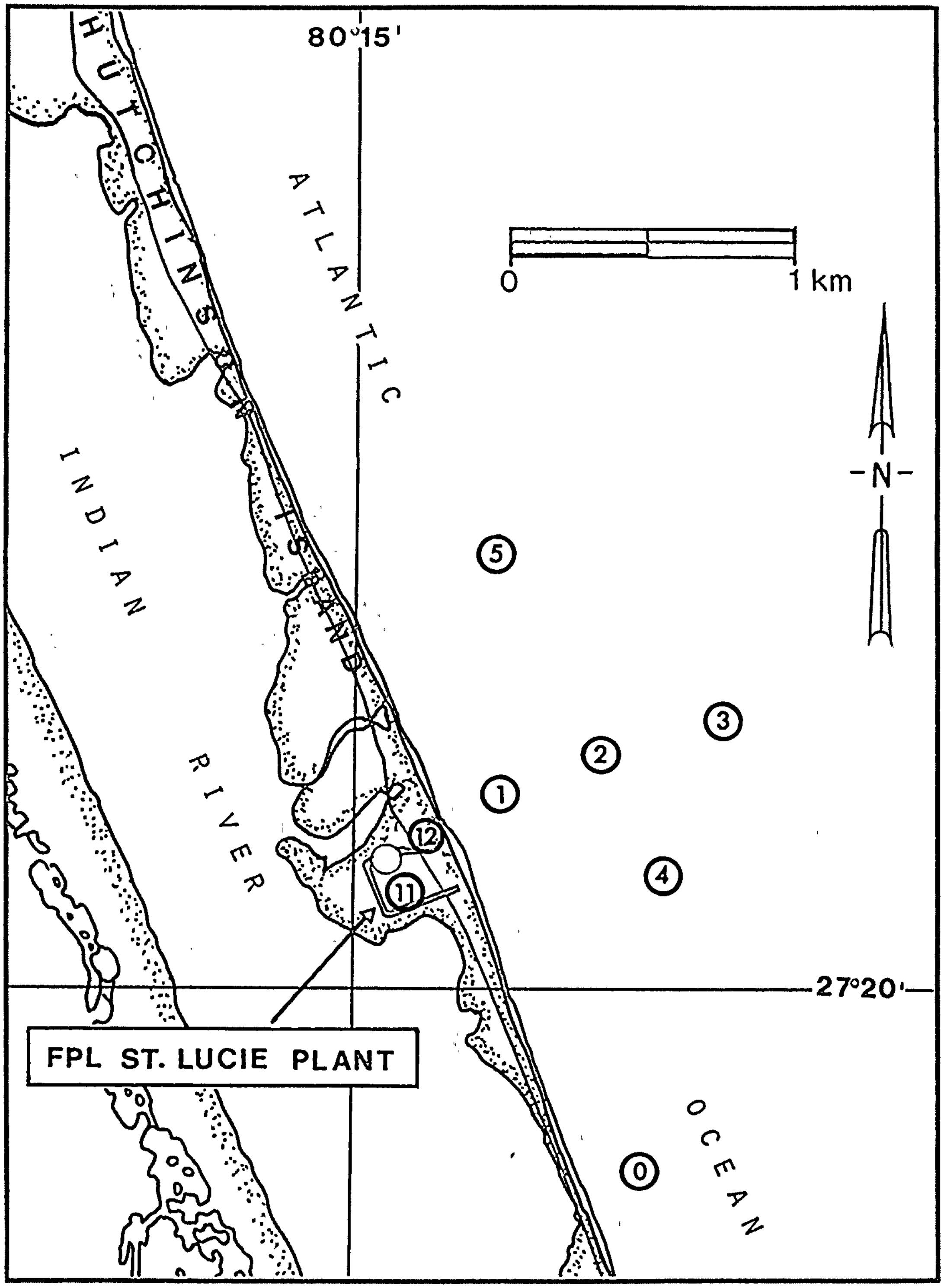


Figure E-1. Locations of zooplankton sampling stations, 1977.

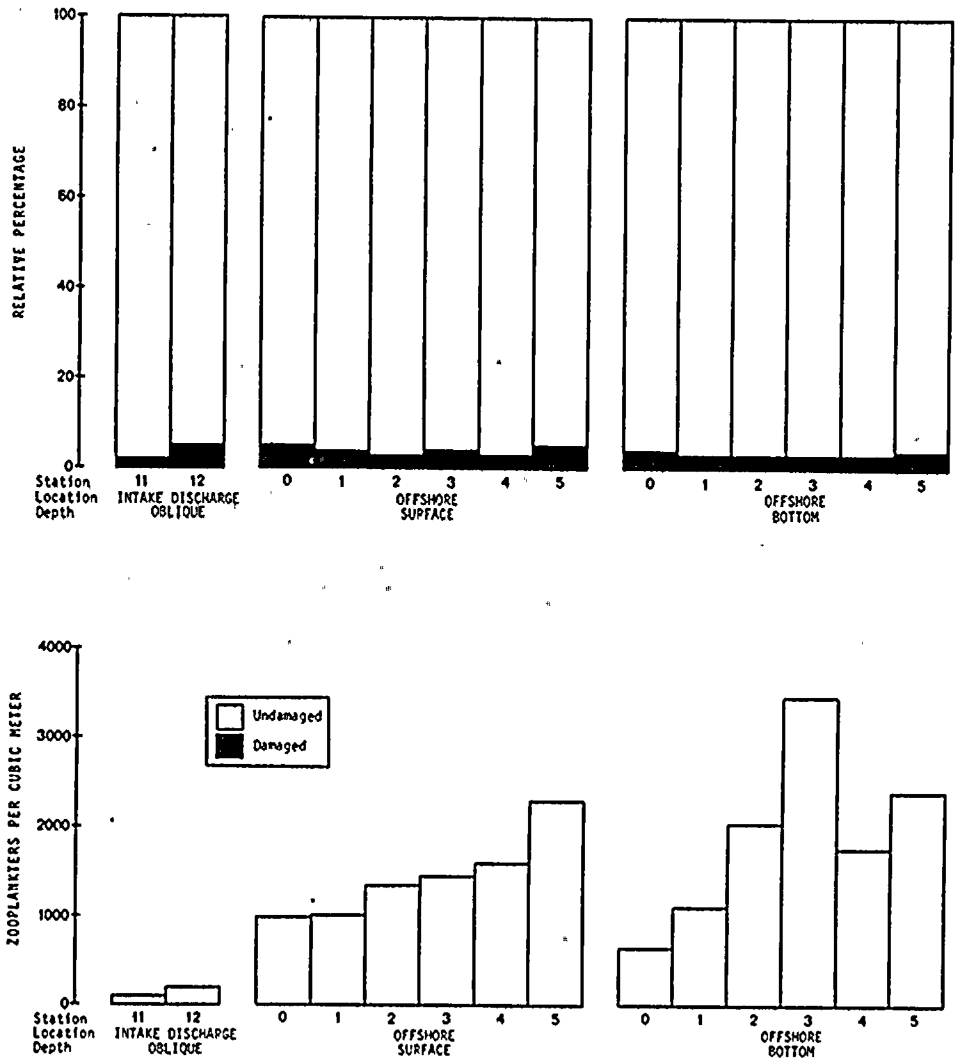


Figure E-2. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, January 1977.

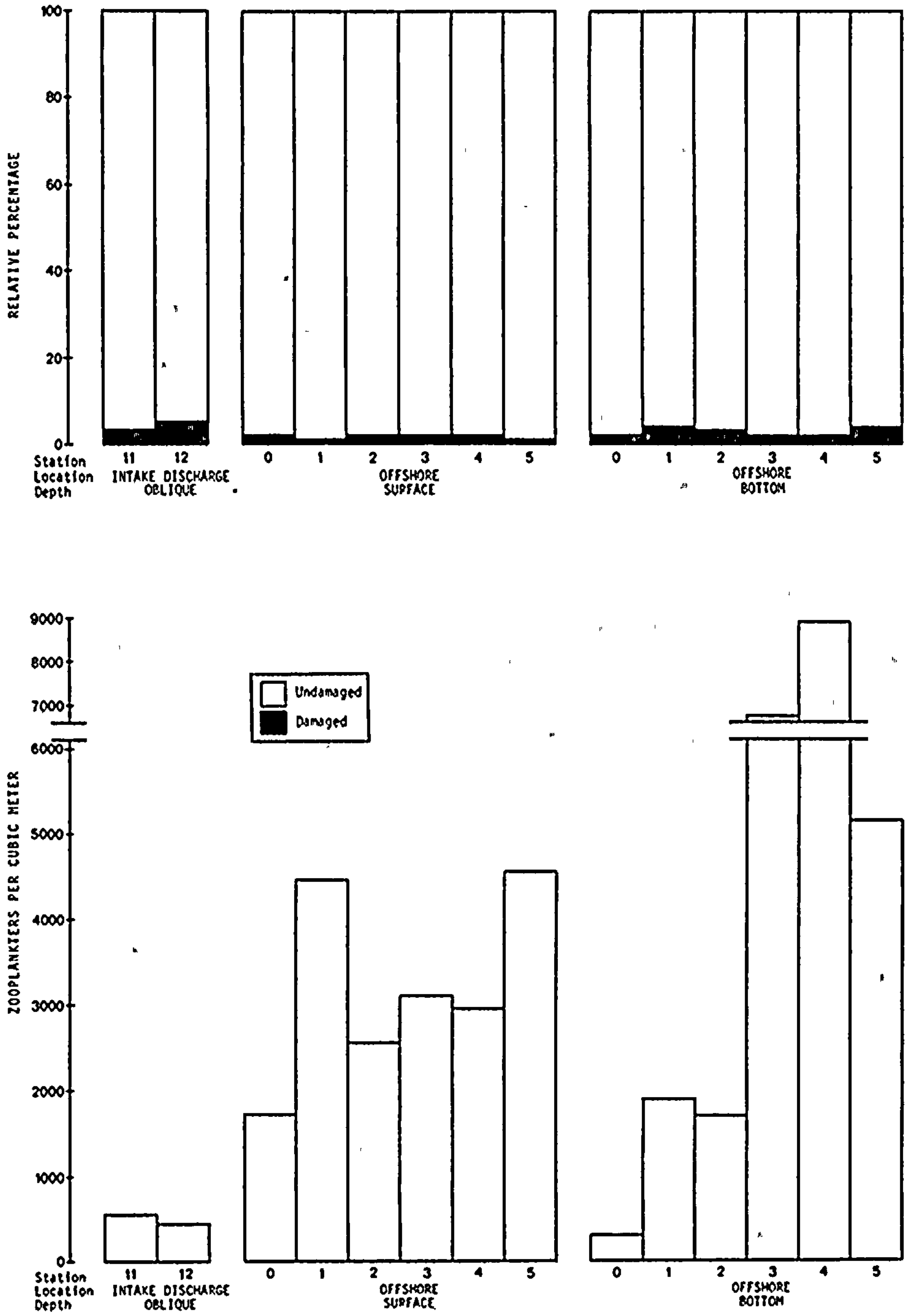


Figure E-3. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, February 1977.

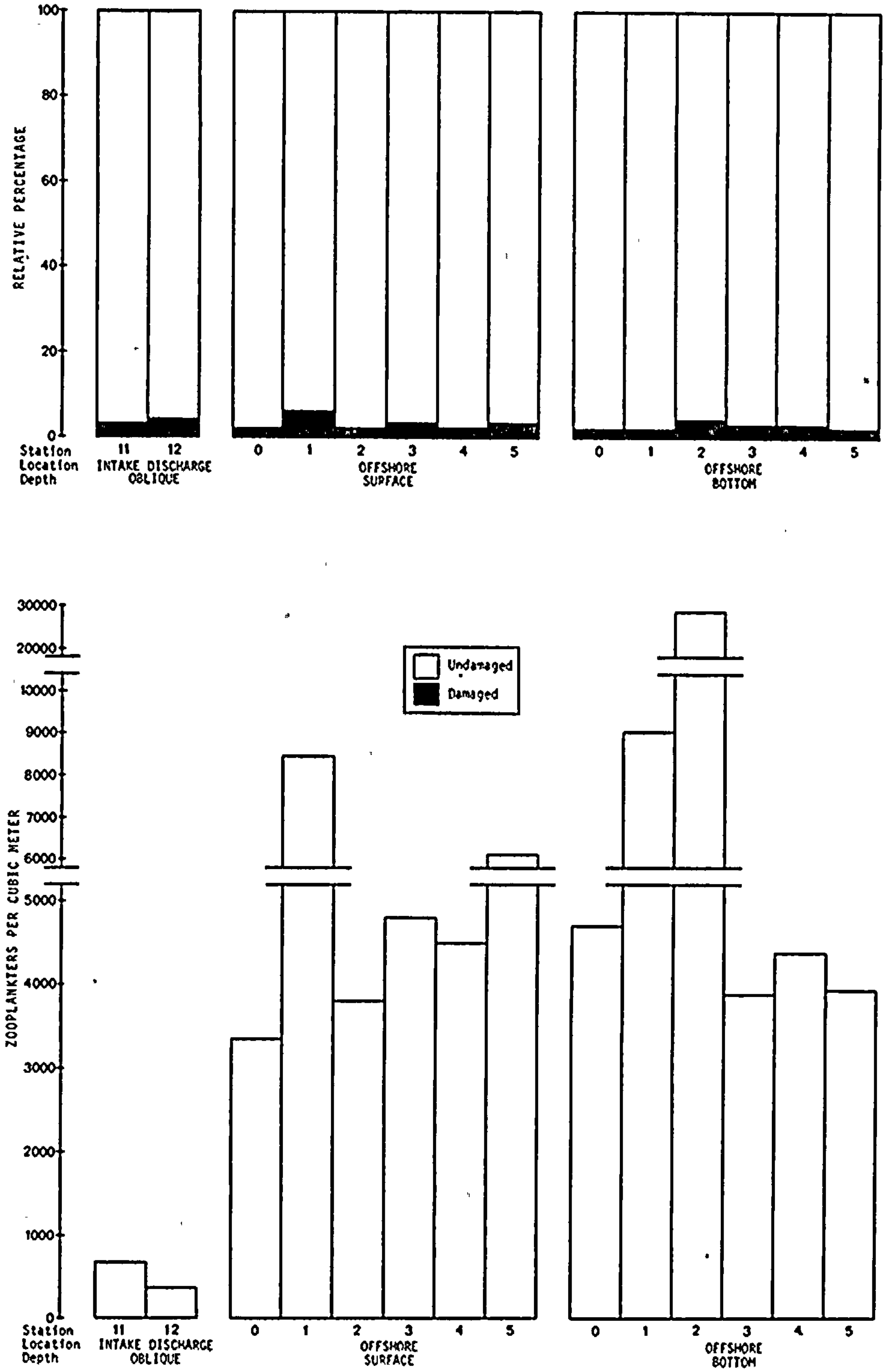


Figure E-4. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, March 1977.

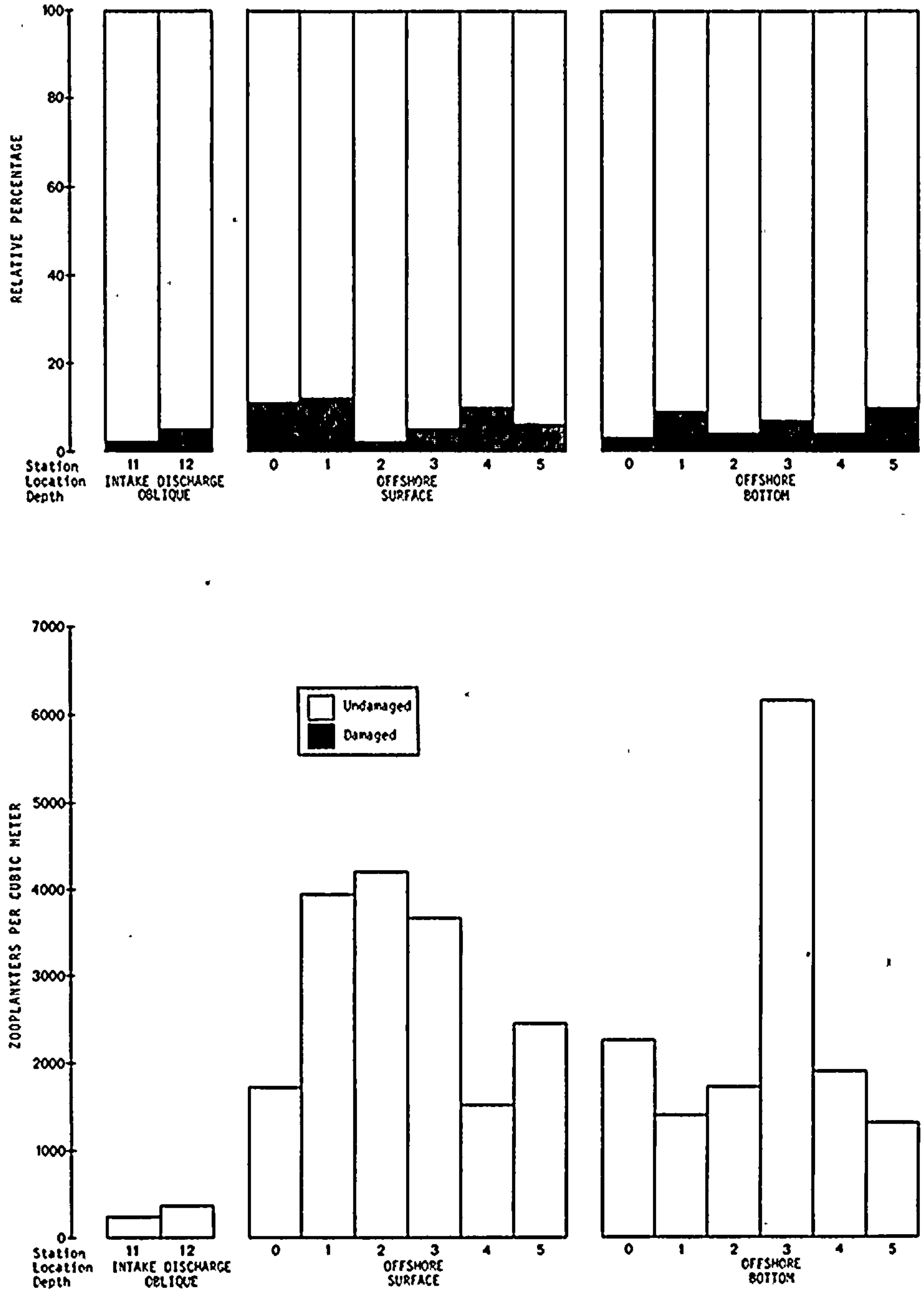


Figure E-5. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, April 1977.

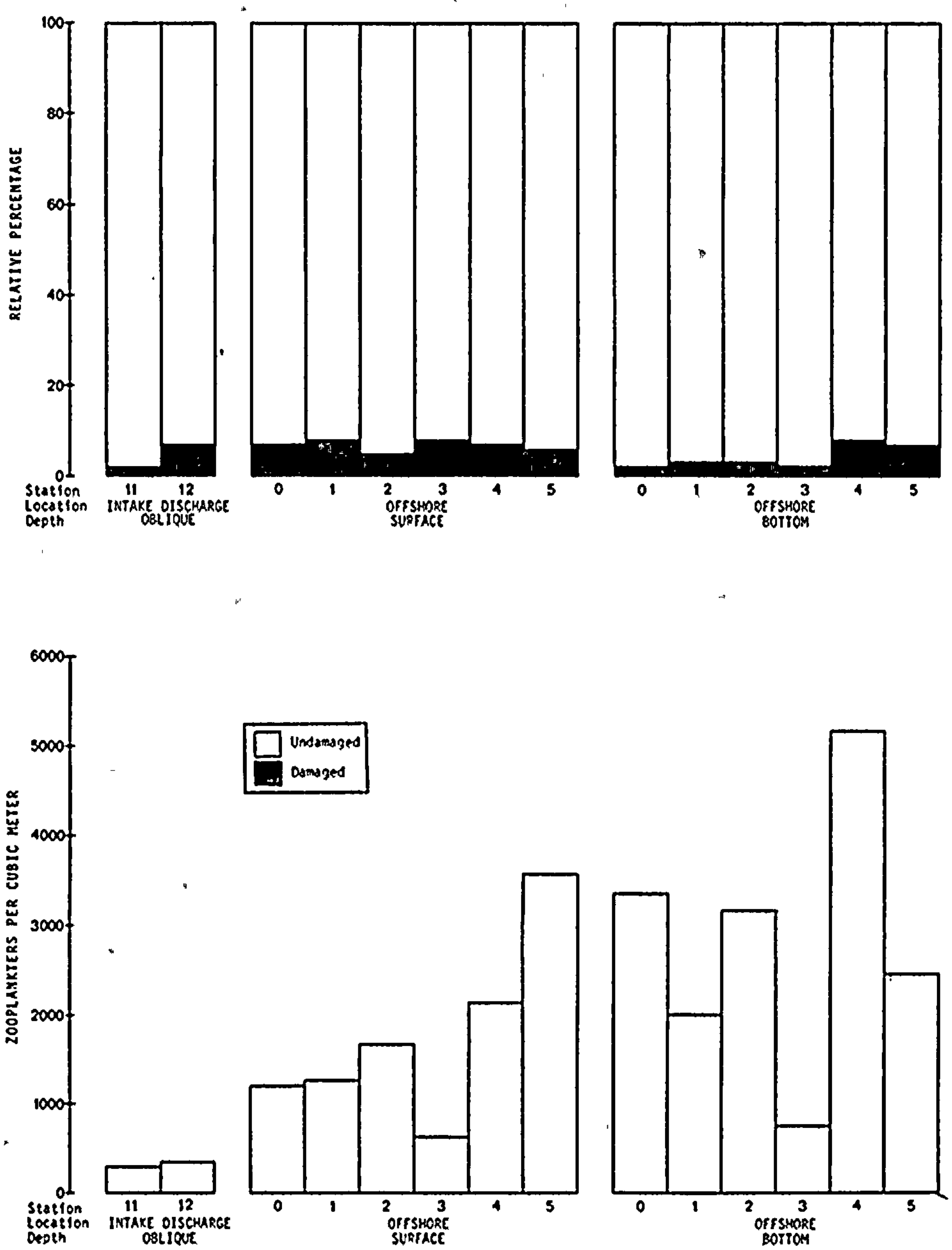


Figure E-6. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, May 1977.

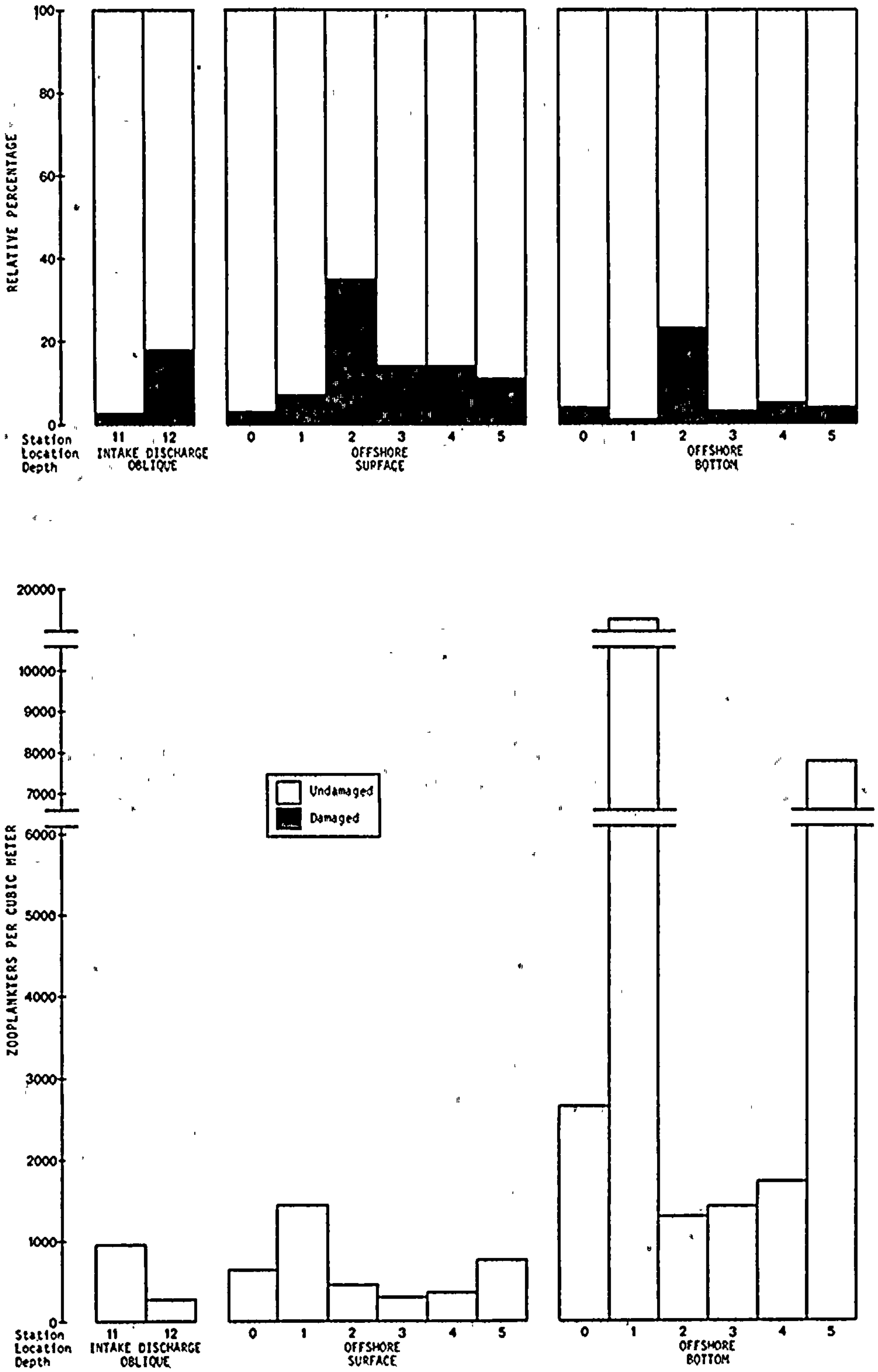


Figure E-7. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, June 1977.

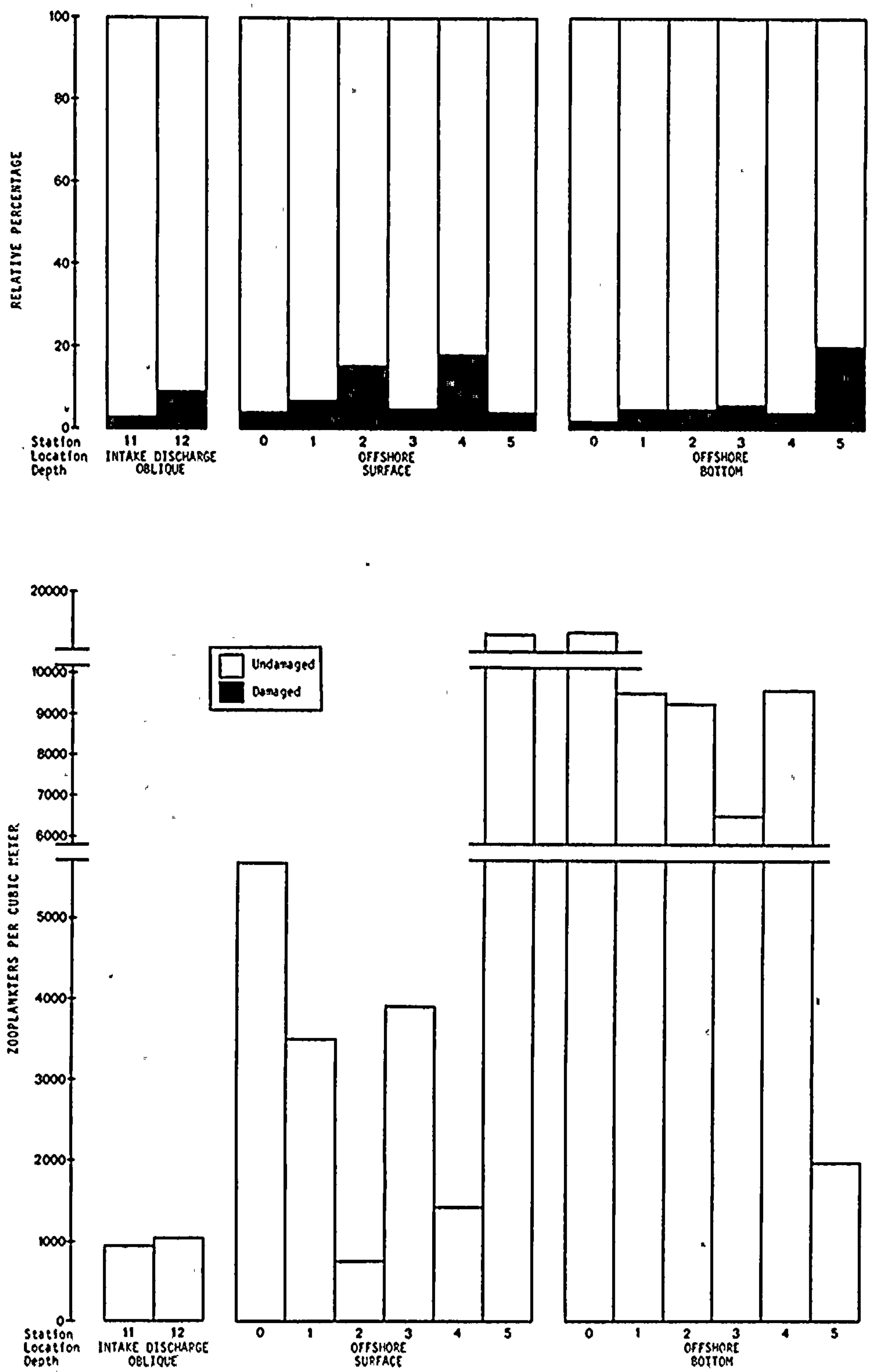
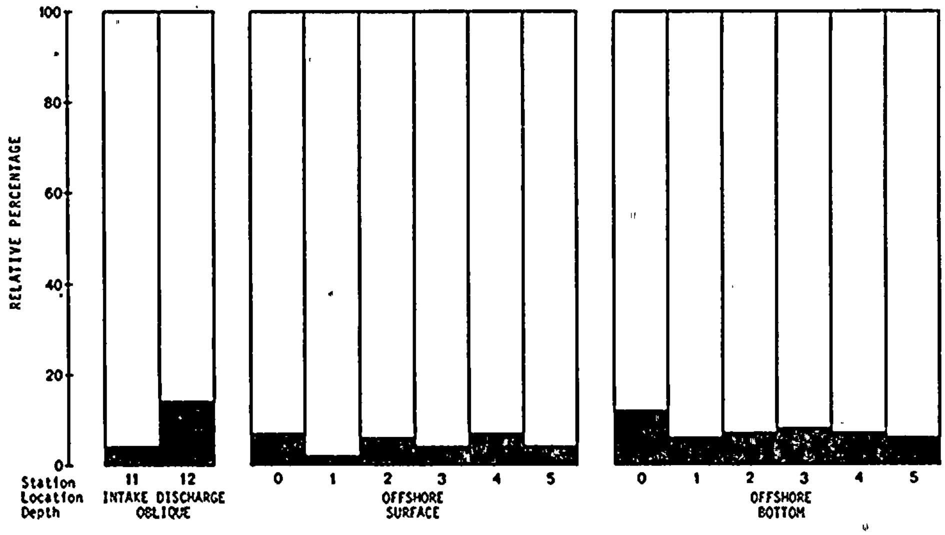


Figure E-8. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, July 1977.



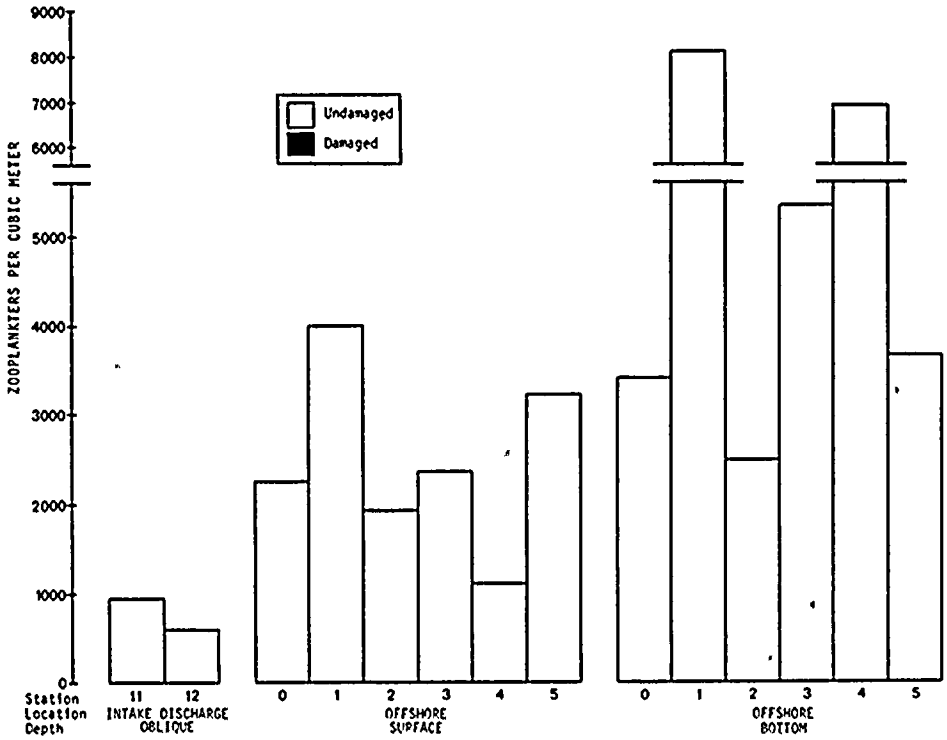


Figure E-9. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, August 1977.

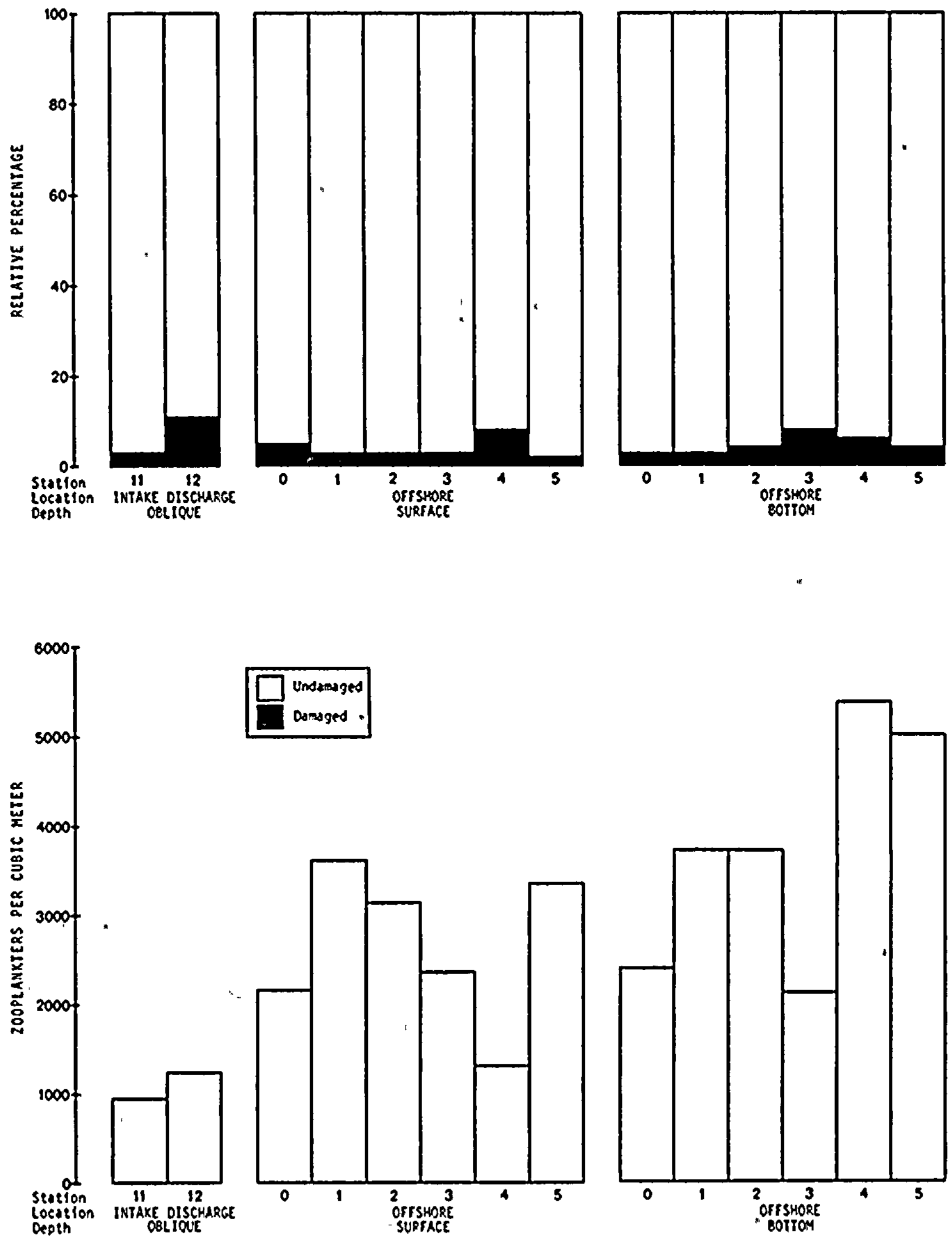


Figure E-10. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, September 1977.

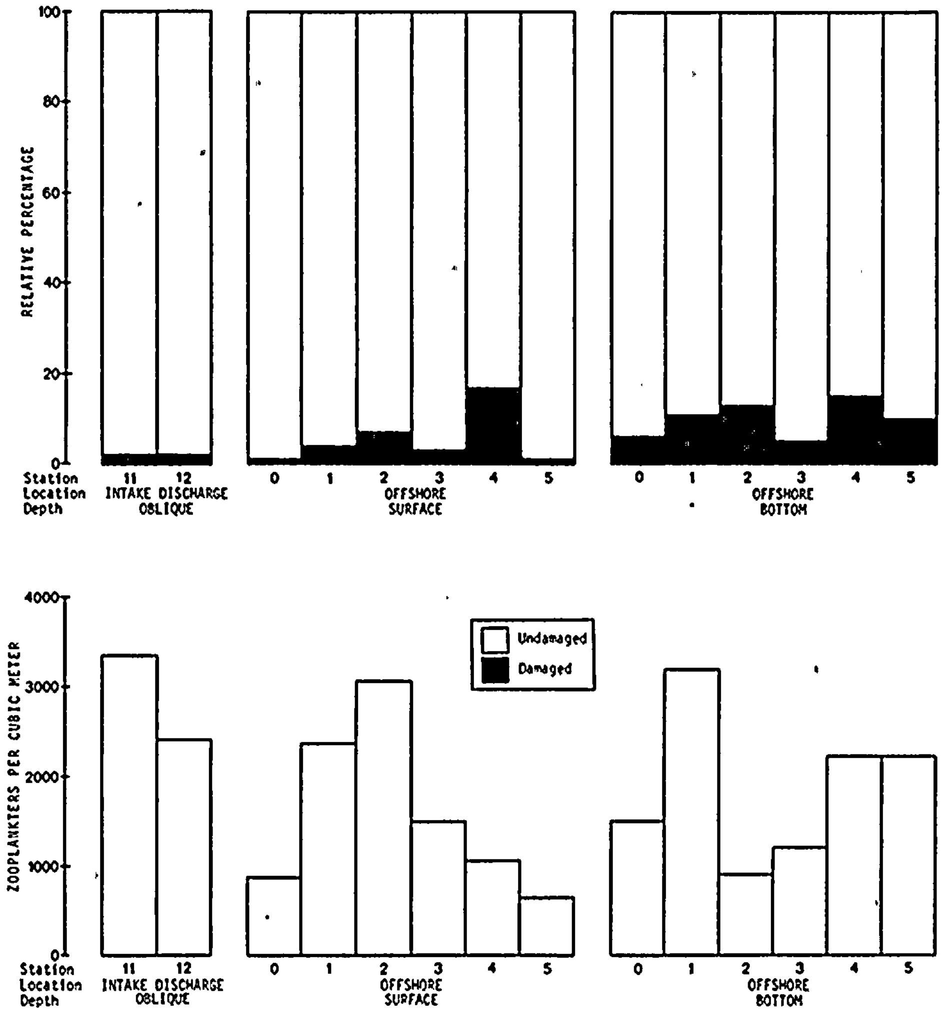


Figure E-11. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, October 1977.

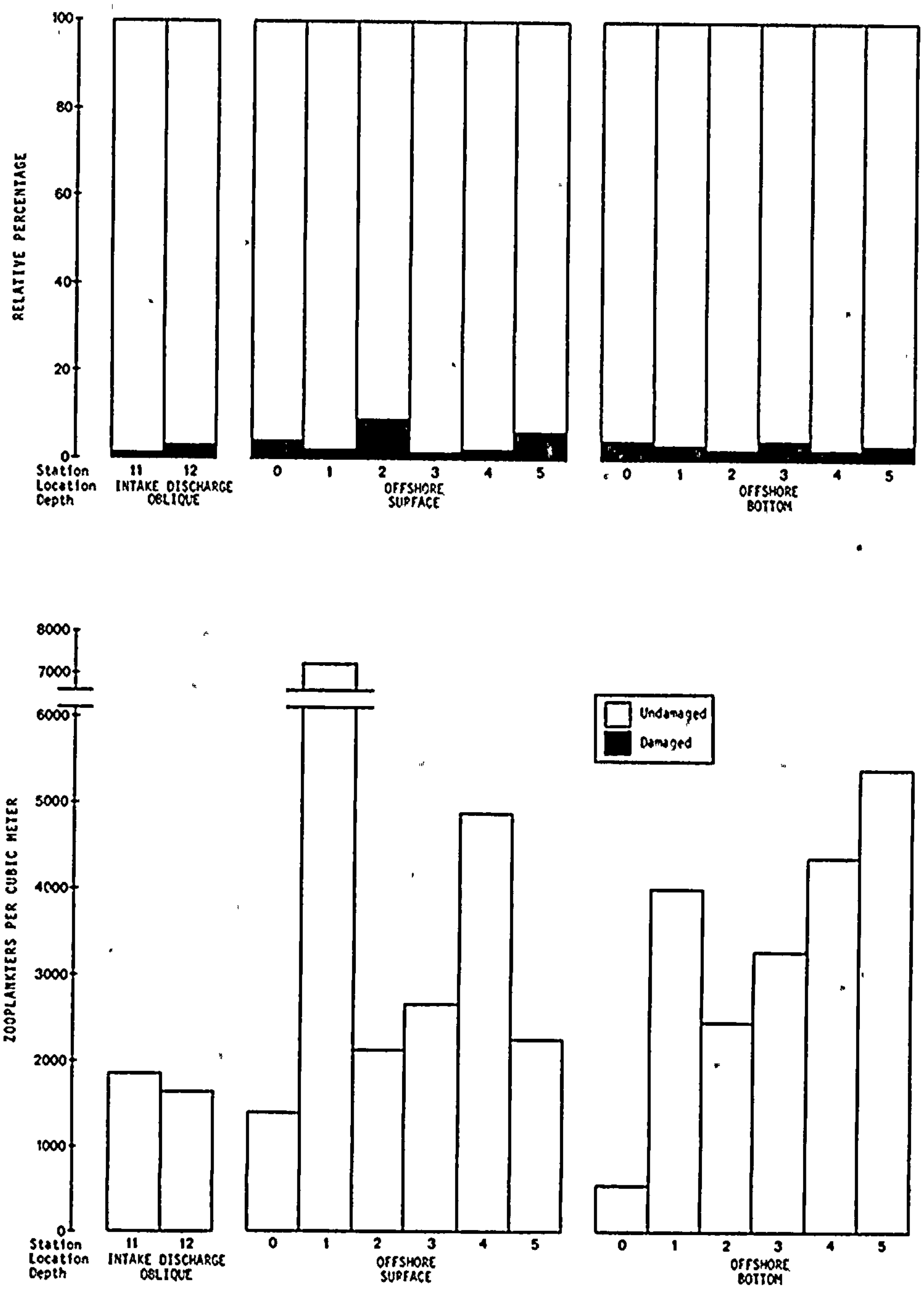


Figure E-12. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, November 1977.

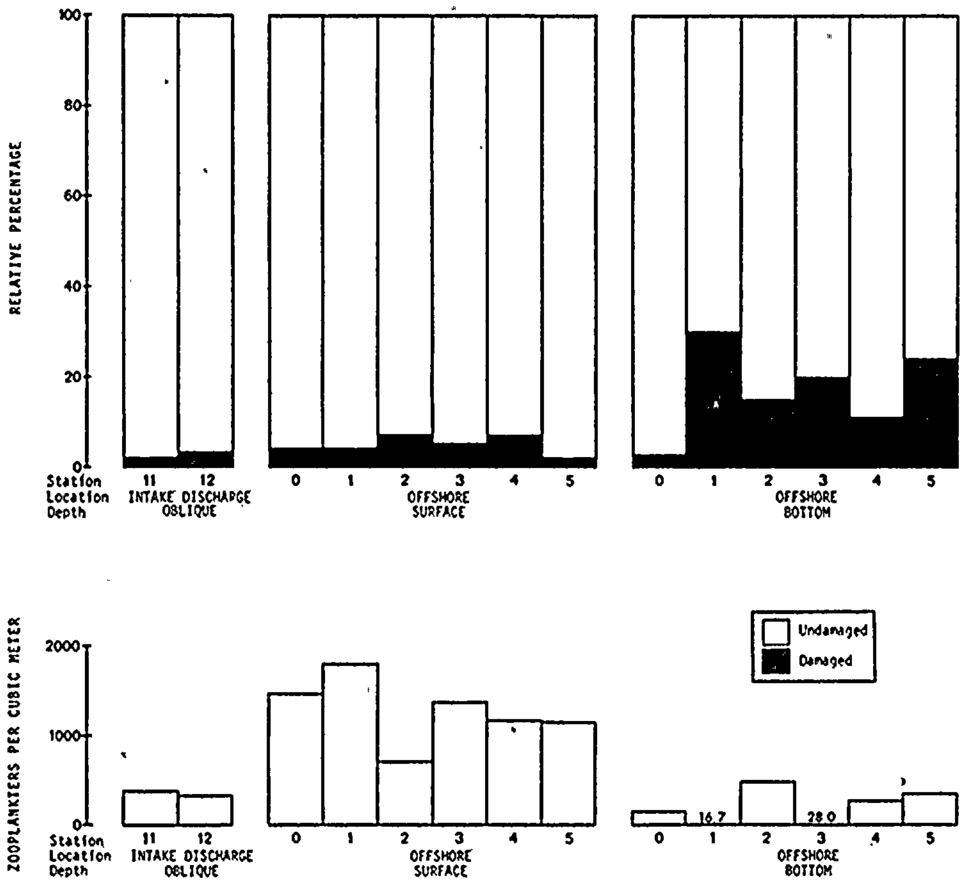


Figure E-13. Undamaged zooplankton density and relative percentages of damaged and undamaged zooplankters, St. Lucie Plant, December 1977.

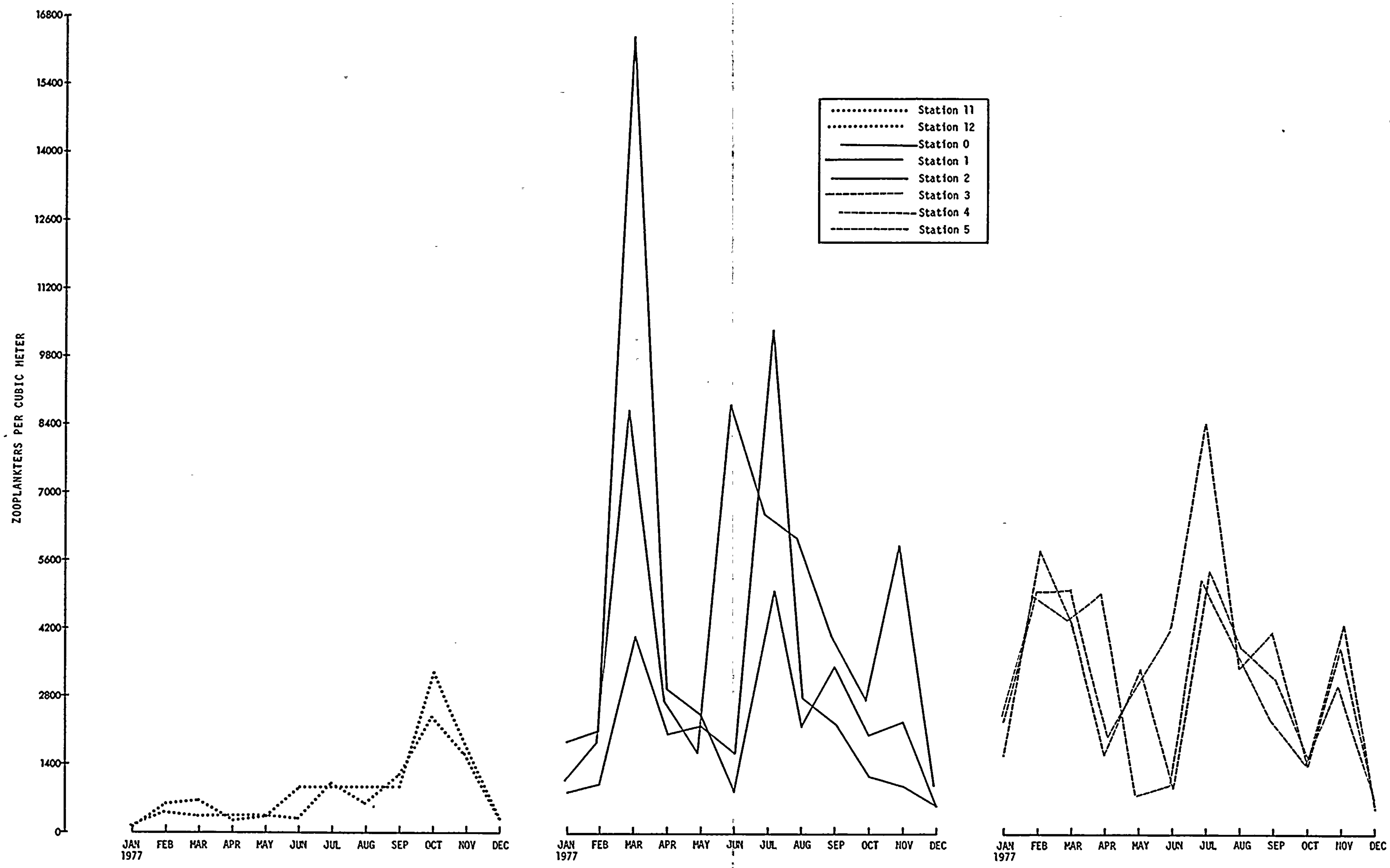


Figure E-14. Mean zooplankters per cubic meter by date and station, St. Lucie Plant, January-December 1977.

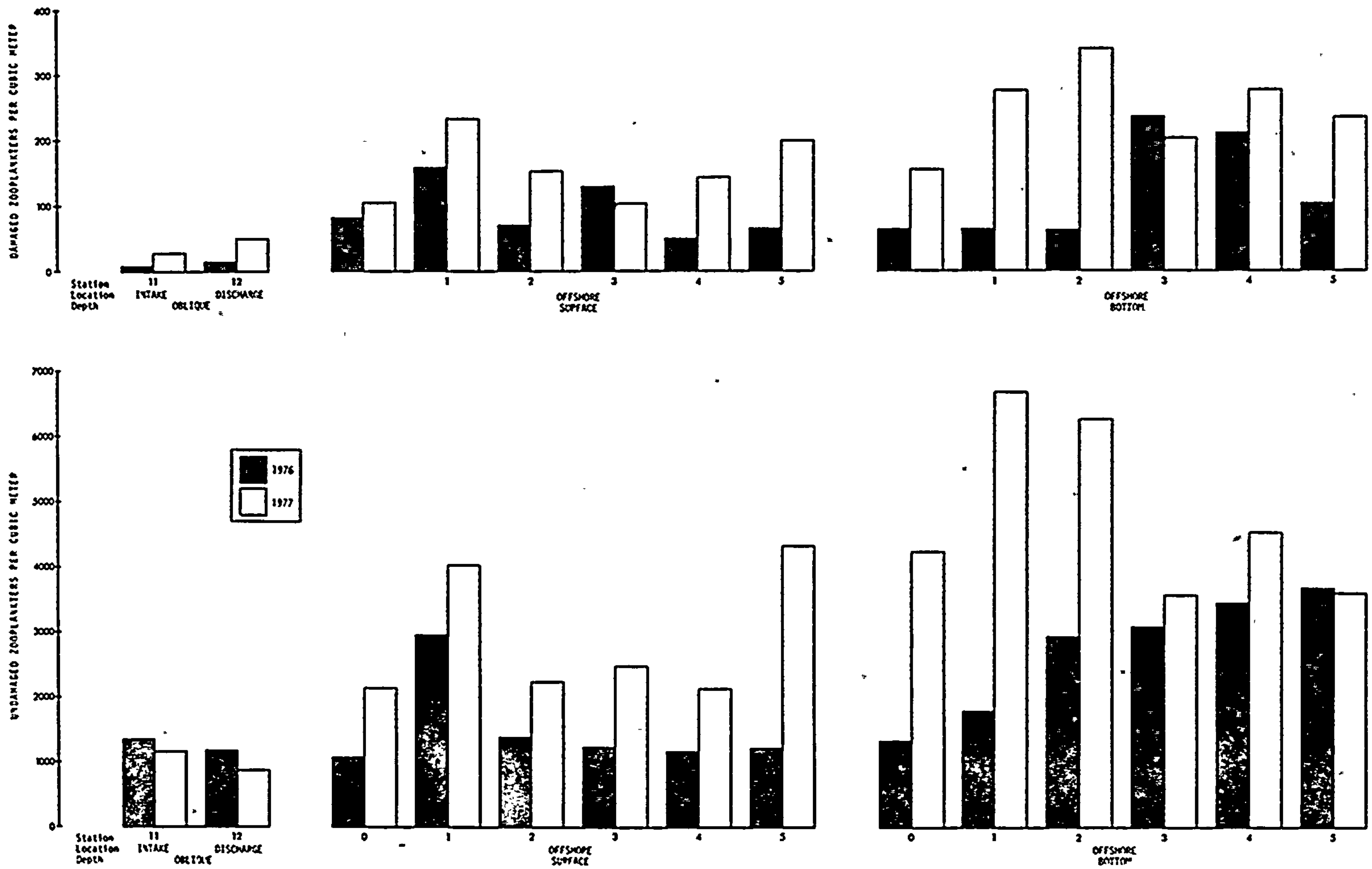


Figure E-15. Annual mean densities of undamaged and damaged zooplankton, St. Lucie Plant, 1976 and 1977.

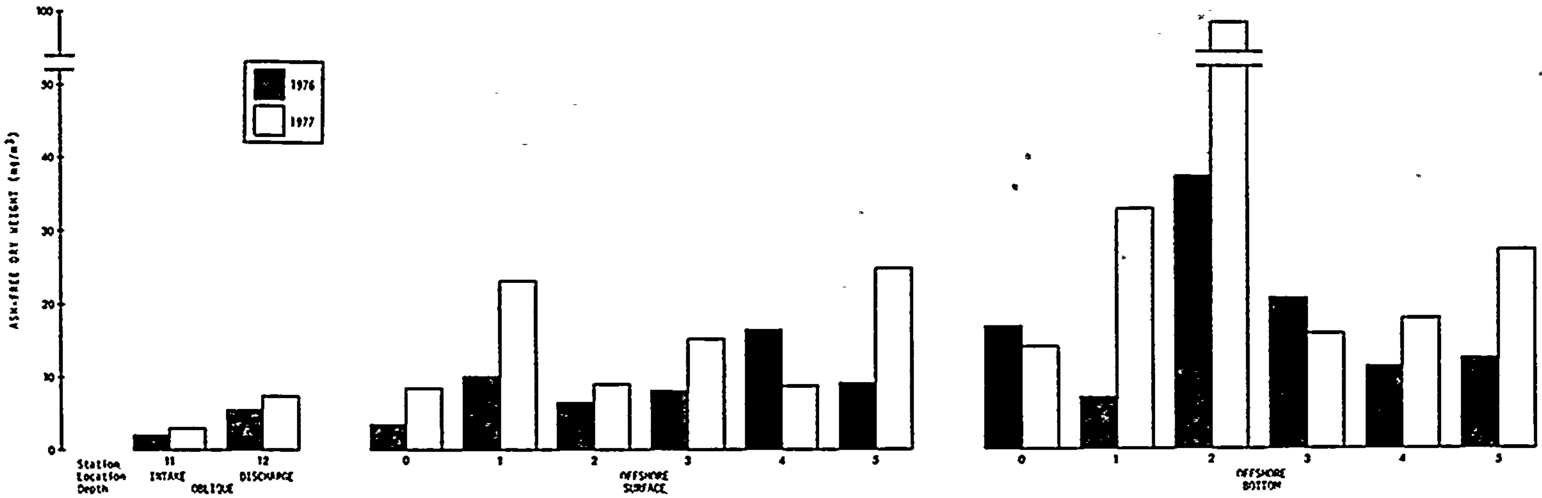


Figure E-16. Annual mean zooplankton biomass values, St. Lucie Plant, 1976 and 1977.

TABLE E-1

SUMMARY OF ZOOPLANKTON COUNTS, ZOOPLANKTON PHYSICAL CONDITION, AND INTAKE AND DISCHARGE TEMPERATURES
ST. LUCIE PLANT
JANUARY-DECEMBER 1977

	Parameters						
	Number per cubic meter[a]		% Total population damaged		Temperature (°C)		
Date	Intake	Discharge	Intake	Discharge	Intake (ambient)	Discharge (thermal)	ΔT
25 JAN	105.5	197.5	2	5	15.5	26.1	+10.6
15 FEB	567.5	459.1	3	5	21.0	32.3	+11.3
11 MAR	680.9	362.1	3	4	21.4	34.4	+13.0
20 APR	237.6	351.9	2	5	24.8	24.9	+0.1
10 MAY	310.4	349.2	2	7	24.0	34.6	+10.6
14 JUN	967.4	288.3	3	18	27.3	38.3	+11.1
12 JUL	948.8	1042.6	3	9	24.9	36.5	+11.6
23 AUG	964.8	607.6	4	14	24.8	37.5	+12.7
13 SEP	963.1	1228.3	3	11	28.9	42.0	+13.1
11 OCT	3331.2	2408.1	2	2	27.1	39.5	+12.4
2 NOV	1862.7	1630.5	1	3	24.2	35.5	+11.3
1 DEC	363.2	319.8	2	3	24.1	37.1	+13.0

[a]Values expressed are undamaged zooplankters and represent the mean of three subsamples.

TABLE E-2

ANALYSIS OF VARIANCE FOR ZOOPLANKTON DENSITIES (No./m^3)
INTAKE AND DISCHARGE STATIONS
ST. LUCIE PLANT
JANUARY-DECEMBER 1977

Undamaged				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month	11	1312610 x 10	1193282	19.31*
Station	1	17621 x 10	176208	2.85
Error	11	67962 x 10	61783	
Total	23	1398193 x 10		

Damaged				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month	11	1746839 x 10^{-2}	1588035 x 10^{-3}	1.976
Station	1	446354 x 10^{-2}	4463539 x 10^{-3}	5.554*
Error	11	884027 x 10^{-2}	803661 x 10^{-3}	
Total	23	3077220 x 10^{-2}		

*Significant at α = .05.

TABLE E-3

ANALYSIS OF VARIANCE FOR ZOOPLANKTON DENSITIES (No./m^3)
INTAKE AND DISCHARGE STATIONS
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977[a]

Undamaged				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	190051 x 10^2	4385348 x 10^2	2.95
Month (M)	9	1561384 x 10^2	173487 x 10^2	2.70
Station (S)	1	85304 x 10^2	85304 x 10^2	1.33
Y x M	9	1192182 x 10^2	132465 x 10^2	2.06
Y x S	1	51752 x 10^2	51752 x 10^2	0.805
M x S	9	535739 x 10^2	59526 x 10^2	0.925
Error	9	578885 x 10^2	64321 x 10^2	
Total	39	4195297 x 10^2		

Damaged				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	857803 x 10^{-2}	8578028 x 10^{-3}	11.11*
Month (M)	9	1010664 x 10^{-2}	1122960 x 10^{-3}	1.45
Station (S)	1	301079 x 10^{-2}	3010790 x 10^{-3}	3.90
Y x M	9	657446 x 10^{-2}	730495 x 10^{-3}	0.946
Y x S	1	200365 x 10^{-2}	2003648 x 10^{-3}	2.59
M x S	9	342877 x 10^{-2}	380974 x 10^{-3}	0.493
Error	9	695189 x 10^{-2}	772432 x 10^{-3}	
Total	39	4065423 x 10^{-2}		

[a]Analysis did not include January and February 1977.

*Significant at α = .05.

TABLE E-4

DIFFERENCES BETWEEN MEAN ZOOPLANKTON DENSITIES (No./m^3)
DAMAGED ZOOPLANKTERS, INTAKE AND DISCHARGE STATIONS
ST. LUCIE PLANT

STATION COMPARISON - JANUARY-DECEMBER 1977

Intake	Discharge	Difference
22.8	50.1	27.3*

YEAR COMPARISON - MARCH 1976-DECEMBER 1977[a]

1976	1977	Difference
12.0	41.3	29.3*

[a]Analysis includes March, May, June, October, and November, 1976 and 1977.

*Significant at α = .05.

TABLE E-5

ANALYSIS OF VARIANCE FOR ZOOPLANKTON BIOMASS (mg/m^3)
ST. LUCIE PLANT
JANUARY-DECEMBER 1977

Intake and Discharge Stations				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month	11	143.2833	13.02576	3.72*
Station	1	80.3366	80.33655	22.9*
Error	11	38.4746	3.49769	
Total	23	262.0945		

Offshore Stations				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month (M)	9	20148.17	2238.686	1.73
Station (S)	5	7532.92	1506.584	1.16
Depth (D)	1	3978.60	3978.603	3.08
M x S	45	54166.39	1203.698	0.93
M x D	9	5079.31	564.368	0.43
S x D	5	6112.52	1222.505	0.96
Error	45	58199.38	1293.319	
Total	119	155217.29		

*Significant at $\alpha = .05$.

TABLE E-6

DIFFERENCES BETWEEN MEAN ZOOPLANKTON BIOMASS (mg/m^3)
ST. LUCIE PLANT

STATION COMPARISON - INTAKE AND DISCHARGE STATIONS, JANUARY-DECEMBER 1977		
Intake	Discharge	Difference
2.8	6.5	3.7*

YEAR COMPARISON - OFFSHORE STATIONS, 1976-1977[a]		
1976	1977	Difference
13.2	24.0	10.8*

DEPTH COMPARISON - OFFSHORE STATIONS, 1976-1977[a]		
Surface	Bottom	Difference
11.8	25.3	13.5*

[a]Analysis includes March, May, June, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$.

TABLE E-7

ANALYSIS OF VARIANCE FOR ZOOPLANKTON BIOMASS (mg/m^3)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

Intake and Discharge Stations[a]

Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	13.1890	13.18897	0.047
Month (M)	8	387.8169	48.47711	1.92
Station (S)	1	9.4557	9.45565	0.37
Y x M	8	437.6901	54.71126	2.17
Y x S	1	43.4940	43.49394	1.72
M x S	8	235.7218	29.46521	1.17
Error	8	169.2625	21.15781	
Total	35	1296.6300		

Offshore Stations[b]

Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	3494.14	3494.143	8.35*
Month (M)	4	16272.06	4068.014	9.73*
Station (S)	5	8223.22	1644.644	3.98*
Depth (D)	1	5470.92	5470.922	13.08*
Y x M	4	4289.58	1072.394	2.56
Y x S	5	3707.31	741.463	1.77
Y x D	1	723.70	723.699	1.73
M x S	20	48668.23	2433.412	5.82*
M x D	4	1745.07	436.268	1.02
S x D	5	11528.24	2305.647	5.51*
Y x M x S	20	10113.11	505.655	1.21
Y x M x D	4	1408.60	352.150	0.84
Y x S x D	5	3460.86	692.172	1.66
M x S x D	20	51655.99	2582.799	6.18*
Error	20	8361.31	418.065	
Total	119	179122.06		

[a]Analysis includes March, May-December, 1976 and 1977.

[b]Analysis includes March, May, June, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$.

TABLE E-8

SIMPLE CORRELATION COEFFICIENTS (r)
FOR ZOOPLANKTON ABUNDANCE AND BIOMASS VS. PHYSICAL PARAMETERS
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

Physical parameter	SURFACE			BOTTOM		
	Biomass (mg/m^3)	Undamaged (No./m^3)	Damaged (No./m^3)	Biomass (mg/m^3)	Undamaged (No./m^3)	Damaged (No./m^3)
Temperature	0.1836*	0.1767*	0.2400*	0.0872	0.1787*	0.2886*
Temperature^2	0.1948*	0.1833*	0.2461*	0.0891	0.1958*	0.2808*
Salinity	0.0628	0.0408	-0.1220	-0.0285	0.0786	-0.0082
Salinity^2	0.0624	0.0393	-0.1231	-0.0282	0.0778	-0.0104
Dissolved oxygen	-0.1567*	-0.0759	-0.2097*	-0.0440	-0.1710*	-0.2283*
Dissolved oxygen^2	-0.1377	-0.0551	-0.1930*	-0.0325	-0.1293	-0.1988*

TABLE E-9

MULTIPLE REGRESSION ANALYSIS
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977

SURFACE			
Dependent variables	Independent variables	R	R^2
Undamaged density	Temperature^2	0.18326	0.03358
	Salinity	0.19697	0.03880
	Temperature	0.20406	0.04164
	Dissolved oxygen	0.20567	0.04230
	Dissolved oxygen^2	0.32176	0.10353
Damaged density	Temperature^2	0.24606	0.06055
	Dissolved oxygen	0.27594	0.07614
	Dissolved oxygen^2	0.33490	0.11216
	Salinity	0.34980	0.12236
Biomass	Temperature^2	0.19481	0.03795
	Temperature	0.23104	0.05338
	Dissolved oxygen	0.24806	0.06153
	Dissolved oxygen^2	0.31854	0.10147
	Salinity^2	0.32556	0.10599

BOTTOM			
Dependent variables	Independent variables	R	R^2
Undamaged density	Temperature^2	0.19098	0.03647
	Temperature	0.23912	0.05718
	Dissolved oxygen	0.26083	0.06803
	Dissolved oxygen^2	0.27852	0.07757
	Salinity	0.28560	0.08157
Damaged density	Temperature^2	0.26027	0.06774
	Dissolved oxygen	0.29218	0.08537
	Dissolved oxygen^2	0.32457	0.10535
	Salinity^2	0.32783	0.10747
	Temperature	0.32834	0.10781
Biomass	Temperature	0.08720	0.00760
	Salinity	0.08884	0.00789
	Temperature^2	0.08929	0.00797

TABLE E-10

ANALYSIS OF VARIANCE FOR ZOOPLANKTON DENSITIES (No./m^3)
UNDAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT

January-December 1977				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month (M)	11	4913657 x 10^2	4466960 x 10^1	4.29*
Station (S)	5	4678502 x 10^1	9357003	0.90
Depth (D)	1	7086271 x 10^1	7086270 x 10^1	6.81*
M x S	55	4533187 x 10^2	8242158	0.79
M x D	11	1118091 x 10^2	1016446 x 10^1	0.98
S x D	5	3589220 x 10^1	7178439	0.69
Error	55	5722304 x 10^2	1040419 x 10^1	
Total	143	1782264 x 10^3		

March 1976-December 1977[a]				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	1447572 x 10^2	1447572 x 10^2	18.57*
Month (M)	7	3146341 x 10^2	4494771 x 10^1	5.77*
Station (S)	5	5491369 x 10^1	1098274 x 10^1	1.41
Depth (D)	1	1177965 x 10^2	1177965 x 10^2	15.11*
Y x M	7	1548944 x 10^2	2212776 x 10^1	2.84*
Y x S	5	2414415 x 10^1	4828830	0.62
Y x D	1	6248683	6248683	0.80
M x S	35	2562377 x 10^2	7321078	0.94
M x D	7	5639042 x 10^1	8055773	1.03
S x D	5	2660252 x 10^1	5320503	0.68
Y x M x S	35	3393227 x 10^2	9694933	1.24
Y x M x D	7	5109795 x 10^1	7299707	0.94
Y x S x D	5	6274066 x 10^1	1254813 x 10^1	1.61
M x S x D	35	3947313 x 10^2	1127804 x 10^1	1.45
Error	35	2728689 x 10^2	7796253	
Total	191	2277381 x 10^3		

[a]Analysis includes March-August, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$.

TABLE E-11

DIFFERENCES BETWEEN MONTHLY MEAN ZOOPLANKTON DENSITIES (No./m^3)
UNDAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
JANUARY-DECEMBER 1977

Month (Mean)	FEB (3675.5)	MAR (7160.2)	APR (2730.1)	MAY (2289.2)	JUN (2923.6)	JUL (6867.6)	AUG (3727.0)	SEP (3194.0)	OCT (1731.9)	NOV (3383.9)	DEC (742.3)
JAN (1715.3)	1960.2	5444.9*	1014.8	573.9	1208.3	5152.3*	2011.7	1478.7	16.6	1668.6	973.0
FEB (3675.5)		3484.7	945.4	1386.3	751.9	3192.1	51.5	481.5	1943.6	291.6	2933.2
MAR (7160.2)			4430.1	4871.0*	4236.6	292.6	3433.2	3966.2	5428.3*	3776.3	6417.9*
APR (2730.1)				440.9	193.5	4137.5	996.9	463.9	998.2	653.8	1987.8
MAY (2289.2)					634.4	4578.4*	1437.8	904.8	557.3	1094.7	1546.9
JUN (2923.6)						3944.0	803.4	270.4	1191.7	460.3	2181.3
JUL (6867.6)							3140.6	3673.6	5135.7*	3483.7	6125.3*
AUG (3727.0)								533.0	1995.1	343.1	2984.7
SEP (3194.0)									1462.1	189.9	2451.7
OCT (1731.9)										1652.0	989.6
NOV (3383.9)											2641.6

*Significant at $\alpha = .05$, Tukey's HSD = 4497.

TABLE E- 12

DIFFERENCES BETWEEN MEAN ZOOPLANKTON DENSITIES (No./m^3)
UMDAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977[a]

Annual		
1976	1977	Difference
2115.1	3851.7	1736.6*

Monthly							
Month (Mean)	APR (2152.1)	MAY (1384.3)	JUN (2166.4)	JUL (5067.3)	AUG (4026.8)	OCT (1813.2)	NOV (2744.9)
MAR (4512.0)	2359.9	3127.7*	2345.6	555.3	485.2	2698.8*	1767.1
APR (2152.1)		767.8	14.3	2915.2*	1874.7	338.9	592.8
MAY (1384.3)			782.1	3683.0*	2642.5*	428.9	1360.6
JUN (2166.4)				2900.9*	1860.4	353.2	578.5
JUL (5067.3)					1040.5	3254.1*	2322.4
AUG (4026.8)						2213.6	1281.9
OCT (1813.2)							931.7

[a]Analysis includes March-August, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$, Tukey's HSD = 2599.

TABLE E-13

DIFFERENCES BETWEEN MONTHLY MEAN ZOOPLANKTON BIOMASS (mg/m^3)
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977[a]

Month (Mean)	MAY (14.8)	JUN (14.9)	OCT (10.3)	NOV (11.3)
MAR (41.6)	26.8*	26.7*	31.3*	30.3*
MAY (14.8)		1.0	4.5	3.5
JUN (14.9)			4.6	3.6
OCT (10.3)				1.0

[a]Analysis includes March, May, June, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$, Tukey's HSD = 17.65.

TABLE E-14

ANALYSIS OF VARIANCE FOR ZOOPLANKTON DENSITIES (No./m^3)
DAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT

January-December 1977				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Month (M)	11	1146225	1042023×10^{-1}	5.02*
Station (S)	5	1563108×10^{-1}	3126216×10^{-2}	1.51
Depth (D)	1	1750422×10^{-1}	1750421×10^{-1}	8.43*
M x S	55	1085215	1973119×10^{-2}	0.95
M x D	11	3186992×10^{-1}	2897265×10^{-2}	1.40
S x D	5	6166812×10^{-2}	1233362×10^{-2}	0.59
Error	55	1141838	2076069×10^{-2}	
Total	143	4084998		

March 1976-December 1977[a]				
Source	Degrees of freedom	Sum of Squares	Mean Square	F
Year (Y)	1	4211548×10^{-1}	4211548×10^{-1}	19.90*
Month (M)	7	1577242	2253203×10^{-1}	10.65*
Station (S)	5	1302098×10^{-1}	2604196×10^{-2}	1.23
Depth (D)	1	1744958×10^{-1}	1744958×10^{-1}	8.25*
Y x M	7	7521925×10^{-1}	1074561×10^{-1}	5.08*
Y x S	5	2208114×10^{-1}	4416227×10^{-2}	2.09
Y x D	1	4391729×10^{-2}	4391729×10^{-2}	2.08
M x S	35	1400134	4000382×10^{-2}	1.89*
M x D	7	1875611×10^{-1}	2679444×10^{-2}	1.27
S x D	5	1587400×10^{-1}	3174800×10^{-2}	1.50
Y x M x S	35	1098996	3139989×10^{-2}	1.48
Y x M x D	7	1525898×10^{-1}	2179855×10^{-2}	1.03
Y x S x D	5	7803405×10^{-2}	1560681×10^{-2}	0.74
M x S x D	35	1062547	3035849×10^{-2}	1.43
Error	35	7406280×10^{-1}	2116080×10^{-2}	
Total	191	8199254		

[a]Analysis includes March-August, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$.

TABLE E-15

DIFFERENCES BETWEEN MONTHLY MEAN ZOOPLANKTON DENSITIES (No./m^3)
DAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
JANUARY-DECEMBER 1977

Month (Mean)	FEB (79.2)	MAR (259.1)	ARP (193.5)	MAY (128.4)	JUN (144.7)	JUL (365.3)	AUG (258.3)	SEP (131.5)	OCT (162.2)	NOV (106.9)	DEC (50.7)
JAN (62.5)	16.7	196.6	131.0	65.9	82.2	302.8*	195.8	69.0	99.7	44.4	11.8
FEB (79.2)		179.9	114.3	49.2	65.5	286.1*	179.1	52.3	83.0	27.7	28.5
MAR (259.1)			65.6	130.7	114.4	106.2	0.8	127.6	96.9	152.2	208.4*
APR (193.5)				65.1	48.8	171.8	64.8	62.0	31.3	86.6	142.8
MAY (128.4)					16.3	236.9*	129.9	3.1	33.8	21.5	77.7
JUN (144.7)						220.6*	113.6	13.2	17.5	37.8	94.0
JUL (365.3)							107.0	233.8*	203.1*	258.4*	314.6*
AUG (258.3)								126.8	96.1	151.4	207.6*
SEP (131.5)									30.7	24.6	80.8
OCT (162.2)										55.3	111.5
NOV (106.9)											56.2

*Significant at $\alpha = .05$, Tukey's HSD = 201.

TABLE E-16

DIFFERENCES BETWEEN MONTHLY MEAN ZOOPLANKTON DENSITIES (No./m^3)
DAMAGED ZOOPLANKTERS, OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT
MARCH 1976 - DECEMBER 1977[a]

Month (Mean)	APR (118.2)	MAY (82.7)	JUN (82.0)	JUL (225.0)	AUG (355.3)	OCT (114.8)	NOV (77.1)
MAR (188.6)	70.4	105.9	106.6	36.4	166.7*	73.8	111.5
APR (118.2)		35.5	36.2	106.8	237.1*	3.4	41.1
MAY (82.7)			0.7	142.3*	272.6*	32.1	5.6
JUN (82.0)				143.0*	273.3*	32.8	4.9
JUL (225.0)					130.3	110.2	147.9*
AUG (355.3)						240.5*	278.2*
OCT (114.8)							37.7

[a]Analysis includes March-August, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$, Tukey's HSD = 135.4.

TABLE E-17

DIFFERENCES BETWEEN SURFACE AND BOTTOM MEAN ZOOPLANKTON DENSITIES (No./m^3)
OFFSHORE STATIONS (0-5)
ST. LUCIE PLANT

Undamaged zooplankters			
Date	Surface	Bottom	Difference
January - December 1977	2643.5	4046.5	1403.0*
March 1976 - December 1977[a]	2200.1	3766.7	1566.6*

Damaged zooplankters			
Date	Surface	Bottom	Difference
January - December 1977	127.0	196.7	69.7*
March 1976 - December 1977[a]	125.3	185.6	60.3*

[a]Analysis includes March-August, October, and November, 1976 and 1977.

*Significant at $\alpha = .05$.

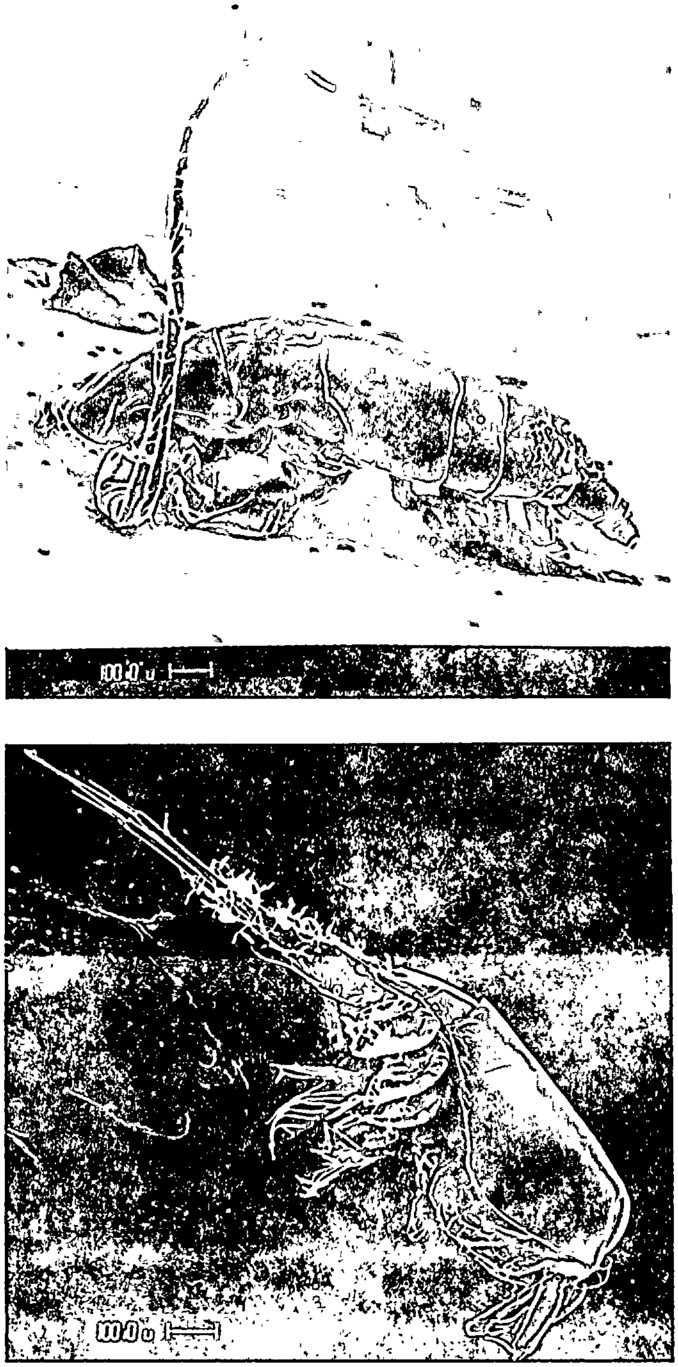


Plate 1. Copepods (scanning electron micrograph).

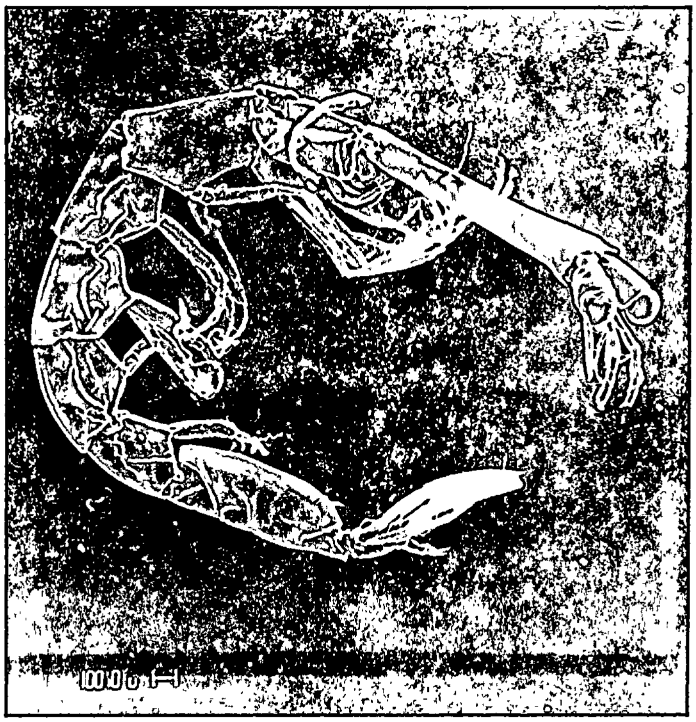


Plate 2. *Lucifer faxoni* (scanning electron micrograph).

F. AQUATIC MACROPHYTES

INTRODUCTION

The offshore aquatic benthic macrophytes were sampled to determine if the operation of the St. Lucie Plant was affecting this community. The term "aquatic macrophytes" refers to aquatic plants large enough to be seen with the unaided eye. In the marine environment this includes the seaweeds and seagrasses. Marine plants grow in many habitats, but their distribution is limited by the availability of light, substrate and oxygen.

Most marine plants are found from the intertidal zone to depths of 30 to 40 meters. Beyond this depth there is usually insufficient light for photosynthesis due to the light-absorbing properties of seawater (Dawson, 1966). Red algae, however, are adapted to low light levels and have been dredged from depths of 170 meters in clear tropical water (McConnaughey, 1970).

Marine macrophytes usually require a hard substrate for attachment and therefore seaweed is rarely found growing in shifting sands or soft mud. Along the east coast of Florida, seaweed is found on rock outcroppings, worm reefs, shell rubble, and artificial substrates. Algae are usually sparse on and near coral reefs due to grazing by herbivorous reef fish.

Water temperature may limit the growth of marine plants directly by affecting the rate of photosynthesis and indirectly by altering the solubility of oxygen in the water. As a result, many marine plants tolerate only a narrow temperature range (Dawson, 1966).

MATERIALS AND METHODS

Aquatic macrophytes were collected on 14 March, 2 June, 7 September, and 4 December at each of the six offshore stations during 1977 (Figure F-1). Each sample was collected by towing a box-type dredge (46 cm x 46 cm x 25 cm) along the ocean bottom for five minutes. The speed of each tow was recorded and used to compute the surface area sampled. Depending on tow speeds, the approximate area sampled ranged from 175-200 m^2. Duplicate samples were taken at each station and preserved with a buffered 5% formalin-seawater solution in labeled containers.

The preserved samples were sorted in the laboratory, and attached macrophytes were scraped from shell and rubble surfaces. Macrophytes were identified to the lowest possible taxon, and representative material was retained as voucher specimens. Species identifications were according to Taylor (1960).

RESULTS AND DISCUSSION

Quantitative analyses were not conducted because insufficient algae was collected. Only qualitative species lists were prepared for each sample.

The offshore stations, 0 to 5 (Figure F-1), are open areas of shell hash with very little hard substrate for algal attachment. All of the algae collected were found on rubble and shell fragments. The algae were often torn or stunted, probably due to mechanical damage from the dredge, ocean currents, or the unstable substrate.

Twenty-eight species of algae were collected during 1977 (Table F-1). The Rhodophyta, or red algae, is the largest and most diverse group of marine plants and comprised 46% of the species collected. This distribution is normal because almost all red algae are benthic, attached forms (Dawson, 1966), and the dredge method of collecting macrophytes selects for attached algae. The bushy red algae of the genera *Agardhiella* and *Gracilaria* have strong disklike holdfasts as young plants and were often found attached to shells and rocks.

Subtropical and tropical algal associations typically show seasonal variations. Species diversity and abundance are usually greatest in summer and early fall. Hutchinson Island is located in the subtropical zone (Phillips, 1961) and the algae reflect the characteristic seasonal trends of this latitude. Small amounts of algae were found only at Station 1 in March (Table F-2). Algae was collected at all stations in June (Table F-3) and at all stations except Station 5 in September (Table F-4). Algal diversity decreased in December and algae was collected only at Stations 4 and 5 (Table F-5). During 1976 (ABI, 1977) and 1977, algal diversity was lowest

in March and highest in September. The June 1977 samples, however, were more diverse than those from June 1976. Reproductive algae were collected in September.

No differences in the number of algal species collected were noted between stations. The only trend noted during the study was the seasonal decrease of algal diversity during the winter and early spring months. This trend is unrelated to power plant operation.

Algal growth at all stations is limited primarily by the lack of substrate. Benthic algae in this offshore area are not important primary producers. The open shifting ocean floor off Hutchinson Island is not a productive area for algae, and material collected was therefore insufficient to make a quantitative evaluation of the benthic macrophyte community. No power plant operation effects were noted on the offshore macrophyte community.

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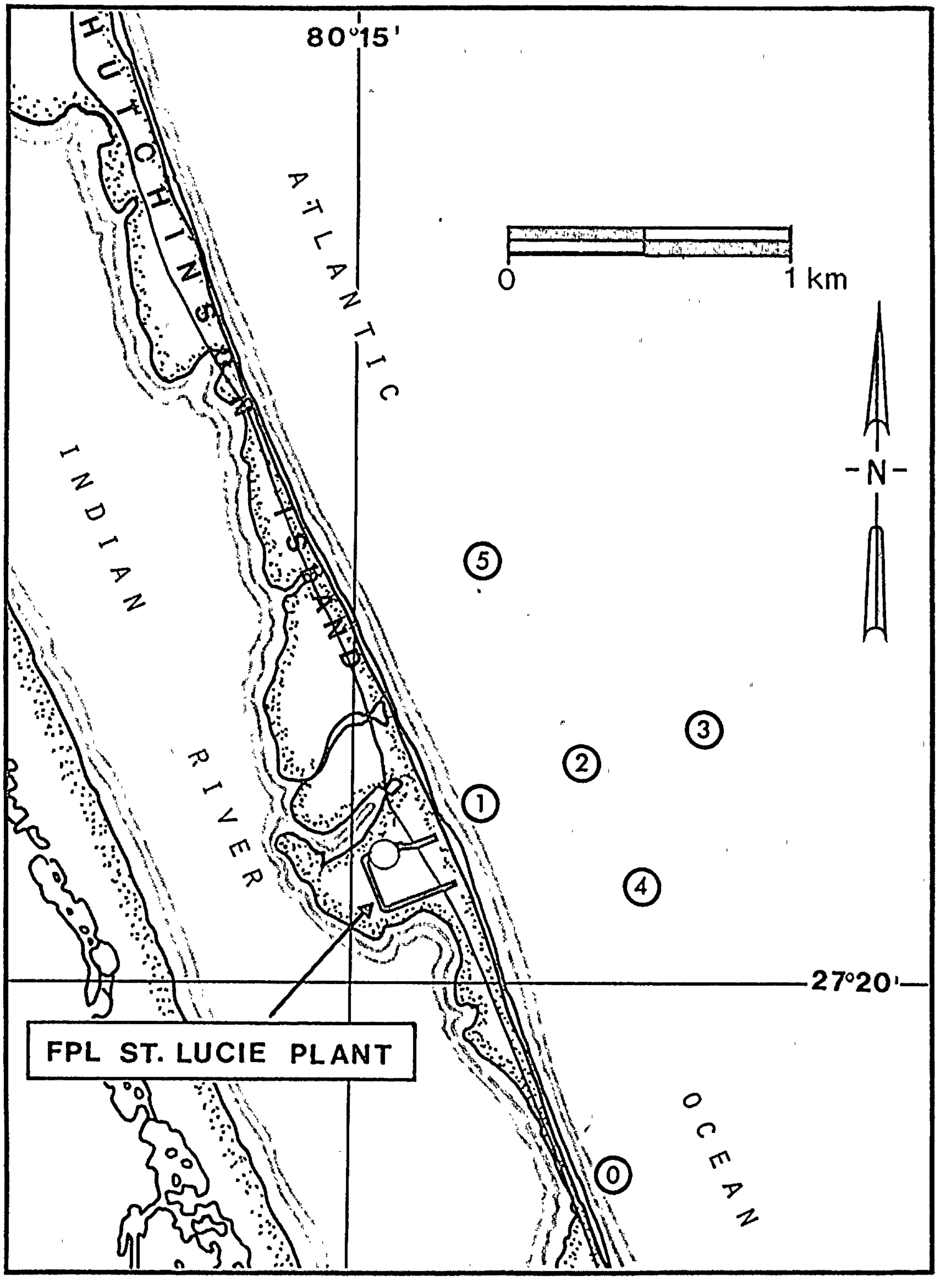

Figure F-1. Locations of macrophyte sampling stations, 1977.

TABLE F-1

MACROPHYTE SPECIES COLLECTED BY DREDGE AT OFFSHORE STATIONS
ST. LUCIE PLANT
1977

CHLOROPHYTA (green algae)
- *Chaetomorpha* sp.
- *Cladophora* sp.
- *Cladophoropsis* sp.
- *Codium decorticatum*
- *C. isthmocladum*
- *Halicystis* sp.
- *Lyngbya* sp.
- *Rhizoclonium* sp.
- *Ulothrix* sp.
- *Ulva lactuca*

PHAEOPHYTA (brown algae)
- *Dictyota* sp.
- *Dilophus guineensis*
- *Ectocarpus rhodochortonoides*
- *Sargassum* sp.
- *Sphacelaria furcigera*

RHODOPHYTA (red algae)
- *Acanthophora spicifera*
- *Ceramium* sp.
- *Chondria* sp.
- *Eucheuma* sp.
- *Gracilaria* sp.
- *Grateloupia* sp.
- *Halymenia* sp.
- *Hypnea* sp.
- *Laurencia* sp.
- *Polysiphonia subtilissima*
- *Polysiphonia* sp.
- *Soliera* sp.
- *Wrangelia* sp.

TABLE F-2

MACROPHYTE SAMPLING RESULTS
ST. LUCIE PLANT
14 MARCH 1977[a]

Station	Species
0	no algae collected
1	*Eucheuma* sp. *Ulothrix* sp.
2	no algae collected
3	no algae collected
4	no algae collected
5	no algae collected

[a] Two replicates per station, approximate area sampled was 175 m^2 per replicate.

TABLE F-3

MACROPHYTE SAMPLING RESULTS
ST. LUCIE PLANT
2 JUNE 1977[a]

Station	Species
0	*Ceramium* sp.
	Chaetomorpha sp.
	Cladophora sp.
	Codium isthmocladium
	Dictyota sp.
	Lyngbya sp.
	Rhizoclonium sp.
1	*Polysiphonia* sp.
	Dictyota sp.
	Lyngbya sp.
2	*Ceramium* sp.
	Chaetomorpha sp.
	Codium sp.
	Dictyota sp.
	Hypnea sp.
	Polysiphonia sp.
	Sargassum sp.
	Soliera sp.
3	*Halicystis* sp.
	Polysiphonia sp.
	Sargassum sp.
	Soliera sp.
4	*Cladophora* sp.
	Cladophoropsis sp.
	Dictyota sp.
	Polysiphonia sp.
	Rhizoclonium sp.
	Soliera sp.
5	*Acanthophera spicifera*
	Chaetomorpha sp.
	Cladophora sp.
	Ectocarpus rhodochortonoides
	Laurencia sp.
	Sphacelaria furcigera

a Two replicates per station, approximate area sampled was 190 m^2 per replicate.

TABLE F-4

MACROPHYTE SAMPLING RESULTS
ST. LUCIE PLANT
7 SEPTEMBER 1977[a]

Station	Species
0	*Cladophora* sp.
	Codium decorticatum
	Dilophus guineensis
	Grateloupia sp.
	Polysiphonia subtilissima
	Soliera sp.
	Sphacelaria furcigera
	Ulva lactuca
1	*Ceramium* sp.
	Cladophora sp.
	Codium decorticatum
	Halymenia sp.
	Soliera sp.
	Ulva lactuca
2	*Ceramium* sp.
	Chondria sp.
	Cladophora sp.
	Codium decorticatum
	C. isthmocladium
	Dilophus guianeensis
	Eucheuma sp.
	Gracilaria sp.
	Halymenia sp.
	Laurencia sp.
	Polysiphonia sp.
	Rhizoclonium sp.
	Sargassum sp.
	Soliera sp.
	Sphacelaria furcigera
3	*Ceramium* sp.
	Codium decorticatum
	Dilophus guineensis
	Laurencia sp.
	Sphacelaria furcigera

[a] Two replicates per station, approximate area sampled was 190 m^2 per replicate.

TABLE F-4
(continued)

MACROPHYTE SAMPLING RESULTS
ST. LUCIE PLANT
7 SEPTEMBER 1977[a]

Station	Species
4	*Ceramium* sp.
	Cladophora sp.
	Codium decorticatum
	Dilophus sp.
	Eucheuma sp.
	Gracilaria sp.
	Halymenia sp.
	Polysiphonia sp.
	Rhizoclonium sp.
	Sphacelaria furcigera
	Ulva lactuca
5	no algae collected

[a] Two replicates per station, approximate area sampled was 190 m^2 per replicate.

TABLE F-5

MACROPHYTE SAMPLING RESULTS
ST. LUCIE PLANT
4 DECEMBER 1977[a]

Station	Species
0	no algae collected
1	no algae collected
2	no algae collected
3	no algae collected
4	*Ceramium* sp. *Chaetomorpha* sp. *Rhizoclonium* sp. *Wrangelia* sp.
5	*Sargassum* sp.

[a] Two replicates per station, approximate area sampled was 200 m^2 per replicate.

G. WATER QUALITY

INTRODUCTION

This study was designed to monitor the physical and chemical parameters of the aquatic habitat at the St. Lucie Plant. The study of physical and chemical parameters provides a measure of water quality and potential productivity. Water quality measurements integrated with biological data provide a unified view of the ecosystem and facilitate the examination of the relationship between the environment and the marine fauna.

The presence of biologically important micronutrients such as inorganic nitrogen species, silicates, phosphates, and total organic carbon is essential for the growth of phytoplankton populations (Yentsch, 1962). Salinity and temperature are also important to the stability and growth of sedentary and motile fauna. Variations in these parameters may cause changes in the metabolism of organisms. Thus, temperature, salinity, and nutrients often have a synergistic effect on the physiological state of marine fauna.

PHYSICAL PARAMETERS

Materials and Methods

Physical oceanographic parameters, including water temperature, salinity, dissolved oxygen, turbidity and percent transmittance

of light, were measured at designated offshore stations at surface, middle, and bottom depths. Stations located within the canals were sampled for temperature, salinity, dissolved oxygen and turbidity at surface and bottom depths. Station locations are indicated on Figure G-1, and parameters measured at each station are given in Table G-1.

Water Temperature Monitoring (continuous)

Ryan-Peabody thermographs were calibrated by comparing meter readings with mercury-in-glass thermometers. Calibrations were made at the beginning and end of a one-month recording period. Thermographs were placed in the water adjacent to the offshore intake and discharge structures at subsurface depths. Data were recorded in °F.

Water Temperature Monitoring (*in situ*)

Water temperatures were recorded *in situ* at biological sampling stations with a Yellow Springs Instrument (YSI) Model 33 salinity, conductivity, and temperature meter. Data were recorded in °C.

Salinity

Salinity was measured by one of two methods:

1. A YSI salinity-conductivity-temperature meter Model 33 with a 50-foot cable and probe was calibrated prior to use by immersion in water containing known amounts of

commercial artificial sea salts. Salinity data were recorded in the field as parts per thousand (°/₀₀).

2. An American Optical refractometer (Model 10419 Goldberg, Temperature Compensating) was calibrated from stock solutions of known sea-salt concentrations. Data were recorded in °/₀₀ in the laboratory.

Dissolved Oxygen

A YSI Model 54 or 51B meter with a 50-foot cable and probe was calibrated by readings taken from oxygen-saturated sea water. Data were recorded from readings *in situ*, at designated depths, in ppm (mg/l).

Turbidity

Water turbidity was measured with either an Interocean Model 515 TR turbidity meter or a Hellige Turbidimeter. Accuracy of the Interocean meter was determined by calibrating the probe which was immersed in distilled water. The Hellige meter was precalibrated by the manufacturer. Offshore turbidity was measured *in situ*, whereas canal samples were returned to the laboratory for analysis. Turbidity was measured as a function of light attentuation over a fixed path length as recommended by EPA (1974). Data were expressed as percent transmittance of light.

Conventional units of turbidity are based upon FTU (Formazine Turbidity Units) and may be related to percent transmittance values by the following:

$$\% \text{ Transmittance} = ae^{bx}$$

where: a = 99.69

b = -0.0254,

and x = FTU (Formazine Turbidity Units).

Luminosity (Light Transmittance)

Luminosity (light transmittance through the water column) was recorded with an Interocean Marine Illuminance Meter Model 510 at offshore stations. Comparisons between incident solar radiation at the surface and at various depths were recorded as luminosity in foot-candles and expressed as percent transmittance of light. Data were taken at surface, middle, and bottom depths at all offshore stations.

Current Velocity

Surface current speed and direction were measured at offshore stations with a General Oceanics Model 2030 digital flowmeter lowered to 0.5 m depth. Surface currents were recorded in cm/sec. After a one-minute reading, direction was estimated with a magnetic marine compass.

Wind Direction, Wind Velocity, and Cloud Cover

Wind direction and velocity were estimated at the same time biological samples were taken. Cloud cover was estimated and expressed as clear, partly cloudy, rainy, or by similar descriptors.

Results and Discussion

Salinity, temperature, dissolved oxygen, and turbidity data were taken to provide supplementary information to the biological aspects of the program. In the event of unusual or extraordinary observations made of the biotic communities, physical parameter data could delineate plant-related causes versus natural phenomena. Statistical procedures used in the following discussion of physical parameters were performed at α=.05.

Water Temperature Monitoring (continuous)

The daily ranges of water temperatures continuously recorded at ocean intake and discharge structures by Ryan-Peabody thermographs are shown in Appendix Figures O-1 and O-2. Thermograph readings at the intake structure ranged from a low of 57°F in January to a high of 87°F in July.

The available data indicate that the increase in discharge temperature above ambient oceanic intake temperatures was greatest in late summer with average monthly ΔT's of 2.0°F and 2.4°F for August and September. Measurements from early summer exhibited the lowest

average monthly ΔT's of 0.6°F and 0.5°F (June and July), while the average ΔT in March was 1.8°F.

Water Temperature (*in situ*)

Water temperatures were measured concurrently with nutrient and phytoplankton samplings at offshore Stations 0 through 5 and at Stations 11 and 12 in the intake and discharge canals, respectively. These data appear in Appendix Table 0-1. Surface intake canal temperatures varied from 15.5°C in January 1977 to 29.2°C in September 1977. During 1977, temperatures were between 10.4 and 13°C higher in the discharge canal than in the intake canal on dates when nutrient and phytoplankton samples were taken. Water temperatures at offshore stations ranged from 16.3°C in January at Station 0 to 30.5°C in July at Station 1.

Stations 0 through 5 were statistically compared to detect temperature differences both between stations and between seasons. Analysis of variance (ANOVA) indicated no significant differences among the six offshore stations at either surface, middle, or bottom depths, but seasonal variations, shown in Figure G-2, were significant. This graph also shows a vertical stratification of temperature which is especially noticeable in the summer months.

Salinity

Salinity values measured for the six offshore stations as well as for the intake and discharge canal stations (Appendix Table 0-2)

were found to be in a narrow range between 35.00‰ and 36.62‰. ANOVA indicated no significant differences among the six offshore stations at surface, middle, or bottom depths for salinity, but seasonal variation was detectable at each depth.

Dissolved Oxygen

Dissolved oxygen values were measured monthly at the six offshore stations and at Stations 11 and 12 in the intake and discharge canals, respectively. These data are listed in Appendix Table 0-3. Dissolved oxygen values ranged from 4.6 to 7.9 mg/liter during the 1977 study. ANOVA indicated no significant differences among the six offshore stations for dissolved oxygen at surface, middle, or bottom depths, but as with the other physical parameters, there was a detectable seasonal variation.

Turbidity

Turbidity measurements made during 1977 for the six offshore stations and the intake and discharge canals appear in Appendix Table 0-4. ANOVA detected no significant differences among the six offshore stations at surface, middle, or bottom depths. Differences were detectable between monthly samplings, with the greatest turbidities occurring in the fall and winter and then diminishing in the summer months.

Light Transmittance

Offshore light transmittance data are listed in Appendix Table 0-5. Values are given for each of the six stations at surface, middle,

and bottom depths as well as on the deck of the boat.

Oceanographic Measurements

Surface current velocities, wind direction and velocity, cloud cover information, and tidal and lunar phase data were collected concurrently with each monthly phytoplankton sampling. These data are maintained in the laboratory and are not included in this report.

CHEMICAL PARAMETERS

Materials and Methods

Samples of water for nutrient analyses were collected monthly at offshore Stations 0, 1, 2, 3, 4, 5 and Stations 11 and 12 located in the intake and discharge canals, respectively (Figure G-1). Duplicate samples were taken from surface, middle, and bottom depths. Surface samples were collected by dipping, and subsurface samples were either pumped or sampled with a Niskin bottle. Water samples to be analyzed for ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, reactive silica, and orthophosphate were passed through 0.45μ membrane filter, placed in acid-washed polyethylene bottles, and quickly frozen. Water samples to be analyzed for total organic carbon were processed similarly but were spiked with 5 ml of concentrated sulfuric acid (H_2SO_4). All chemical analysis samples were shipped to the laboratory on the day of collection. .

Methods of analysis used to measure these selected nutrients appear in either APHA (1976), EPA (1974), or Strickland and Parsons (1972). A summary of the parameters analyzed and the respective methods is given in Table G-2. Statistical procedures used in the following discussion of chemical parameters were performed at $\alpha=.05$.

Results and Discussion

The distribution of nutrients in the marine environment is a function of diffusion, currents and biological turnover. Nearshore nutrients are generally considered to be well-mixed and homogeneous as a result of turbulence induced by winds or currents (Bowden, 1970). High concentrations of ocean nutrients are spatially limited and usually associated with upwelling (Spencer, 1975), a river-ocean interface (Stefansson and Richardson, 1963), or ocean waste disposal outfalls (EPA, 1971).

The results of analyses for ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), reactive silicates (SiO_2), orthophosphates (PO_4-P), and total organic carbon (TOC) from monthly collections of seawater are presented in Appendix Tables 0-6 through 0-7.

Each chemical parameter was independently compared over the entire year by a two-way analysis of variance. Offshore Stations 0 through 5 were statistically compared to detect significant differences ($\alpha=.05$) both between stations and between sampling periods (seasonal

variations). These statistical comparisons were performed independently for surface, middle, and bottom depths. The results of these statistical analyses are summarized in Table G-3. With the exception of silica measurements at the bottom depths, no significant differences were found among the six offshore stations (0-5) for any chemical parameter at any depth. With the exception of surface TOC and bottom nitrite measurements, significant differences betweeh months were found for all chemical parameters at each depth.

Results of nutrient concentrations reported by Worth and Hollinger (1977) for the nearshore coastal environment adjacent to the St. Lucie Plant between February 1972 and August 1973 compare very favorably with the results compiled for 1977 by Applied Biology, Inc. The approximate nutrient concentration ranges for the 1972-1973 period are given below:

NH_3-N	-	<0.01 - 0.09 mg/liter
NO_3-N	-	<0.01 - 0.075 mg/liter
NO_2-N	-	<0.001 - 0.010 mg/liter
SiO_2	-	0.05 - 1.5 mg/liter
PO_4-P	-	<0.01 - 0.5 mg/liter

No significant differences in nutrient concentrations were detected among offshore Stations 0-5 during 1977. However, seasonal variations at surface, middle, and bottom depths were found to be significant (Figures G-3 through G-8). The ranges in concentration

for each nutrient during the 1977 period are very similar to those in the 1972-1973 data.

Figures G-3 through G-8 show that ammonia and nitrate concentrations increase in late fall and winter, silica reaches a maximum in late summer, and total organic carbon peaks in the spring, while nitrite and phosphate show only small increases in fall and winter months, respectively.

Nutrient concentrations measured in the intake and discharge canals (Stations 11 and 12) were statistically compared to control Station 0 to determine differences either between stations or between monthly sampling periods. The only significant differences detected between stations were for surface NH_3-N concentrations. This parameter was significantly greater at Stations 11 and 12 than at Station 0, while no difference was detected between Stations 11 and 12. Significant seasonal variations were found for each nutrient being analyzed.

SUMMARY

Concentrations of nutrients in the nearshore environment adjacent to the St. Lucie Plant, as judged by monthly samples collected at the six offshore stations, are dispersed homogeneously but vary significantly with respect to time. Statistical analysis of nutrient concentrations measured monthly at the six offshore stations, which include a distant control station, indicates that the operation of the

St. Lucie Plant has no significant effect on the selected nutrients measured in this study. The yearly range in nutrient concentrations compares favorably with data collected from similar locations during 1972-1973; and no significant differences (α=.05) were found when Stations 1-5 were compared with the control station (0).

Similarly, no significant differences (α=.05) were found among the six offshore sampling stations for temperature, dissolved oxygen, salinity, or turbidity measurements. Even though water with a differing physical parameter makeup is discharged into the nearshore environment by the St. Lucie Plant, the effect on the measured parameters, as judged from these statistical comparisons, appears to be minimal. Seasonal variations were significant for all the physical parameters, as expected, just as with concentrations of the selected nutrients.

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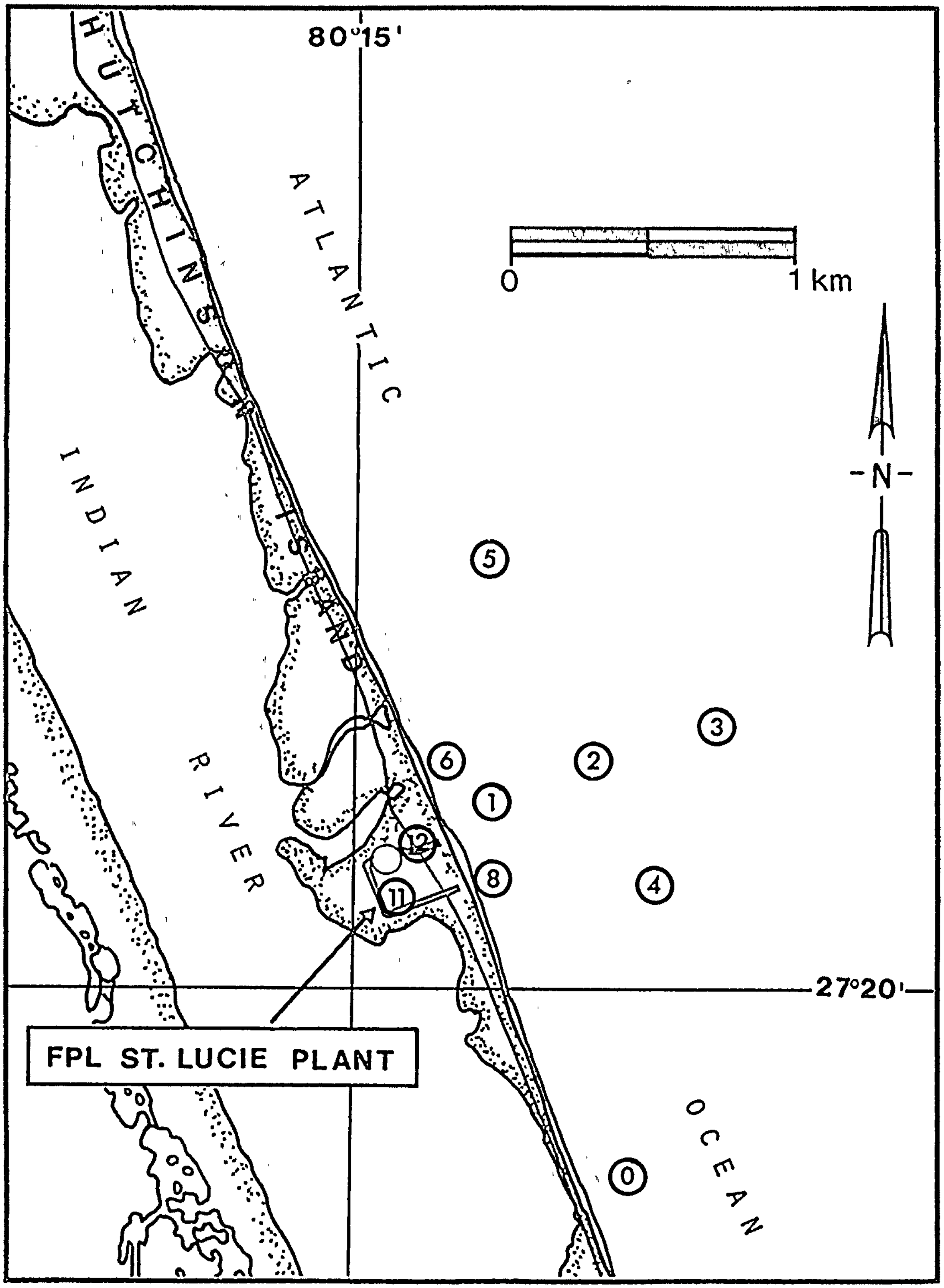

Figure G-1. Locations of water quality sampling stations, 1977.

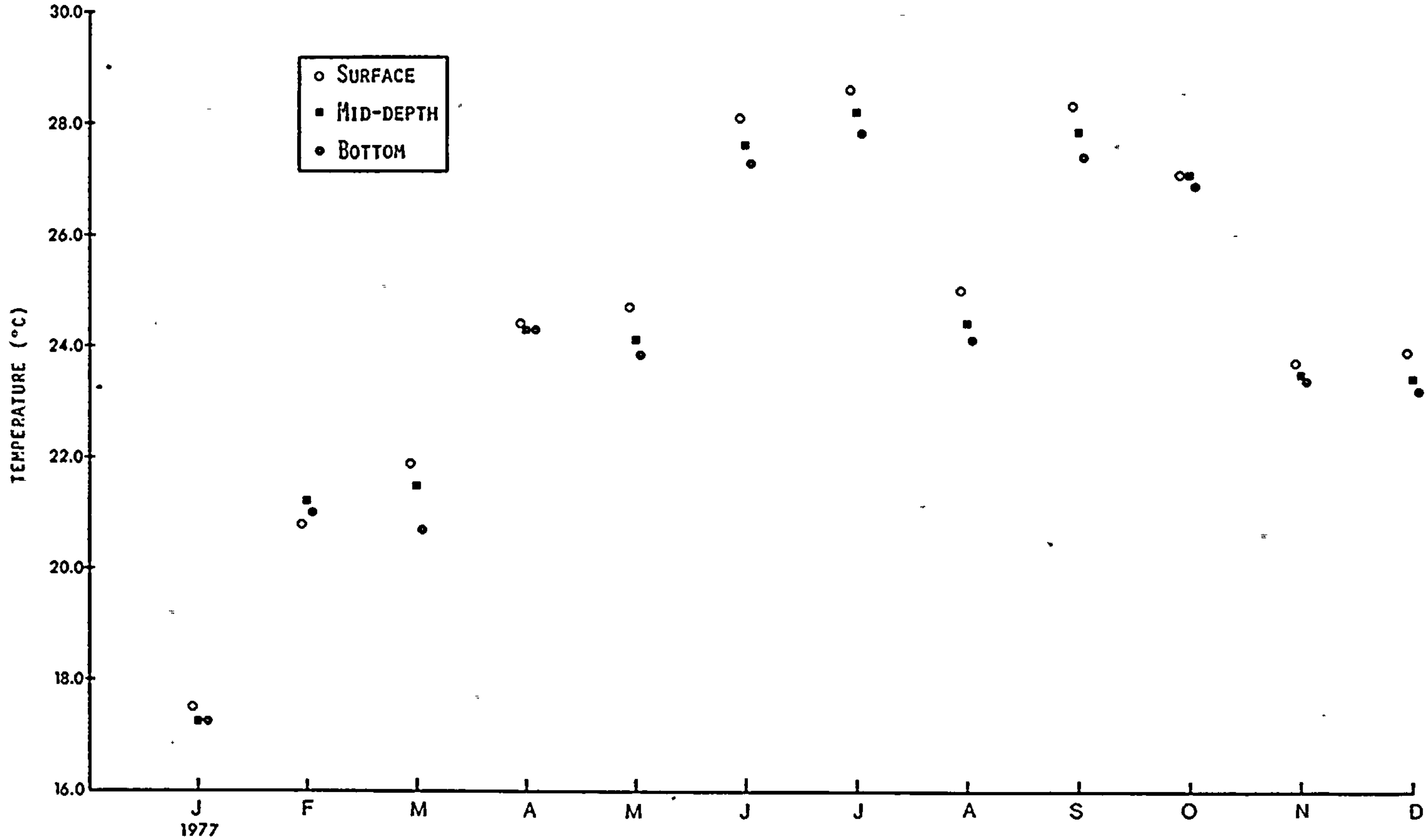

Figure G-2. Mean temperature values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

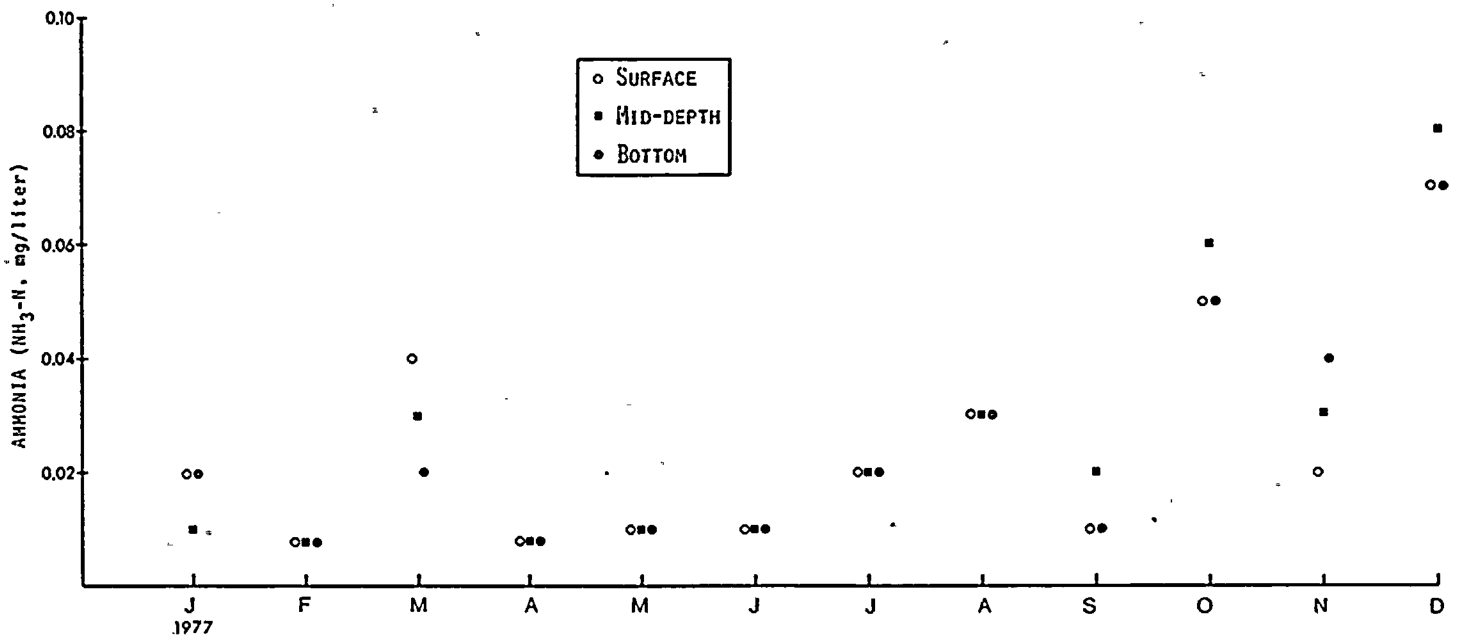

Figure G-3. Mean ammonia values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

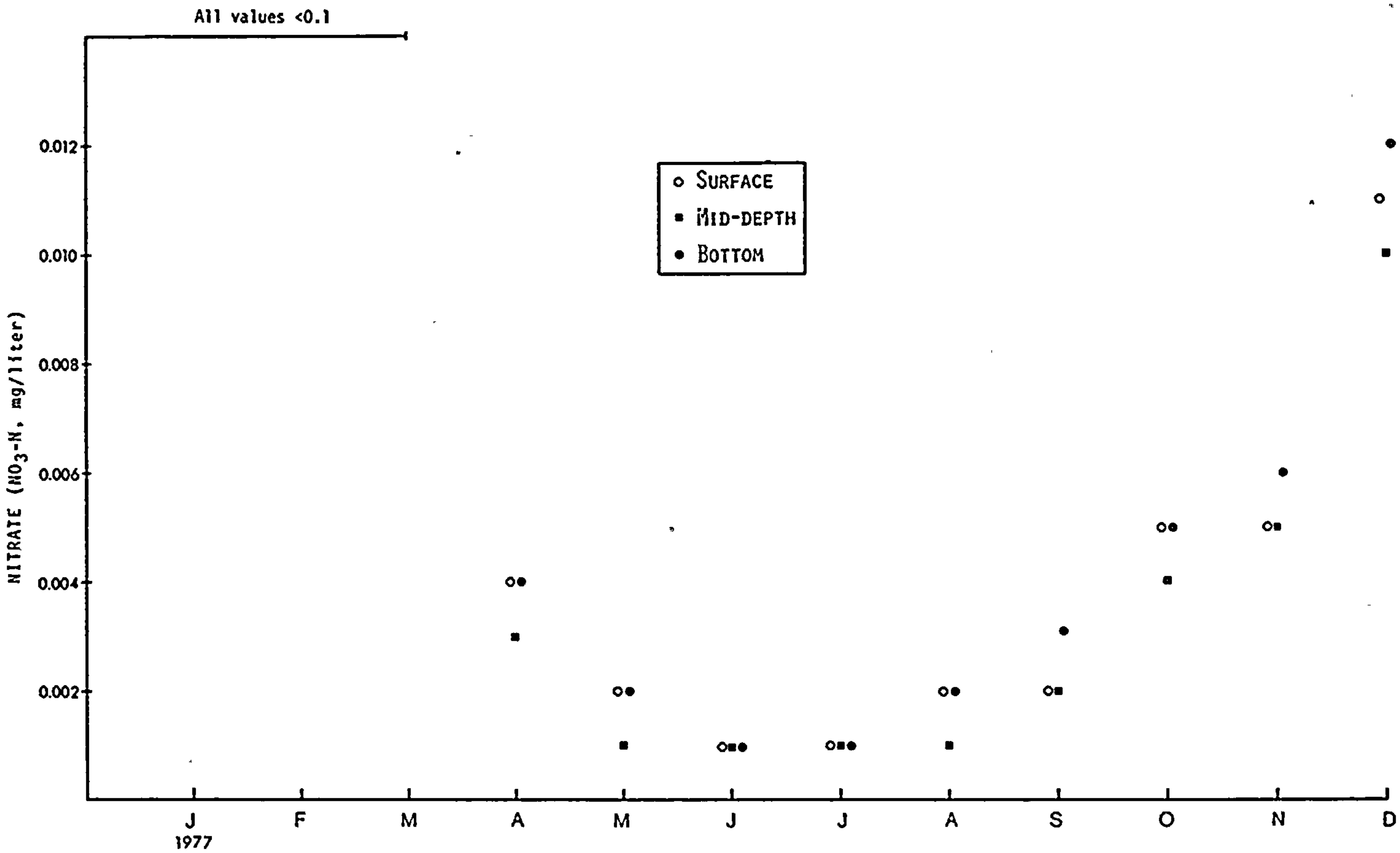

Figure G-4. Mean nitrate values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

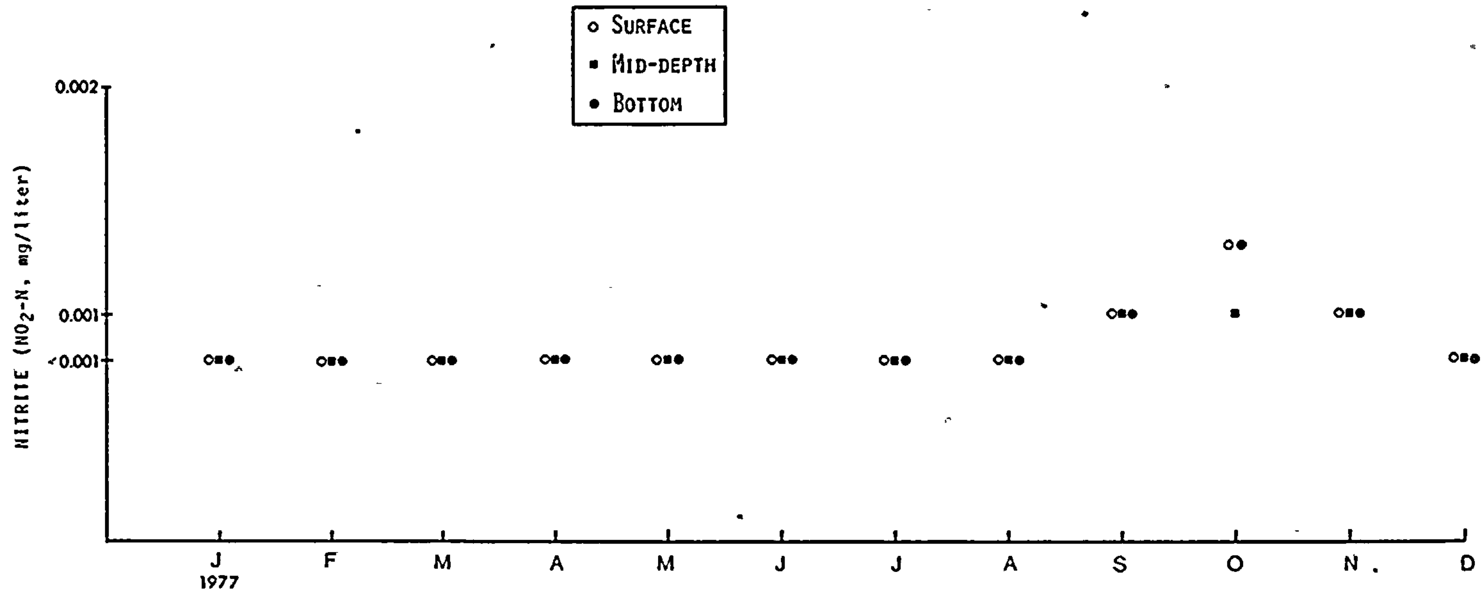

Figure G-5. Mean nitrite values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

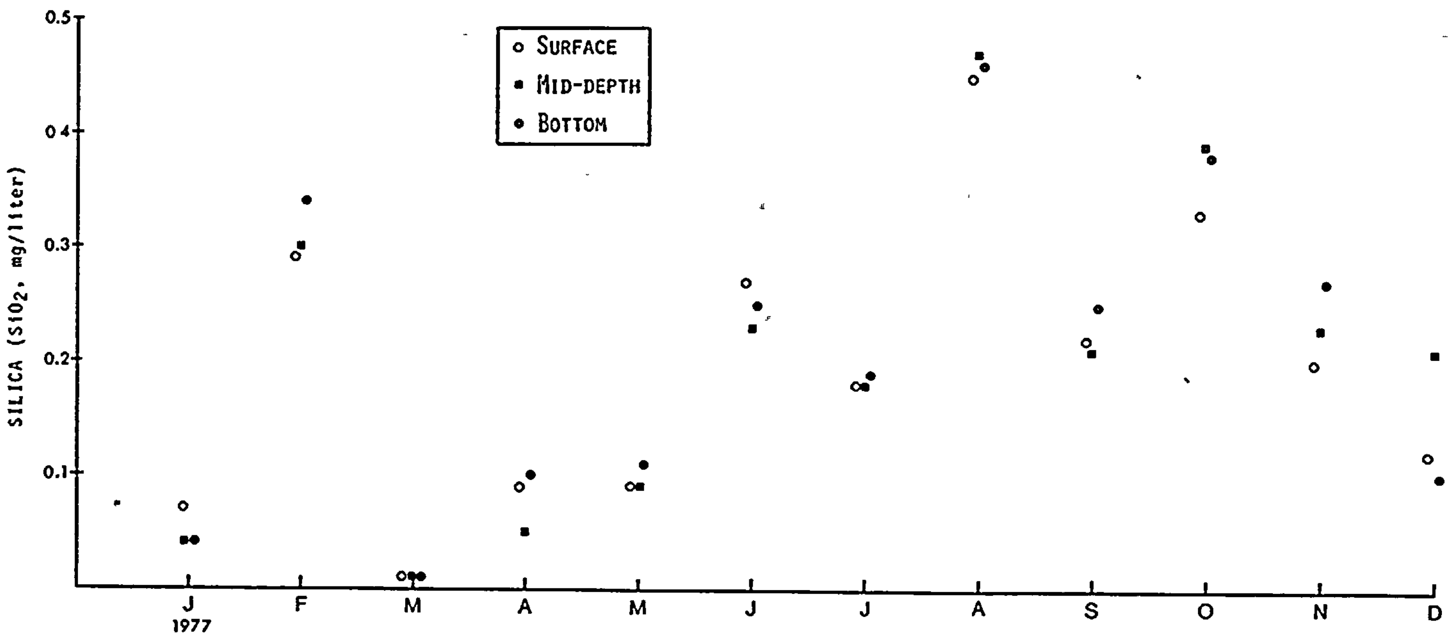

Figure G-6. Mean silica values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

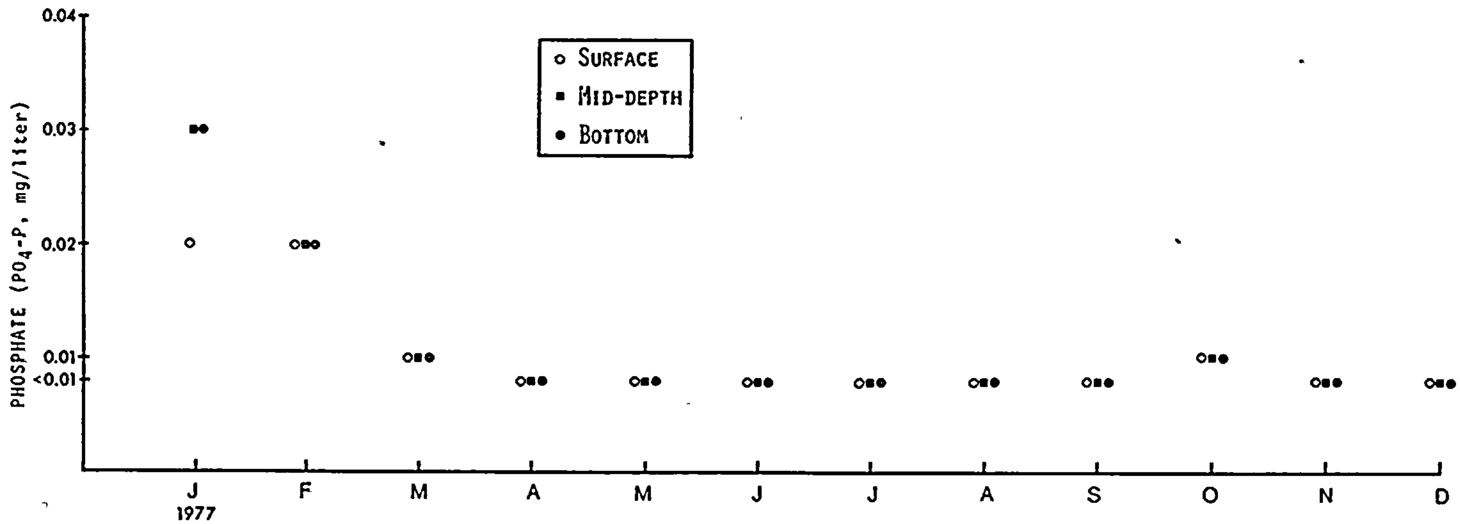

Figure G-7. Mean phosphate values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

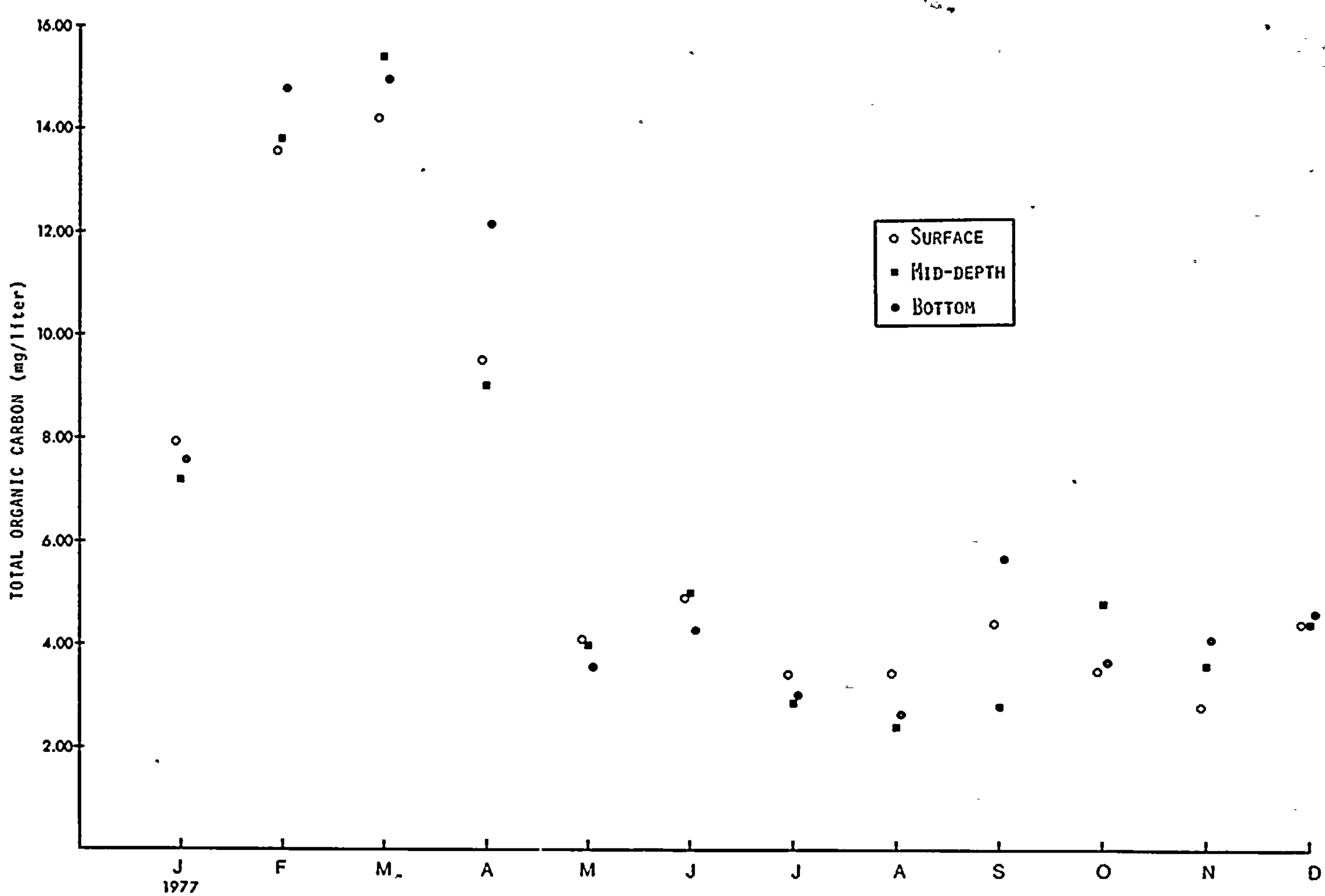

Figure G-8. Mean total organic carbon values for nearshore Stations 0-5 combined, St. Lucie Plant, 1977.

TABLE G-1

PHYSICAL/CHEMICAL PARAMETERS MEASURED FOR EACH STATION
ST. LUCIE PLANT, 1977

Parameter	0	1	2	3	4	5	6[a]	7[a]	8[a]	11	12	Offshore intake	Offshore discharge
water temperature (continuous)												✓	✓
water temperature (*in situ*)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
salinity	✓	✓	✓	✓	✓	✓				✓	✓		
dissolved oxygen	✓	✓	✓	✓	✓	✓				✓	✓		
turbidity	✓	✓	✓	✓	✓	✓				✓	✓		
luminosity	✓	✓	✓	✓	✓	✓							
current velocity	✓	✓	✓	✓	✓	✓							
wind direction, velocity, cloud cover[a]	✓	✓	✓	✓	✓	✓				✓	✓		
tidal cycle, lunar phases[a]	✓	✓	✓	✓	✓	✓				✓	✓		
$N\text{-}NO_3$	✓	✓	✓	✓	✓	✓				✓	✓		
$N\text{-}NO_2$	✓	✓	✓	✓	✓	✓				✓	✓		
$N\text{-}NH_3$	✓	✓	✓	✓	✓	✓				✓	✓		
$Si\text{-}SiO_2$	✓	✓	✓	✓	✓	✓				✓	✓		
$P\text{-}PO_4$	✓	✓	✓	✓	✓	✓				✓	✓		
TOC	✓	✓	✓	✓	✓	✓				✓	✓		

[a] Data records are maintained in the laboratory and are not included in this report.

TABLE G-2

METHODS OF ANALYSIS USED TO MEASURE
SELECTED WATER PARAMETERS
ST. LUCIE PLANT
1977

Parameter	Method	Reference
Ammonia nitrogen (NH_3-N)	Indophenol	Strickland and Parsons 1972, p. 87
Silicates (SiO_2-Si)	Heteropoly blue	APHA, 1976, p. 490
Nitrate nitrogen (NO_3-N)	Brucine	APHA, 1976, p. 427
	[a]Cadmium Reduction	APHA, 1976, p. 423
Nitrite nitrogen (NO_2-N)	Diazotization	APHA, 1976, p. 434
Ortho-phosphate (PO_4-P)	Ascorbic acid	APHA, 1976, p. 481
Total organic carbon (TOC)	Combustion-infrared	APHA, 1976, p. 532

[a]This method used after March 1977.

TABLE G-3

SUMMARY OF STATISTICAL ANALYSIS
OF PHYSICAL AND CHEMICAL DATA
ST. LUCIE PLANT, 1977

	Analysis of variance between stations (0-5)			Analysis of variance between months		
Parameter	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
NH_3-N	NS	NS	NS	*	*	*
NO_3-N	NS	NS	NS	*	*	*
NO_2-N	NS	NS	NS	*	*	NS
SiO_2	NS	NS	*	*	*	*
PO_4-P	NS	NS	NS	*	*	*
TOC	NS	NS	NS	NS	*	*
Salinity	NS	NS	NS	*	*	*
Dissolved Oxygen	NS	NS	NS	*	*	*
Temperature	NS	NS	NS	*	*	*
Turbidity	NS	NS	NS	*	*	*

* Significant at α=0.05. NS = not significant.

H. NESTING TURTLES

INTRODUCTION

The Florida Power & Light Company (FPL) has been studying marine turtles since 1971 to evaluate potential impacts of the construction and operation of the St. Lucie Plant on turtle nesting behavior. When plant construction began in 1971, FPL in conjunction with the Florida Department of Natural Resources (FDNR) initiated a long-term study of the nesting behavior of sea turtles, principally Atlantic loggerheads, on Hutchinson Island. This 37.5 km stretch of sandy beach, which extends from St. Lucie Inlet to Ft. Pierce Inlet (Figure H-1), may be the largest marine turtle rookery in the United States (NMFS, 1976).

It is of concern to FPL that the presence of the St. Lucie Plant and the warm water discharge from the plant's cooling system do not adversely affect the reproductive behavior of marine turtles. Since very little is known about their behavior, research was conducted during the summer nesting season on alternate years from 1971 through 1977. Observations of nesting and predation were used in conjunction with tagging and recapture studies to produce data on the nesting success and site specificity of female sea turtles and an assessment of the effects of the St. Lucie Plant on the Hutchinson Island rookery.

Marine Turtles at Hutchinson Island

Three species of marine turtles are known to nest on Hutchinson Island. The most common is the Atlantic loggerhead turtle (*Caretta caretta*), followed by the green turtle (*Chelonia mydas*) and the leatherback turtle (*Dermochelys coriacea*). The leatherback turtle is classified as an endangered species by the Federal government [Federal Register 41(208):47180-47198], and all marine turtles are protected by Florida Statutes (307.12; 1974).

Each year, from about May to September, hundreds of loggerhead turtles nest along the beaches of Hutchinson Island. In addition to loggerheads, about 8 to 15 green turtles and several leatherback turtles were observed nesting during the study years. Leatherback turtles nest infrequently along the U. S. Atlantic coast, so Hutchinson Island may be an important U. S. Atlantic rookery for this species.

In view of the declining world populations of marine turtles caused by fishing pressures and loss of nesting habitat through coastal development (IUCN, 1969; IUCN, 1971; NMFS EIS draft, 1976), the Hutchinson Island rookery is of special importance in maintaining sea turtle populations. Loss of this rookery would seriously deplete the populations of these protected species in the United States.

MATERIALS AND METHODS

Nine segments of Hutchinson Island beach (Figure H-1), each 1.25 km long and roughly equidistant, were surveyed 5 to 7 days per week during the marine turtle nesting season. Although the nesting season varies somewhat, it usually begins in early May and continues through the end of September. Since sea turtles lay their eggs at night, the nesting beach was patrolled at night from about 9:00 p.m. to 5:00 a.m. Small off-road vehicles provided beach transportation so that all survey areas could be patrolled several times during the course of an evening.

When turtles emerged from the sea to nest on the beach, their location was noted. Care was taken not to disrupt turtles prior to nesting. Once a turtle had begun to deposit eggs or was seen returning to the sea, an identification tag (Monel self-piercing, National Band and Tag Co., No. 4-1005, size No. 49) was applied on the right foreflipper. Tagging was conducted south of area 4 in 1971, 1973 and 1975, and in areas 2 through 7 in 1977. The length and width of each turtle was measured with calipers, and the general physical condition of each individual was noted. Turtles were not weighed because of the difficulty in placing specimens, which may weigh in excess of a hundred kilograms, upon scales. Nest locations were marked with numbered stakes in order to relocate them.and monitor predation on eggs.

Often a turtle will crawl up on the beach and even begin nest excavation only to return to the sea without depositing eggs. Extraneous light, sound, movement or other factors increase the likelihood of these "false crawls." Although the presence of biologists in the turtle rookery areas at night may have affected turtle behavior by increasing the number of false crawls, the effect would be constant throughout the survey areas.

The study data were derived from daytime nest counts, raccoon predation of nests, and nighttime tag and recapture studies over four alternating years. The intensity and efficiency of the daytime nest count and predation study remained relatively constant over the entire study period. However, the nighttime tagging studies in 1971 and 1973 were affected by variables such as study effort intensity, numbers of available observers, and study efficiency (differing modes of transportation). Accordingly, comparisons between each of the four study years should be interpreted with caution.

RESULTS AND DISCUSSION

Nesting Activity on Hutchinson Island

Nesting site selection in marine turtles is an integral part of the nesting behavior. It is thought that many environmental factors, some of which are listed in Table H-1, play an important part in this behavior. A review of these factors indicates that only beach stability shows a trend with the observed variation in nesting

activity. Worth and Smith (1976) related year-to-year changes in nesting density to variations in beach topography. Historically, the northern portion of Hutchinson Island has been subject to heavy beach erosion that produces a steep-sloped beach which may be as little as 3 m wide. Turtles encountering this beach are often rebuffed by insurmountable cliff-like ledges and nest elsewhere. In addition, high tides along areas 1 through 3 frequently wash the beach plain, the area of beach from mean high water to the base of the primary dune face, and may cause severe erosion, with resultant nest loss, throughout the nesting season.

By contrast, the southern half of the island (areas 6-9) has relatively wide, gently sloping beaches that are 30 to 40 m in width, the widest being in area 9. It appears that female turtles may select a nesting site on the basis of beach length, slope, stability, and accessibility.

Coincident with the general trend of decreasing north-to-south erosion rates (increasing beach stability) was a trend of increased nesting activity (Figure H-2). This gradient of increasing activity was observed in all survey years.

To test the validity of the apparent relationship of topography with nesting activity, a statistical model was generated using observations from the four study years. A linear model was fit to the

number of crawls as a function of nesting area location. Different slopes and intercepts for each year were permitted. This model obtained a multiple correlation coefficient of 0.8978 and accounted for 80.6% of the variability in crawls. A strong positive correlation was demonstrated between nesting activity and topographical suitability of the beach.

With the above model, the number of crawls at area 4 (nearest the St. Lucie Plant) was predicted for each year and a 95% confidence interval was constructed for this number. Predicted and observed crawl activities were compared to see how closely the observed number of turtle crawls compared with those predicted by the linear model (Table H-2). In 1975, observed crawl activity in area 4 was only 58% of the predicted number. The other study years showed crawl activity levels reasonably close to predicted values. The 1975 decline in crawl activity could most probably be attributed to the construction of the St. Lucie Plant offshore intake and discharge systems. During the 1975 study, construction crews were operating on a 24-hour schedule using drag lines and other heavy equipment with strong lights. It is reasonable that this activity made area 4 less desirable as a nesting beach. In 1977, however, nesting activity in this area returned to the general pattern observed during the other study years.

Nesting Success at Hutchinson Island

Nesting success is defined as the ratio of successful nesting to the total number of nesting attempts. Nesting success distribution along the Hutchinson Island beaches was examined to determine whether this ratio in the vicinity of the St. Lucie Plant was significantly different from that in other areas of the island.

Nesting success data (Figure H-3) demonstrated significant variations (P=0.05) between nesting areas within three of the study years (false crawl data were not taken in 1971). Nesting success was reduced throughout the island in 1975 and 1977. This reduction cannot be readily explained. Although nesting success declined in area 4 during 1975 and 1977, the percentage of successful nests was similar, 51.4% and 53.5%, respectively. Variables that can affect nesting trends, discussed earlier (Table H-1), may also influence nesting success. An apparent reduction in nesting success in 1977 was observed at the southern half of the beach, particularly in nesting areas 6, 7 and 8. Here, nesting success was less than 50% of nesting attempts. Probable causes were a rapid increase in commercial development of beach properties near these areas. These developments, steadily increasing since the early 1970's, provide increased levels of human activity along the beaches at night. Caldwell (1962) has documented similar declines in nesting due to beach development along Jekyll Island in Georgia.

Site Specificity

Site specificity, the tendency of a turtle to return accurately on successive nestings to the locality of previous nestings, has been well documented in green turtles (Carr, 1972). Evidence suggests that loggerhead turtles, although not as site-specific as green turtles, do return to the same location with each successive nesting attempt (Caldwell et al., 1959; Worth and Smith, 1976).

Site specificity was studied on Hutchinson Island in 1973 and 1977 by calculating the distance between successive nesting attempts of tagged turtles. Data from 1973, when the tagging effort was south of the plant, was compared with 1977 tagging data from areas in the vicinity of the plant. The calculated mean distances between successive nesting crawls of 4.6 km (2.9 mi) in 1973 and 4.1 km (2.6 mi) in 1977 are very similar and approach values reported by Hughes and Brent (1972). These findings indicate that plant operation in 1977 had no observable effect on the site-specificity behavior of loggerhead turtles.

Renesting Intervals

The time between two successive nestings of Atlantic loggerhead turtles has been established at about 2 weeks (Caldwell, 1962; Hughes et al., 1967). This time interval varies considerably, possibly in response to changes in water temperature. Hughes and Brent (1972) indicated that as seasonal water temperatures increased, the renesting interval for loggerheads decreased. The renesting interval for Hutchinson

Island turtles in 1973 ranged from 11 to 17 days (Worth and Smith, 1976). During 1977, the renesting interval for turtles tagged in areas adjacent to the St. Lucie Plant ranged from 13 to 15 days. This similarity suggests that the St. Lucie Plant discharge had no observable effect on the renesting interval of loggerhead turtles.

Water Temperatures and Onset of Nesting Season

Variations in ambient water temperatures have been associated with changes in the timing of both nesting activity and nesting rates (Hughes and Brent, 1972; Worth and Smith, 1976). During all four study years, the nesting season began when maximum ocean temperatures ranged between 22 and 24.5°C (Figure H-4). A positive relationship between rising water temperatures and increased crawl activity was observed at the onset of each nesting season at Hutchinson Island (Figure H-4). Crawl activity levels increased until June or July and then declined, despite generally rising water temperatures throughout the nesting season. Thus, ocean water temperatures appear.to exert some influence on the level of nesting activity during the early weeks of the season. Evidence for this influence is strengthened by examining the 1973 data, when cooler ocean temperatures in June coincided with delayed crawl activity. When ocean temperatures increased in July, a corresponding increase in crawl activity was noted. The lower water temperatures in June may have partially inhibited nesting until July, when the warmer waters coincided with a greater influx of nesting females. In contrast, increased nesting activity was observed

during the early nesting season periods of 1975 and 1977, when ambient ocean temperatures were warmer than those in the other years of observation.

The onset of the nesting season in response to ocean temperatures could be further influenced by additional factors such as day length (photoperiod). Synergistic effects of temperatures and photoperiod on reproductive biology have been observed in other reptiles (Crews, 1975; Callard et al., 1972; Cloudsley-Thompson, 1971). If water temperature is the mechanism that triggers nesting activity, it follows that unseasonably warm water might induce premature nesting. A source of warmed water is provided by the St. Lucie Plant offshore discharge structure, which emits a surface plume of water up to 3°C above ambient water temperatures. If premature nesting is induced by the plant's warm water discharge, why would this be of concern?

Marine turtle eggs must incubate at nest temperatures of 29-35°C in order to hatch, and increased mortalities can occur if temperatures are not optimal (Bustard, 1971). The percentage of fertile eggs that mature and hatch is therefore influenced by the time of year in which they have been deposited. If turtle eggs were deposited too early in the year, the beach temperatures would not be warm enough to maintain the requisite temperatures. Since developing turtles have no heat-regulatory mechanisms, they are dependent upon favorable location and ambient temperatures for survival. Eggs laid

too early or too late in the nesting season would have considerably less opportunity to develop and hatch. Loggerhead turtle eggs usually hatch in about 49 to 62 days (Caldwell, 1962); warmer temperatures produce earlier hatching, and cooler temperatures extend hatching times (Hughes and Richard, 1974).

A more subtle factor, yet one equally important in terms of hatching success, is the condition of the sandy beaches in which the eggs must incubate. Nests laid too early or too late in the year are more likely to be destroyed by beach erosion. Beach erosion is more frequent during the fall, winter, and early spring when wind speeds increase and the direction changes to onshore, from the northeast. Onshore winds increase sediment transport and erosion so that beach stability is reduced from September through early May. Nests which are exposed or broken up by waves do not survive. The marine turtle nesting season occurs during this period of greatest beach stability.

To examine the hypothesis that the St. Lucie Plant warm water discharge may induce seasonally premature egg-laying, crawl activity observations at area 4 were compared with those in areas 1-3 and 5-9. (The plant discharge structures are located offshore from area 4). The median of crawl activity was calculated to identify the week in which exactly one-half of the turtles during each nesting season had attempted to nest. It should be noted that sea turtles do not begin nesting the same week each year, but the nesting season is reasonably

consistent in duration, about 20-21 weeks long. For purposes of comparison, the onset of the nesting season was identified as week no. 1 and the last week of nesting was designated as week no. 20 or 21, regardless of its position in the calendar year.

Minor differences were noted between years in the timing at which the nesting season began (Table H-3). Crawl activity (nesting crawls, false crawls and combined nesting plus false crawls) did not begin or end uniformly throughout all areas during the years studied. The week of median crawl activity ranged from week 8 to week 11 of the nesting season. The week in which median crawl activity occurred in area 4 was similar to that in the remaining areas within each year. Plant operation in 1977 did not appear to have a major impact on timing of nesting activity.

Predation

The principal predator of marine turtle eggs on Hutchinson Island is the raccoon. Raccoons forage on the beaches at night, dig open the nests and devour the eggs. Predation on nests varies from year to year. Predation in all nine survey areas destroyed 28% of the nests in 1971 and 43.6% in 1973. In 1975, predation destroyed only 20.8% of the nests, but in 1977 predation losses increased to 38.6%.

Predation rates by nesting area and year are shown in Figure H-5. The low predation levels observed at areas 6 and 7 in all four study

years were probably the result of commercial development and construction that destroyed raccoon habitat. Preconstruction land clearing for the St. Lucie Plant prior to 1971 also removed raccoon habitat, and in 1971 nest predation in area 4 was lower than that in areas 3 and 5.

Predation (and the number of nests deposited) declined in 1975 in all areas. Construction activity may have inhibited raccoons wandering along the beaches in search of food. In 1977, when construction had been completed, predation increased at area 4 and all other areas. Predation rates were high in areas 1, 2, 3 and 9 throughout the four study years. These areas, at the northern and southern perimeters, are among the last remaining undeveloped areas. Therefore, large raccoon populations are found there.

Population Size Estimates

Turtle population estimates are based on both the total estimated number of nests and the frequency of multiple renesting within the season. Hutchinson Island surveys have shown that the renesting frequency varies from one to four. The varied renesting frequency makes it difficult to estimate the population accurately. For this reason, earlier population estimates are probably inaccurate. Also, in any such survey only female sea turtles are sampled, so male components of the population are excluded.

Estimates of the total number of nests deposited by loggerhead turtles vary. Routa (1968) estimated that there were 5265 loggerhead turtle nests containing a total of 658,125 eggs along 36 kilometers of Hutchinson Island. His estimate was based on observations of 705 nests on three 1-mile stretches of beach. This estimate, however, did not allow for the north to south variation in nest density noted on the island.

In the present study, variations in nesting density were taken into account by a curve which provided an estimate that the number of nests in 1977 on 32.8 km of Hutchinson Island beaches was 2108. This estimate was then adjusted to eliminate the females that appeared on the beaches more than once. The renesting component of the population was derived by tag and recapture studies. The female loggerhead population for 1977 was thus estimated from the ratio of the number of tagged turtles to the number of nests recorded from these tagged turtles. This yielded an estimated population of 1491 nesting females.

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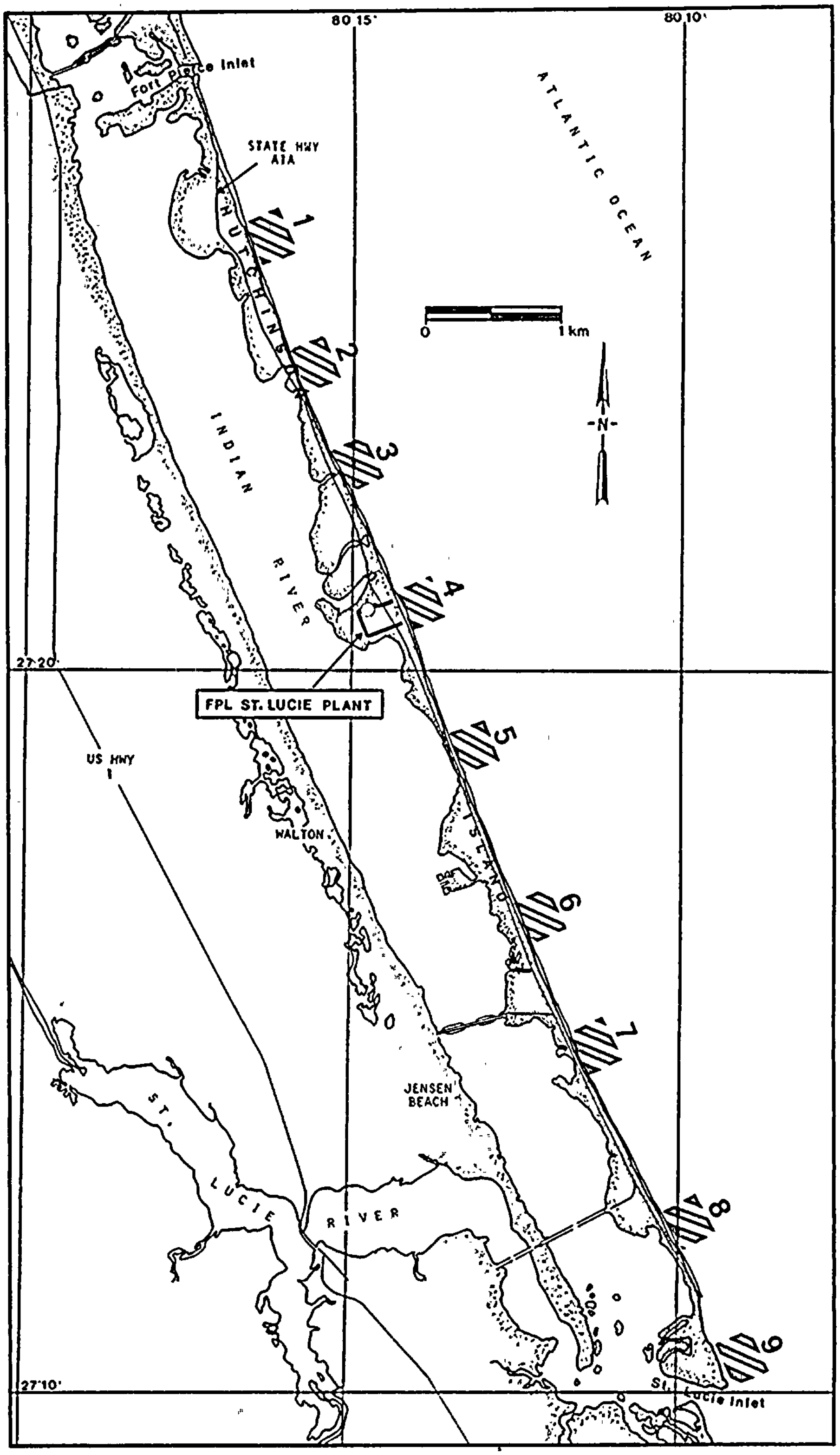

Figure H-1. Locations of turtle nesting areas surveyed on Hutchinson Island.

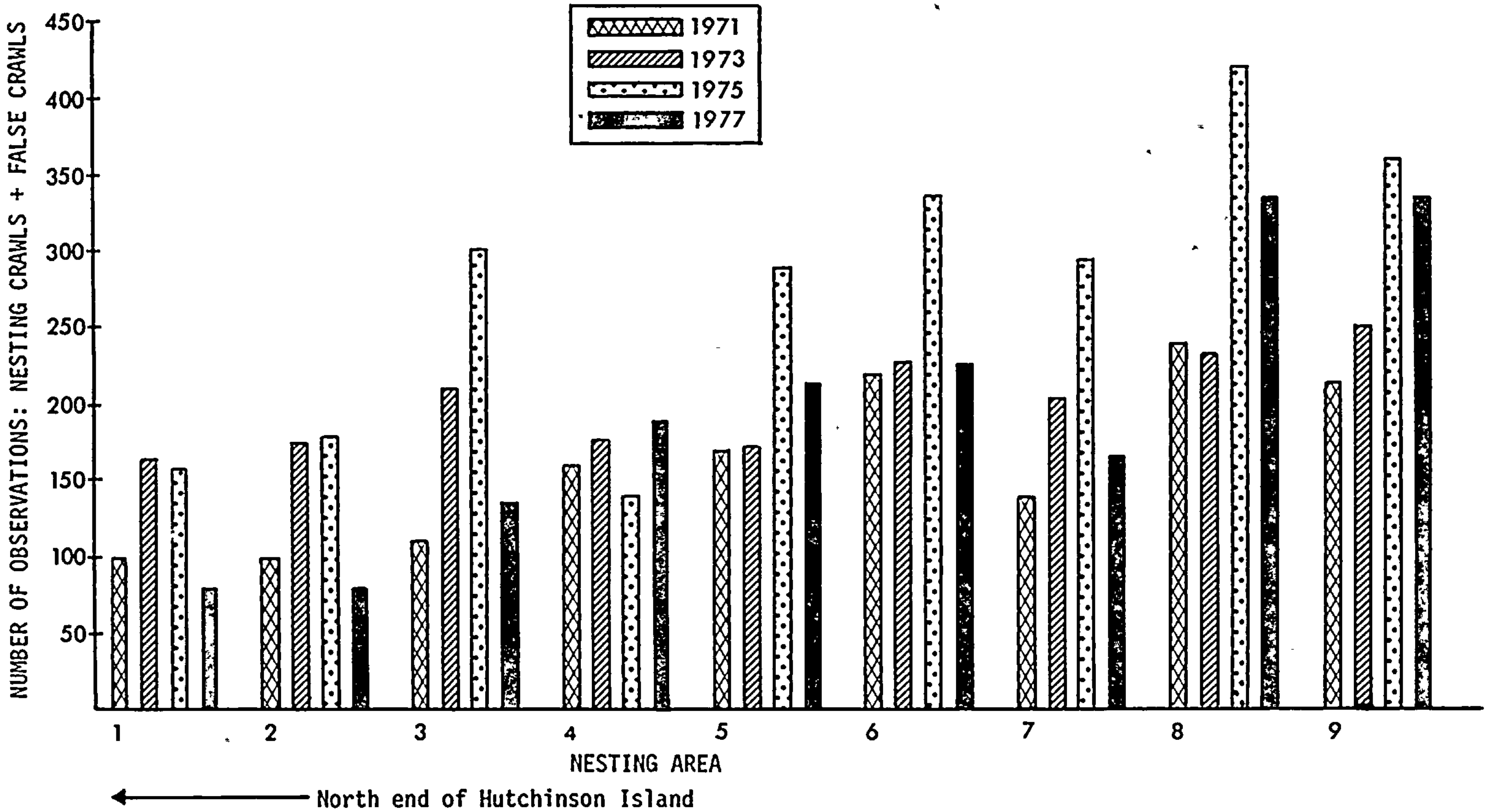

Figure H-2. Total number of observed marine turtle crawls by nesting area and year, Hutchinson Island.

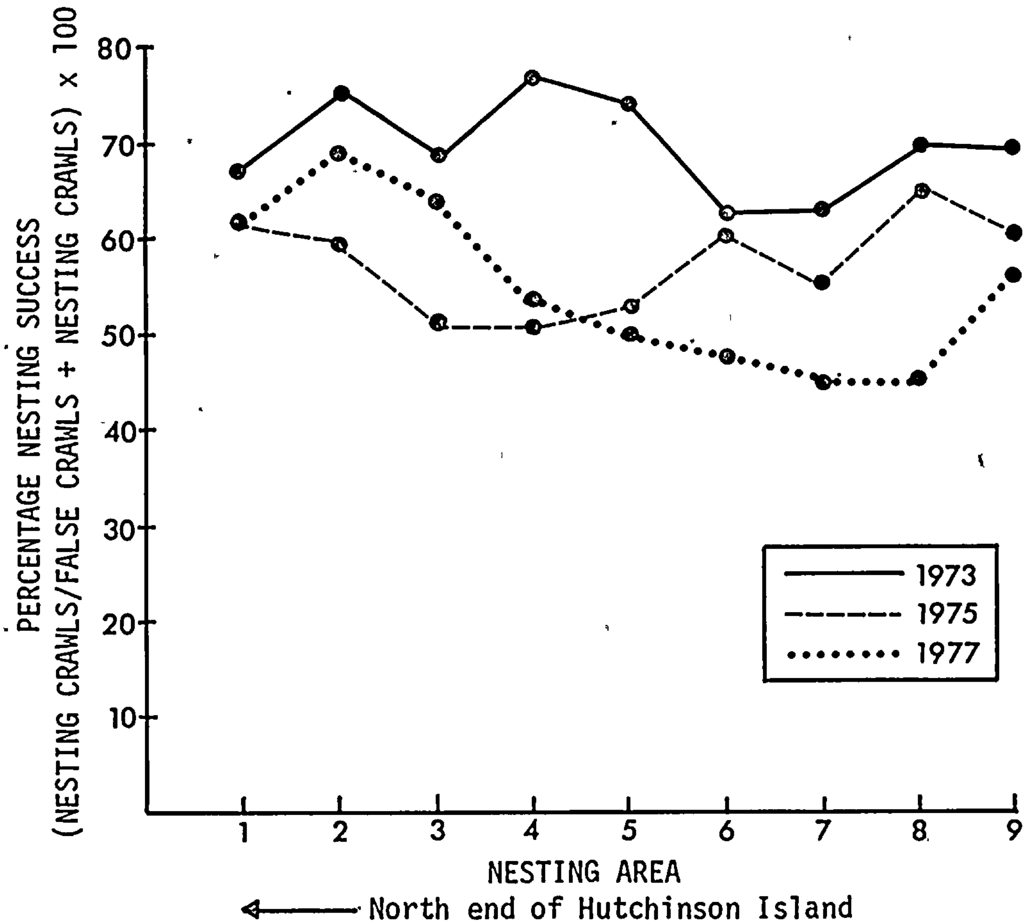

Figure H-3. Percentage nesting success of marine turtles by nesting area and year, Hutchinson Island. (No false crawl data were recorded in 1971.)

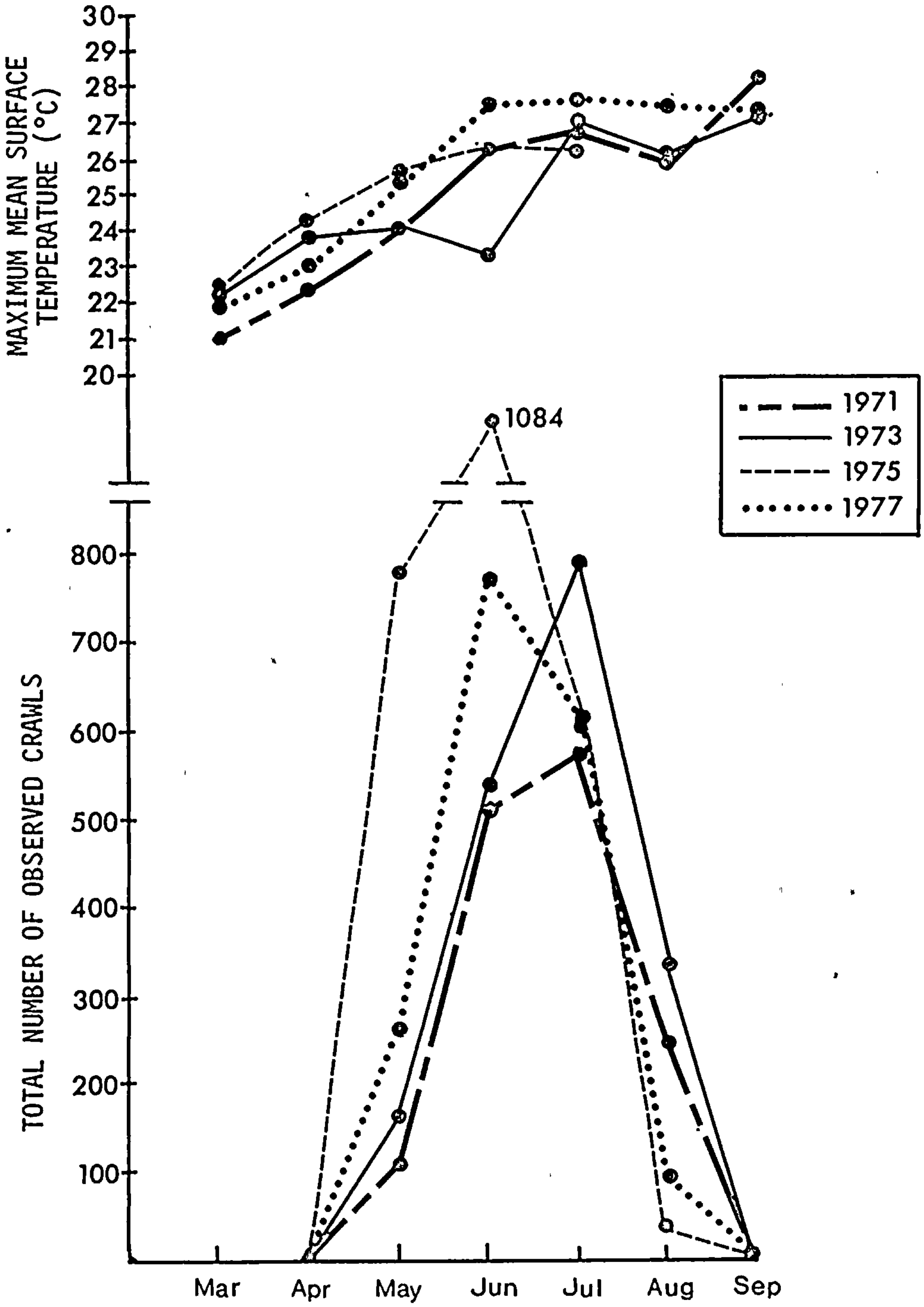

Figure H-4. Comparison of marine turtle nesting activity to ocean water temperatures by month and year, Hutchinson Island.

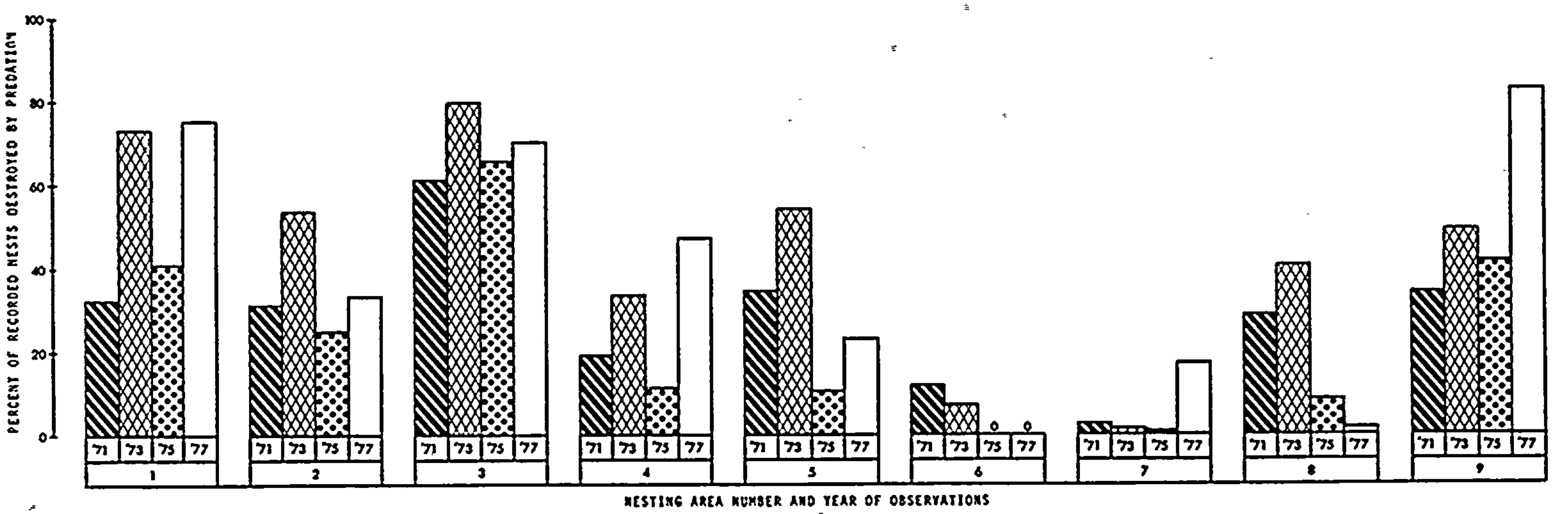

Figure H-5. Percentage of marine turtle nests destroyed by predation for each nesting area and year, Hutchinson Island.

TABLE H-1

ENVIRONMENTAL FACTORS THAT MAY INFLUENCE NESTING OF MARINE TURTLES

Factor	Nesting area and influence[a]																										
	1			2			3			4			5			6			7			8			9		
	S	M	H	S	M	H	S	M	H	S	M	H	S	M	H	S	M	H	S	M	H	S	M	H	S	M	H
Long-term beach erosion			✓			✓			✓		✓			✓		✓			✓			✓			✓		
Short-term beach erosion			✓			✓			✓		✓				✓	✓			✓					✓	✓		
Silhouette[b]			✓			✓			✓			✓			✓		✓		✓					✓			✓
Lighting	✓			✓			✓				✓		✓			✓				✓			✓		✓		
Human activity	✓			✓			✓			✓			✓				✓				✓	✓			✓		
Dune height	✓			✓				✓			✓		✓			✓			✓					✓	✓		

[a] S = slight influence; M = moderate influence; H = heavy influence.

[b] Silhouette refers to the shadow above the beach plain that results from the background lighting and skylight being excluded by the beach dune and/or beach front and dune-associated vegetation.

TABLE H-2

NUMBER OF CRAWLS OBSERVED VERSUS CRAWLS PREDICTED
BY LINEAR MODELING FOR EACH STUDY YEAR
IN NESTING AREA 4 AT HUTCHINSON ISLAND
ST. LUCIE PLANT
1971, 1973, 1975 AND 1977

Year	No. observed crawls [O]	No. predicted crawls [P]	Percentage of predicted observed
1971	155	143	108.0%
1973	174	192	90.6%
1975	140	239	58.6%
1977	187	164	114.0%

TABLE H-3

WEEK NUMBER FOLLOWING ONSET OF NESTING SEASON
IN WHICH MEDIAN NESTING ACTIVITY[a] OCCURRED
BY YEAR AND AREA
ST. LUCIE PLANT
1971, 1973, 1975 AND 1977

Year	Nesting season onset	Areas 1-3, 5-9			Area 4		
		Nesting crawl	False crawl	False and nesting crawl	Nesting crawl	False crawl	False and nesting crawl
1971	1st week in May	9	-	9	-	-	-
1973	1st week in May	11	11	11	11	8	10
1975	3rd week in April	8	9	9	9	8	9
1977	1st week in May	9	10	9	9	8	8

[a] Median nesting activity was calculated by N/2, where N = total no. of observations per season.

I. HATCHLING TURTLE EXPERIMENTS

INTRODUCTION

The purpose of this study was to consider the influence of water temperature on hatchling marine turtles. Sustained swimming speed, which may be critical to the survival of the turtle, was used as a response indicator. The study also examined, in part, the physiological response of hatchlings to abrupt thermal changes, such as those that might be encountered in a discharge from an electric generating station, and the effect of these temperatures on the health and well-being of the hatchlings.

Atlantic loggerhead turtles (*Caretta caretta*) use the barrier islands along the southeastern U. S. as nesting areas. During the summer, adult females crawl up the beach at night and deposit about 120 eggs in a 60-cm deep nest hole. Fifty to seventy days later, the eggs hatch and the hatchling turtles dig out of the nest and crawl to the ocean. While tracking studies have been limited, it is thought that the turtles migrate to the offshore weed line for food and protection (Fletemeyer, 1978). This terrestrial exposure of an otherwise aquatic organism and the offshore swim are extremely sensitive periods because of the susceptibility of the hatchling turtles to natural predation as well as to environmental alterations by the activity of man.

Commercial development of the barrier islands along the east coast of Florida has promoted considerable concern for and study of the nesting habits, life history, and long-term survival of the loggerhead turtle (Gallagher et al., 1972; Worth and Smith, 1976). One of the last major nesting rookeries in existence is on Hutchinson Island, Florida, where large resort motels, condominiums, restaurants and an electric generating facility are located. Although commercial development is not uncommon on the island, large tracts of uninhabited beach still remain. Research on the island has indicated that the areas of low development are the favored nesting areas for the adult turtles (see Section H, Nesting Turtles).

Loggerhead turtle hatchlings have an extremely short terrestrial existence. They emerge from the nest, primarily at night, and rapidly crawl across the beach and into the sea. They spend the rest of their lives in the sea except for the periodic nesting on the beach by the mature female. Because this post-hatching period is extremely sensitive, strong behavioral patterns for survival are ingrained in the hatchlings. These patterns restrict emergence from the nest to nocturnal periods and compel orientation and movement toward the sea. Once in the sea, the turtles must be able to swim rapidly to an area where food and protection are available.

Nest emergence of green turtles was examined by Hendrickson (1958), who suggested that temperatures in excess of 33°C would

inhibit activity in the nest chamber and that hatchlings would resume activity only when lower temperatures returned at night. Nocturnal emergence is thought to enhance the survival of the sea turtle hatchlings by protecting the turtles from the high surface temperatures of tropical beaches and reducing predation by gulls and other visually oriented predators. Mrosovsky (1968) substantiated Hendrickson's observations but suggested 28.5°C as the level at which green turtles become lethargic in the nest. Both authors agreed that thermal inhibition of activity is a major factor limiting emergence of hatchling sea turtles. Bustard (1967) suggested that the inactivity of a few turtles near the surface of the nest would have a dampening effect on the activity of those below, thereby limiting emergence of any turtles from the nest regardless of their nest position.

Once on the surface of the sand, the turtles move rapidly to the sea. Ehrenfeld and Carr (1967) identified the sea-finding orientation of hatchlings as primarily a visual process and suggested that the brighter portion of the environment, which under natural conditions would be over the ocean, is the attractant for the hatchling turtles. Additional work on the mechanisms involved in the sea-finding ability of the turtles has been performed by Ehrenfeld (1968), Mrosovsky and Shettleworth (1968), and Mrosovsky (1970 and 1972). These studies show that, for a variety of reasons, hatchling turtles will move toward the brightest available light. It has been documented that artificial lights at developments near hatching sites

will disorient the turtles and they will migrate away from the sea (Philibosian, 1976). Mrosovsky (1968) examined green and hawksbill turtles for thermal inhibition of this phototropism but neglected to relate the conclusion that 29°C would cause cessation of activity by turtles to the fact that, once the turtles enter the water, natural ocean temperatures over much of the turtles' range can be higher than 29°C.

MATERIALS AND METHODS

Hatching and Maintenance

Loggerhead turtle nests were excavated from the sand on Hutchinson Island, Florida, immediately after the adult female left the nest site. Twenty-five or more eggs from each of 13 nests were transported by commercial aircraft to Atlanta, Georgia, where they were incubated in sand-filled 12-liter plastic pails until they hatched. The incubation room temperature varied between 27° and 30°C over the period of study. To reduce disturbance of the eggs, internal nest temperatures were not taken although they are known to be slightly higher than ambient temperature due to metabolic heat production by the eggs (Carr and Hirth, 1961).

Nests were collected between 26 May and 5 August 1977, and hatching occurred between 4 August and 22 October 1977. Turtles were allowed to emerge naturally from the nest to the surface of the sand. No light was allowed in the room during incubation, hatching or the

holding period before testing to eliminate pre-test conditioning to a light stimulus. After the turtles emerged, the surface sand was wetted to prevent their dessication. No turtle was tested more than 48 hours after emergence to reduce the potential of different responses from turtles of different ages (Mrosovsky, 1968). Each turtle was used for one experiment only.

Test Tanks

Swimming tests were conducted in two shallow pools containing artificial seawater. The pools were each 8.2 x 0.5 m and were made with cement blocks lined with black plastic to retain the water. For insulation, 2.5-cm thick styrofoam was placed between the plastic liner and the floor. Each tank was marked into four 1.8-m compartments with a 0.5-m turning area at each end (Figure I-1).

Temperature was controlled by regulating room temperature and by using immersion heaters controlled by one or more high-precision mercury thermoregulators coupled to an electronic temperature control relay (Versatherm Models 2151 and 2149). Temperatures at the start of each test were controlled to ±0.3°C. Heaters were removed from the tanks immediately before the swimming test to eliminate physical obstructions to swimming turtles. Heat loss from the water averaged less than 0.5°C during these tests.

Light Regimes

Tests were conducted in a light-tight laboratory room enclosed in black plastic sheeting. The only illumination in the room was from two 15-watt lightbulbs reflecting on a white sheet at each end of the tank. These provided sufficient illumination for researchers to see the turtles swimming and constituted the only phototropic stimulus.

The light intensity for the phototropic stimulus was the lowest illumination that allowed the experimenters to observe the turtle. Illumination in the tanks ranged from 7.2 lux[a] at the distal end of the pool to 96.8 lux near the proximal end. Light levels at selected locations are given in Table I-1. Some light scattering and reflection from the plastic sheeting were apparent, but the turtles oriented to the brightest light and swam toward it with little deviation.

Experimental Procedures

A swimming test consisted of placing a single turtle at one end of the tank and allowing him to swim toward the light at the far end of the tank. When the turtle completed the length of the tank, the light stimulus was switched to the other end of the tank. The turtle would rapidly orient and swim toward the new light location. In this fashion, turtles were tested for 30 or more lengths of the tank. The times required to swim each 1.8-m distance were measured with a digital stopwatch with cumulative interval timing. The swimming speeds for the four quarter-laps were averaged for all turtles. Data are presented in cm/sec.

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[a]1 lux = 1 meter-candle.

All turtles except those used for lethal temperature tests were returned to Hutchinson Island and released.

Thermal Regimes

To simulate natural thermal exposure, individual turtles were transferred directly from the sand in the nest pail to the swimming tank without thermal acclimation. Test temperatures of 25.6, 27.8, 28.9, 30.0 and 33.3°C (Fahrenheit equivalents: 78, 82, 84, 86 and 92°F) were selected as reflective of summer ocean temperatures at Hutchinson Island and elevated temperatures potentially encountered near the offshore discharge of the FPL facility. Since hatching turtles may encounter the thermal plume, additional tests were conducted in a fluctuating thermal regime to simulate the experience of a turtle swimming in and out of a thermal plume. After swimming speed had been established over 10 or 20 laps at one temperature, the turtles were quickly transferred to the second test tank containing water 2.3°, 3.3° or 4.5°C warmer. The swimming speed at the increased temperatures was determined over the same number of laps as the initial test, and the turtle was returned to the lower temperature to complete the last third of the test.

Lethal Effects

Temperatures in four 80-liter aquaria containing 60 liters of artificial seawater were thermostatically controlled within 0.1°C. Three groups of five turtles each were tested for thermal tolerance by raising the temperature 1°C per day from an ambient temperature of 28°C. Brett (1946) recommended this rate of thermal increase for fishes to

ensure adequate acclimation time at each temperature increase. Data from Weathers and White (1971) and Spray and May (1972) indicate this rate of thermal increase is adequate for turtles. A fourth group was maintained at ambient temperature as a control. Attempts to establish a sublethal criterion for the maximum thermal tolerance were unsuccessful, so mortality criteria were used. Data from all tests were pooled and percentage total mortality was plotted against time (Figure I-2) in the method of McLeese (1956). The temperature at which 50% mortality is predicted (LD_{50}) was determined to be 37.4°C for hatchling loggerhead turtles.

RESULTS

Naive turtles placed in the test pools exhibited a delayed orientation to light that lasted less than a minute. The turtles remained in the first 0.5 m of the tank before slowly starting to swim toward the light. Swimming speeds increased rapidly over the first five laps as the turtles acclimated to their environment and exhibited a stronger response to the light stimulus. Most turtles had reached their maximum swimming speeds of 23 and 30 cm/sec between laps 7 and 10. The slow acclimation period shown by all turtles in the first few laps probably does not exist in the natural environment during the period when the hatchlings orient and crawl toward the sea.

A physiological capability and behavioral mechanism which allows for a maximum effort as the turtle first encounters the water gives the animal a selective advantage for getting through the dangerous surf zone. Initial maximum effort was exhibited by turtles at all temperatures, with faster rates associated with the higher temperatures (Table I-2).

Swimming Speed at Constant Temperatures

After they had attained their maximum rates, turtles exposed to constant temperatures of 25.6° and 27.8°C showed a gradual decrease in speed over the remaining laps of the test but stabilized at approximately 19.5 cm/sec. Turtles tested at 28.9°C showed a more marked decline in speed but also stabilized at approximately 19.5 cm/sec. Turtles tested at 30°C slowed considerably, and their speed had not stabilized by lap 60 (Figure I-3). Turtles tested at 33.3°C attained the highest maximum speed of almost 30 cm/sec at lap 7, then slowed an an erratic but precipitous fashion. The decline in speed was continuous over the remaining 35 laps that the turtles lasted.

Turtles tested at 30°C showed a greater reduction in speed than those tested at lower temperatures, but they continued to orient to the light and swim for the duration of the experiment. Of the seven turtles tested at 33.3°C, six stopped before completing the 60 laps. These turtles remained at the surface of the water and swam aimlessly in the tank. They appeared active and alert but would not orient to the light. A brighter light was substituted with no effect. When non-responsive turtles were then placed in water at 30°C, they showed no resumption of the phototropotaxis within five minutes. The single turtle that finished the test maintained an average rate of 15.5 cm/sec (individual turtles are not plotted in Figure I-2).

To test for significant differences between the swimming speed responses of turtles at different temperatures (after they had reached their maximum rates), linear regression analysis was applied to the data from the time of maximum speed to the end of the test (Table I-3). The results show significant differences between swimming speed reduction rates at all temperatures except 25.6 and 27.8°C, and 30.0 and 33.3°C (Table I-4).

In general, swimming speed and temperatures showed a positive relationship during the initial 17 laps (122 meters) followed by an inverse relationship. However, the swimming speeds of turtles exposed to 28.9°C were higher than would be expected with this pattern (Figure I-3). Fry (1967) summarized several studies and determined that organisms perform best when tested at the temperature to which they were acclimated. This concept could apply to the present study since the 28.9°C tests were conducted at the mean incubation temperature and all the turtles in this test were from the same nest. The faster rates could also reflect nest variation that was ordinarily reduced by mixing nests and tests at other thermal regimes.

Swimming Speeds in Fluctuating Temperatures

Experiments to determine turtle responses to fluctuating thermal regimes were conducted with a base temperature, an elevated temperature and a return to base temperature, as specified in Table I-5. Tests using 25.6 and 30.0°C as the base temperatures were

conducted over the course of both 30 and 60 laps. The swimming speeds of turtles subjected to a fluctuating thermal regime were compared with the swimming speeds of turtles tested at a constant temperature that was equal to the base temperature. In the 30-lap tests, the turtles were exposed to each temperature for 10 laps. When the base temperature was 25.6°C, temperature elevations of both 3.3° and 4.4°C produced an immediate increase in the swimming speed of the turtles. During the 10 laps at this elevated temperature, the turtles showed a decline in swimming speed but maintained speeds above those of the 25.6° base. At lap 21 the turtles were transferred back to the base temperature, and their swimming speeds showed a cold shock response by an immediate and pronounced decline in swimming speed. This shock response was reduced within one or two laps, and the swimming speed returned to a constant but lower rate than the base speed (Figure I-4). The same temperature regime (25.6/30.0/25.6°) was used in a 60-lap test with thermal changes every 20 laps (Figure I-5). Although the thermal responses were not as pronounced as in the 30-lap tests, the turtles did show a general decrease in swimming speed during the higher temperature period and a sharp cold shock response when returned to water at 25.6°.

Only two turtles were tested at a 25.6/28.9/25.6° 60-lap regime, and they showed extremely erratic responses.

Turtles exposed to thermal regimes of 30.0/32.2/30.0° and 30.0/33.3/30.0° over 30 laps showed a response pattern similar to that described for the 30-lap studies with the 25.6° base (Figure I-6). Following the cold shock, turtles that had been exposed to 32.3°C recovered quickly to the rate of the control animals. Those that had been subjected to 33.3°C were comparatively slow to return to the control rate. Sixty-lap tests were done only at 30.0/33.3/30.0° and are shown in Figure I-7. Turtles tested over the same thermal regimes showed similar patterns in both 30-lap and 60-lap tests.

DISCUSSION

Prange (1976) found the speed of juvenile green turtles forced to swim against a current ranged between 14 and 35 cm/sec. That result is consistent with the speeds observed in this study for loggerhead hatchlings, considering their smaller size and the different stimuli applied.

The responses of ectothermic animals to temperature have been widely investigated and reviewed by Precht et al. (1973). They concluded that, within a moderate range of thermal tolerance, activity or speed in ectotherms generally increases with increases in temperature and then falls when a species-specific critical temperature level is exceeded. Although little work has been published on swimming speed in hatchling turtles, the activity reaction of the hatchlings to

fluctuating environmental factors is typical of activity responses in other organisms. However, when hatchlings were transferred to a higher temperature, an immediate reduction in activity, which lasted for one lap, was observed. Since motivation to move toward light is extremely high, the immediate decreases observed in hatchling activity with increased temperature would be unexpected unless the organism were being exposed to stress conditions. The unexpected decrease in activity may reflect a reaction to handling stress rather than a thermal stress response (Saunders, 1963). However, several transfer tests without thermal change gave varied results which indicate that handling was not the primary influence.

The heat-induced lethargy in the nest described by Hendrickson (1958) and Mrosovsky (1968) may influence the swimming speed of turtles in the water. Mrosovsky and Shettleworth (1968) examined the effects of temperature on crawling response in green turtle hatchlings. One-minute crawling tests after acclimation to temperatures of 19, 21, 23, 26 and 29°C showed reduced activity at higher temperatures. This supports the concept of reduced swimming speed at higher temperatures, although crawling tests over 26°C produced a marked lethargy while, in the present study, swimming activity limitation was not conspicious below 29-30°C. One-minute tests, however, are extremely short and may be influenced by a stress-associated reduction in activity due to handling. The differences in temperature level at which heat-limited responses are evident may also be due to the differences in thermal

history of the individual turtles, species, test duration or other factors. The thermal lethargy at 33°C reported by Hendrickson (1958) corroborates the present study. This lethargy in swimming turtles was primarily a cessation of the phototropotaxis rather than a loss of motility. It is not known at present whether this response is reversible.

Although additional data on physiological stress are needed, temperatures in the range tested should not be stressful because the mean ocean temperature at Hutchinson Island during the July, August, and September period of maximum emergence is about 30°C. The relatively high lethal temperature (LD_{50}) of 37.4°C also indicates that these thermal ranges are not stressful to physiological systems.

SUMMARY

An environmental condition available to turtles swimming offshore from Hutchinson Island is an encounter with a thermal discharge from the St. Lucie Plant. This plant emits a thermal plume with a maximum surface discharge ΔT of 5.5°F. Turtles swimming at ambient temperatures and encountering this rapid, but small, thermal increase would be expected to show alterations in their swimming speeds. Experimental studies indicated that the turtle behavioral and physiological responses reflect both the amount of thermal increase and the absolute temperature to which they are exposed.

The predicted temperature at which 50% mortality of hatchling turtles would occur was 37.4°C. This is considerably higher than surface temperatures associated with the offshore discharge at the St. Lucie Plant.

Temperatures of 33.3°C produced a reduction in swimming speed and an impairment of orientation to brightness cues. Temperatures of 30°C, which are within normal maximum range for ambient ocean temperatures, are also high enough to produce a significantly reduced swimming speed in hatchling loggerheads. Temperatures below 30°C seem to have negligible effects on hatchling turtles. It should be noted that, while there is no evidence that potential offshore temperatures cause permanent impairment or mortality, additional work is needed to determine whether these temperatures influence the migration of hatchlings to the weed line.

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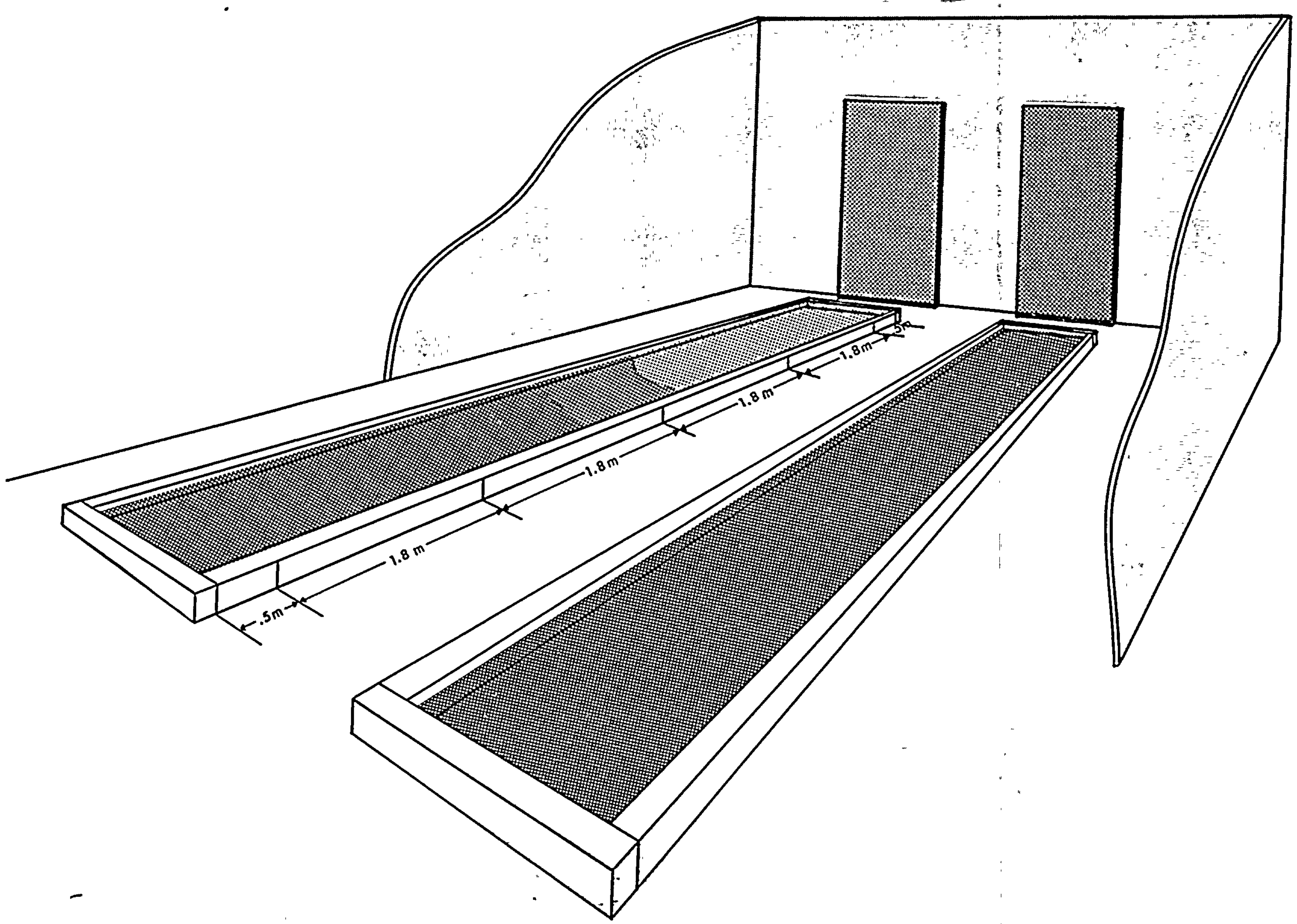

Figure I-1. Diagrammatic view of hatchling loggerhead turtle testing tanks with one of four lights in operation.

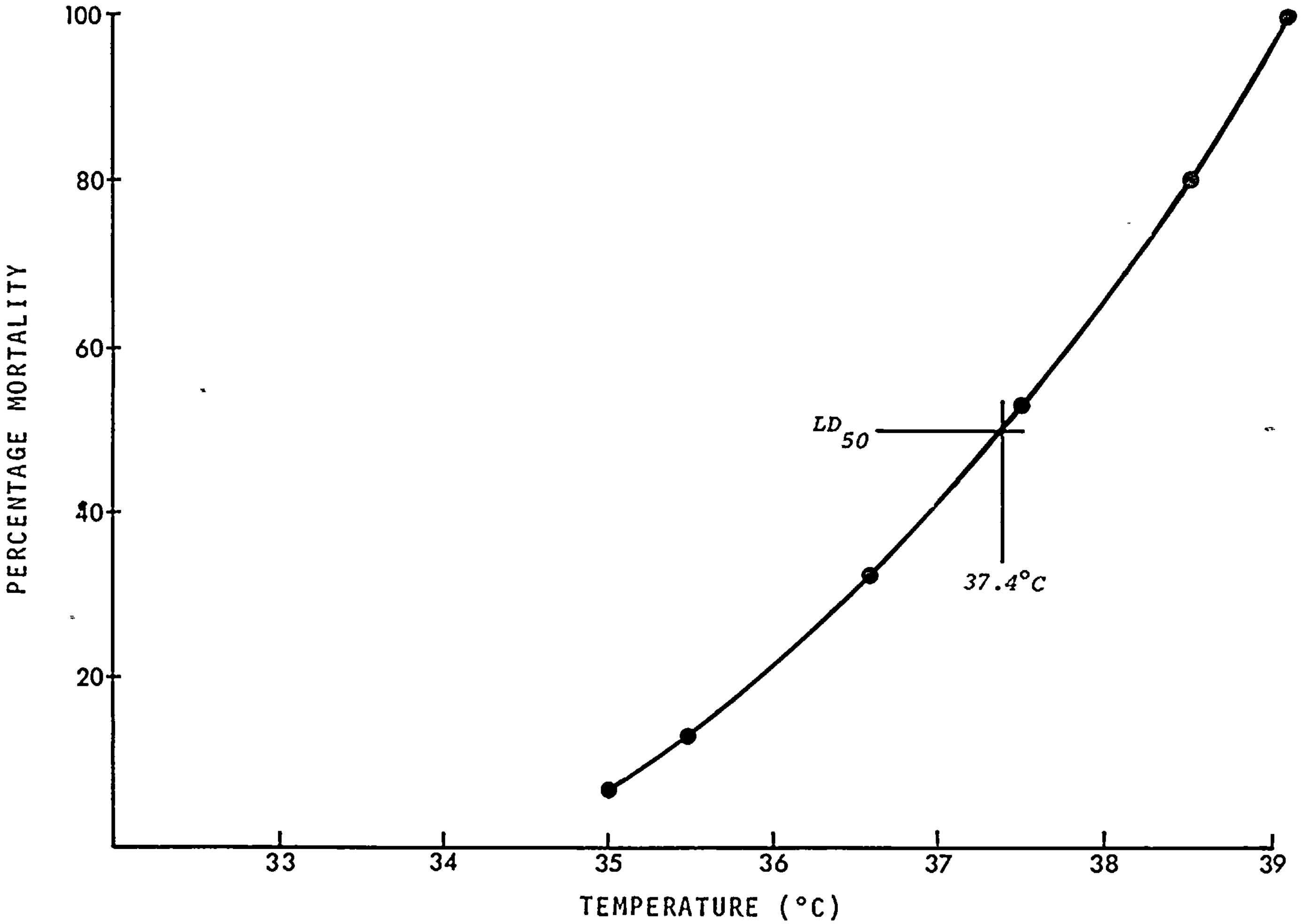

Figure I-2. The relationship between percentage total mortality and temperature for hatchling loggerhead turtles.

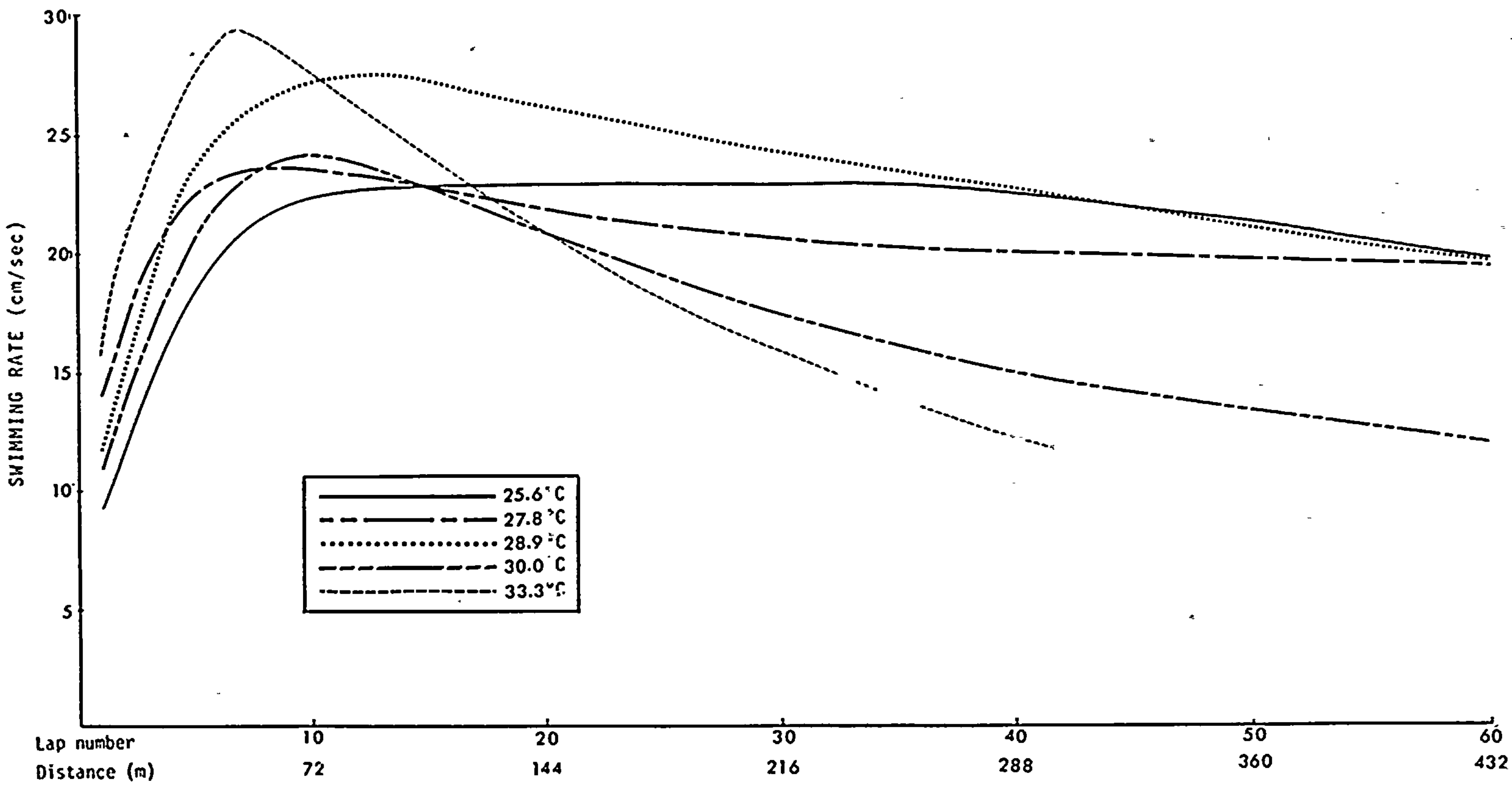

Figure I-3. Swimming speed of hatchling loggerhead turtles at various temperatures (line fitted by inspection).

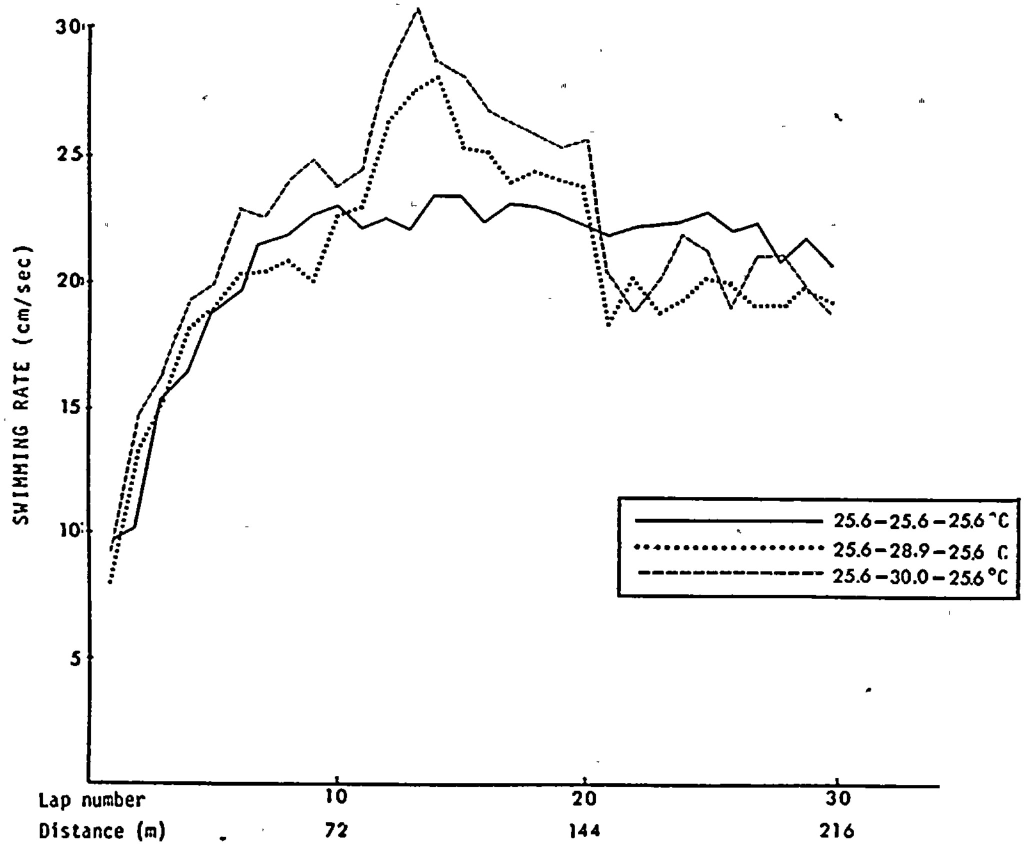

Figure I-4. Average swimming speeds over 30 laps for hatchling loggerhead turtles exposed to three temperature regimes: one constant at 25.6°C, and two fluctuating every 10 laps with a base of 25.6°C.

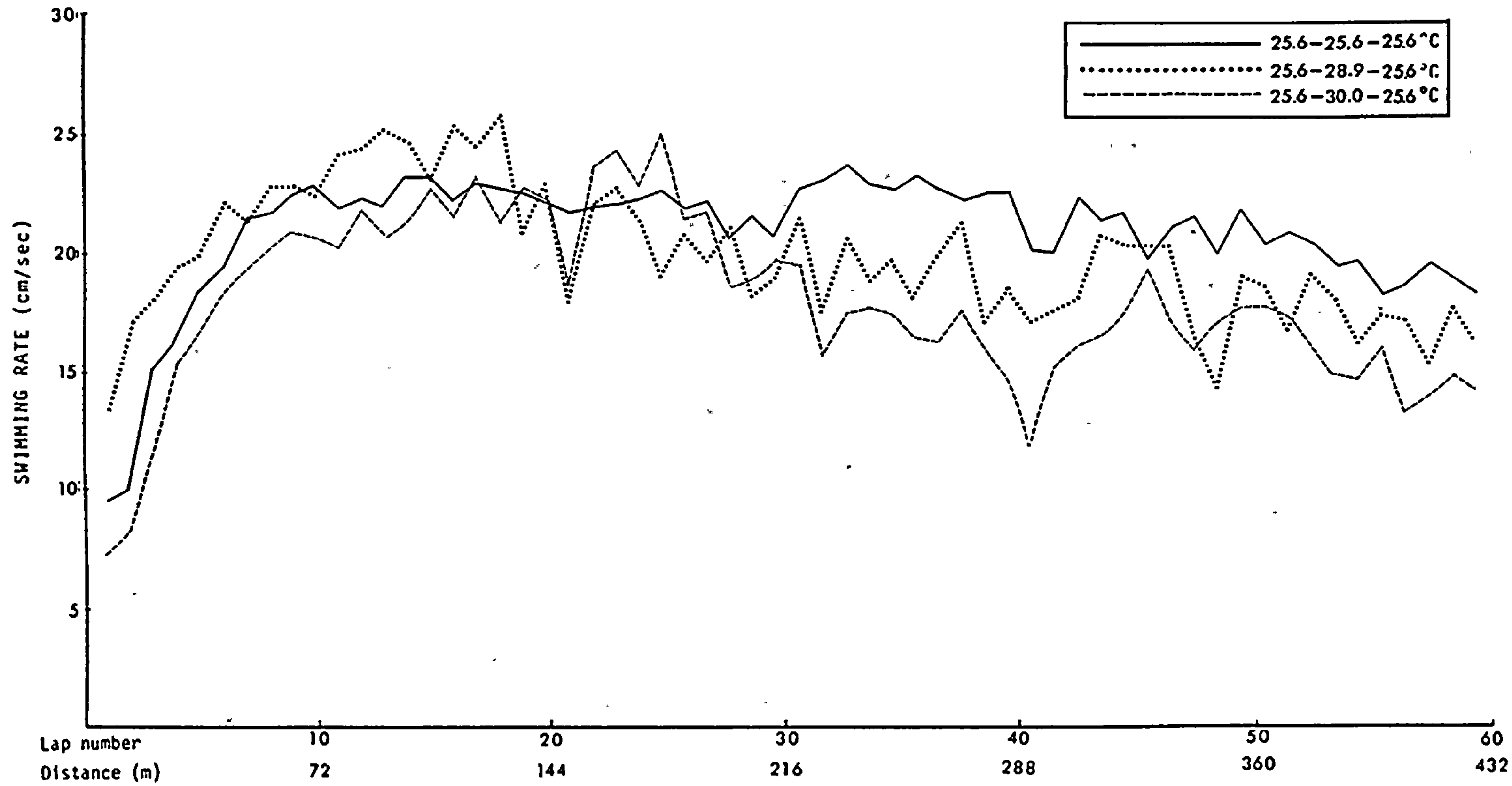

Figure I-5. Average swimming speed over 60 laps of hatchling loggerhead turtles exposed to three temperature regimes: one constant at 25.6°C, and two fluctuating every 20 laps with a base of 25.6°C.

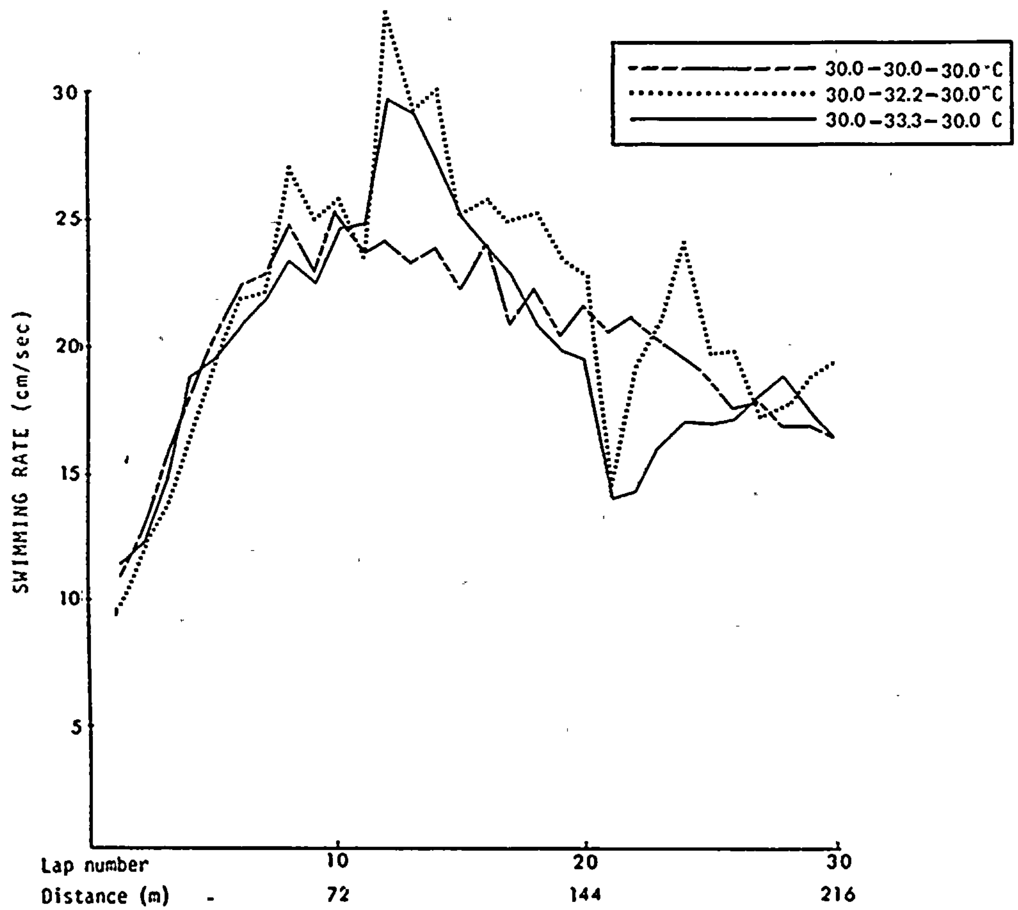

Figure I-6. Average swimming speed over 30 laps of hatchling loggerhead turtles exposed to three temperature regimes: one constant at 30.0°C, and two fluctuating every 10 laps with a base of 30.0°C.

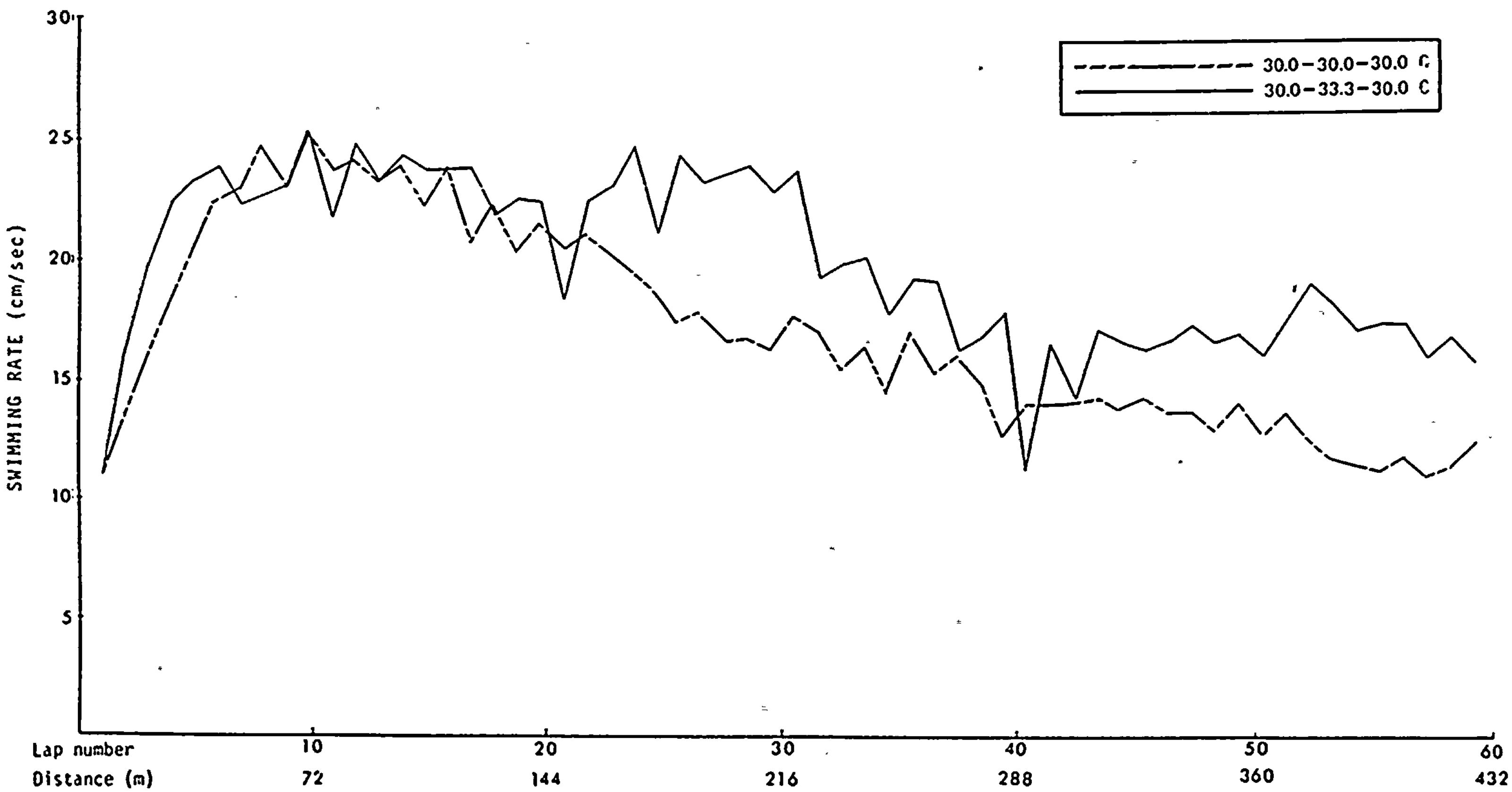

Figure I-7. Average swimming speed over 60 laps of hatchling loggerhead turtles exposed to two temperature regimes: one constant at 30.0°C and one fluctuating every 20 laps with a base of 30.0°C.

TABLE I-1

LIGHT INTENSITY AT SELECTED DISTANCES ALONG EXPERIMENTAL TANKS
HATCHLING TURTLE EXPERIMENTS
1977

Distances in meters to end of tank	Lux[a]
8.2	7.2
7.7	7.7
5.9	10.7
4.1	20.0
2.3	42.9
0.5	96.8

[a]1 lux = 1 meter-candle.

TABLE I-2

AVERAGE SWIMMING SPEED IN CM/SEC AT 10-LAP INTERVALS
FOR TURTLES TESTED AT SELECTED TEMPERATURES
HATCHLING TURTLE EXPERIMENTS
1977

Temperature	Lap					
(°C)	10	20	30	40	50	60
25.6	22.8	22.4	20.8	23.1	21.5	18.8
27.8	23.5	22.1	20.4	18.8	19.3	19.0
28.9	27.0	27.1	24.4	23.9	19.5	20.9
30.0	25.4	21.6	16.4	12.8	14.2	12.6
33.3	28.3	20.2	17.3	10.5	-	-

TABLE I-3

RESULTS OF REGRESSION ANALYSES OF SPEED AND DISTANCE (LAP)
FROM MAXIMUM TURTLE SPEED TO END OF TEST
HATCHLING TURTLE EXPERIMENTS
1977

Temperature (°C)	Slope (b)	Intercept (a)	Error sum of squares	N
25.6	-0.052	23.610	0.01421	270
27.8	-0.079	23.170	0.02919	200
28.9	-0.178	29.502	0.01845	190
30.0	-0.264	26.024	0.01486	450
33.3	-0.308	28.125	0.04031	169

TABLE I-4

RESULTS OF t TEST FOR SIGNIFICANT DIFFERENCES
BETWEEN REGRESSION SLOPES
HATCHLING TURTLE EXPERIMENTS
1977

Temperature	33.3	30.0	28.9	27.8	25.6
25.6	9.37*	14.53*	7.81*	1.26	-
27.8	6.59*	10.33*	4.00*	-	
28.9	4.26*	5.43*	-		
30.0	1.79	-			
33.3	-				

*Significant at 0.05.

TABLE I-5

THERMAL REGIMES FOR FLUCTUATING TEMPERATURE TESTS
HATCHLING TURTLE EXPERIMENTS
1977

Temperature regime (°C)	Laps	N
25.6 - 28.9 - 25.6	30	6
	60	2
25.6 - 30.0 - 25.6	30	3
	60	3
30.0 - 32.2 - 30.0	30	2
30.0 - 33.3 - 30.0	30	6
	60	6